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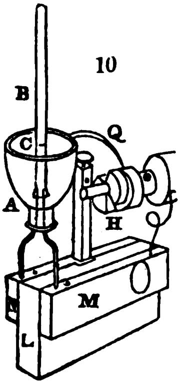
Henry O. Stowe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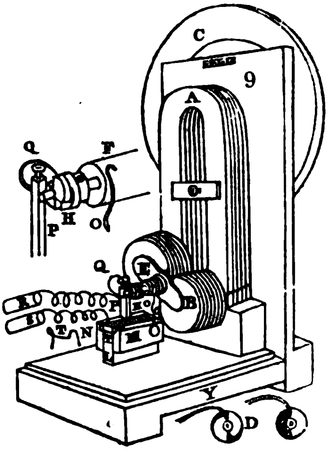
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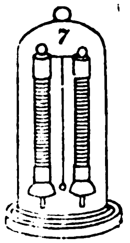
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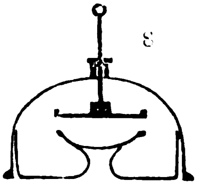
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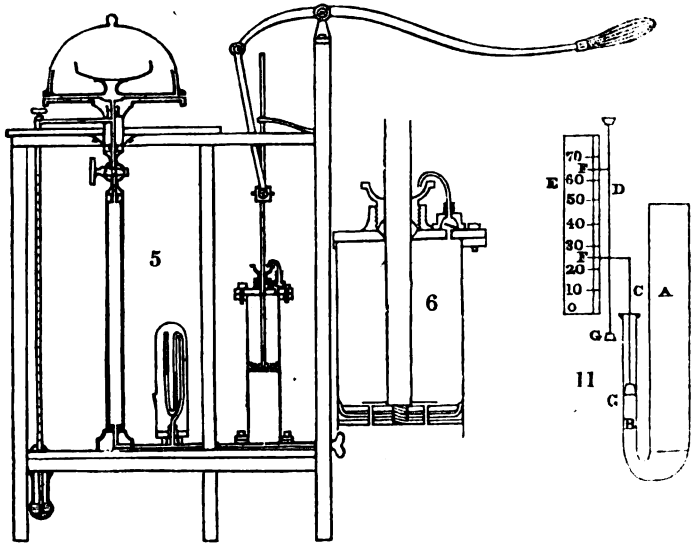
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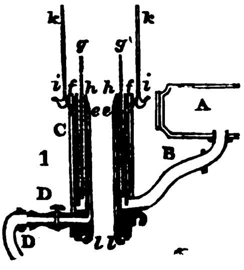
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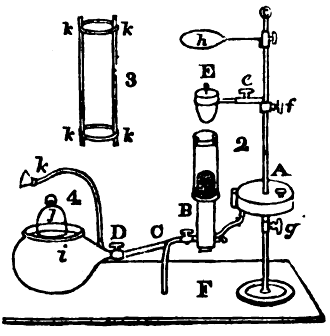
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A

MANUAL OF CHEMISTRY,

CONTAINING

THE PRINCIPAL FACTS OF THE SCIENCE,

IN

THE ORDER IN WHICH THEY ARE DISCUSSED AND ILLUSTRATED IN THE LECTURES

AT

HARVARD UNIVERSITY, N. E.

AND

SEVERAL OTHER COLLEGES AND MEDICAL SCHOOLS IN THE UNITED STATES.

COMPILED AND ARRANGED AS

A TEXT BOOK FOR THE USE OF STUDENTS,

AND PERSONS ATTENDING LECTURES ON CHEMISTRY.

THIRD EDITION,

COMPRISING A SUMMARY OF THE LATEST DISCOVERIES AS CONTAINED IN THE WORKS OF
BRANDE, TURNER, THOMSON AND OTHER DISTINGUISHED CHEMISTS, ILLUSTRATED
WITH UPWARDS OF TWO HUNDRED ENGRAVINGS ON WOOD.

BY JOHN W. WEBSTER, M. D.

ERVING PROFESSOR OF CHEMISTRY AND MINERALOGY IN HARVARD UNIVERSITY.

BOSTON:
PUBLISHED BY MARSH, CAPEN, LYON AND WEBB.
1839.

TUTTLE, DENNETT AND CHISHOLM'S
POWER PRESS,
No. 17 School Street, Boston.

TO

JOHN GORHAM, M. D.

LATE ERVING PROFESSOR OF CHEMISTRY,

AND

JAMES JACKSON, M. D.

HERSEY PROFESSOR OF THE THEORY AND PRACTICE OF PHYSICK, IN HARVARD
UNIVERSITY, EMERITUS,

THE

FOLLOWING PAGES

ARE INSCRIBED.

Harvard University, 1836.

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TO THE THIRD EDITION.

THE two former editions of this work were based upon the excellent Manual of Professor Brande, but the progress of chemical science has rendered it necessary to deviate so much from his arrangement, that in the present edition it has been entirely remodelled. In several institutions, where this work had been in use as a text book, it became necessary to seek for some other, in consequence of its having become out of print.

Several editions of Dr Turner's Elements of Chemistry having appeared in this country, under the able supervision of a gentleman eminent for his scientific attainments, that work was adopted in many institutions. As Dr Turner's work was not so practical and elementary as was desirable, a new edition of it, calculated to meet the wants of beginners, was commenced by the compiler of this, but was subsequently relinquished on learning that Professor Bache was preparing a new edition of the former.

In August, 1838, a part of this new edition was published, since that time no more of it has appeared. The delay was attributed to the decease of the author, but it was soon after announced that the publication of the sixth edition of the Elements would be continued by the brother of Dr Turner and Professor Liebig. A portion of their joint work appeared in London, a part of which was republished in this country, and a few pages followed in England on organic chemistry. More than a year has elapsed and no more has been published. Under these circumstances, and at the repeated request of gentlemen connected with various colleges, a new edition of this Manual was commenced and has been completed, in which is incorporated much of the most important elementary part of Turner and Liebig's work.

It was deemed advisable to reduce the size of the work, and to embody more practical details and more copious experimental illustrations, than are generally given in the larger works.

This edition has therefore been compiled from the volumes of Turner, Brande, Faraday, Liebig, Thomson, and others, and as an introduction to them, with no more alteration than was required to preserve uniformity and connexion.* The frequent references and designation of the writers'

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* Numerous errors (probably of the press) in the English edition of Turner and Liebig's work have been corrected.

names by the initial letters, will enable those who are desirous of studying the subjects more in detail to turn to the originals.

Chemical formulæ have been largely employed in the present edition: those of Turner and Liebig, so far as they have been used in the three parts of the sixth English edition of Turner's *Elements* that have appeared.

Dr Thomson's recent volume,* the most complete treatise on Organic Chemistry which we have in the English language, has been made the basis of the division to which it relates. In that work the author has, with vast labour, collected and embodied the materials that have been for several years accumulating from the labours of the French and German chemists, and which are scattered through so many of their works and journals. Although in Organic Chemistry the arrangement of Dr Thomson has been, for the most part, followed, it has not been rigidly adhered to, as it promised more advantage to the beginner to connect the description of some substances more immediately with the bodies affording them.

As but a very limited portion of time is given to the department of what has been usually called Animal Chemistry, in most institutions and courses of lectures, it was concluded that a very concise chapter would answer the purpose. Many of the facts also that have usually been arranged in that division, are previously alluded to in the preceding chapters. It was therefore thought that the account of animal substances in the text book of Dr Reid, of Edinburgh, with some additions, would be sufficient.

In regard to chemical analysis its details have now become so extended, that they require a distinct work, and as those who intend to prosecute them must very much rely upon their familiar acquaintance with chemical science, and refer to the treatises particularly devoted to this department, what related to that subject in former editions has been omitted. No one who intends to prosecute chemical analysis will fail to consult the ample details of Rose, Berzelius, Faraday, Dumas, and the various Journals and Transactions in which the original analyses and papers have appeared.

Electricity and Electro-Magnetism, are now most usually discussed in collegiate courses of instruction in the department of Mechanical Philosophy.

The description of complicated apparatus has been avoided, as such is seldom attainable by the pupil and not necessary for elementary study. So also has it been thought sufficient to refer, for abstruse points of theory, and description of complicated processes, to original papers, to which those who zealously undertake the study of chemistry will necessarily have recourse. The full descriptions of processes in the *Chemical Arts*, given by Dr Ure in his lately published *Dictionary of Arts and Manufactures*, have rendered it unnecessary to retain many in the present edition of this work.

Copious tables of chemical formulæ and of atomic weights, which had been prepared, have been omitted, as it was found that their insertion

---

* *Chemistry of Organic Bodies.* London: 1838. pp. 1076.

would have materially increased the size and expense of the volume, and such are at hand in the larger works on the science.

To the gentlemen who have aided the progress of the work, by public documents, valuable suggestions, or written communications, the compiler would express his obligations, especially to the Honorable John Quincy Adams, R. M. Patterson, Esq., of the U. S. Mint, Professor Silliman, A. A. Hayes, Esq., Drs C. T. Jackson and S. L. Dana, as also to Francis Peabody, Esq., of Salem, for his usual liberality in allowing several new instruments, from his richly appointed laboratory, to be copied and described.

In accordance with a better taste which prevails among the scientific men of Europe, all titles have been omitted, it being deemed sufficient that the names quoted are considered as *authorities*.

HARVARD UNIVERSITY, CAMBRIDGE, 1839.

NOTE.—All the articles of apparatus figured in this work are now manufactured or furnished by N. B Chamberlain, Philosophical Instrument Maker, School-street, Boston. The glass apparatus is beautifully made by the New-England Glass Company, and Electro-Magnetic Apparatus by Daniel Davis, Jr Cornhill, Boston.

NOTE.

The letter D. refers to Davy's *Elements of Chemical Philosophy*.
H. " Henry's *Chemistry*.
U. " Ure's *Dictionary of Chemistry*.
M. " Murray's *System of do*.
T. " Turner's 1st and 2d part.
Tr5 " " *Elements*, 5th edition.
T. and L. refer to Turner and Liebig's continuation.
T. in chap. ix. refers to Thomson's *Organic Chemistry*.
B. " Brande's *Manual*.
F. " Faraday's *Chemical Manipulation*.

EXPLANATION OF PLATES.

Description of Frontispiece.

Figs. 1 and 2 represent a modification of the Argand lamp, contrived by Dr C. T. Jackson, and which he has called oxyalcohol and air blast lamp.

Fig. 1. A, reservoir for alcohol containing 10 oz. measures; B, connecting tube from reservoir to burner; C, burner containing the elevator and blow-pipe; D, blast tube for oxygen or air from the bellows or gasometer; *e e*, inner cylinder or blow-pipe, expanded to a trumpet form at top, where the opening may be regulated by turning the screw *l l*, so as to bring it nearer or farther from the interior lip of the elevator, *f f*, the space ought to be $\frac{1}{100}$ inch. *g g*. wick elevated by means of a spiral groove in the elevator, *f f*, and the outer cylinder, *h h*, which has a slit and points to move it by turning the chimney-holder, *i i*. *k k*, chimney made of mica and supported by two copper rings and strips, see Fig. 3.

Fig. 2. The lamp ready for work. A, reservoir; B, burner; C, blast tube connected with the gasometer or bellows pipe, and controlled by a cock in order to shut off or let on the blast at pleasure; E, crucible of platina on a stand ring and support fixed by the clamps *e* and *f*; *g*, screw for fixing the lamp at any required height on the rod or stand; *h*, brass retort ring for larger vessels used to support a retort, or for evaporations, digestions, &c.

Fig. 3. Copper frame for a mica chimney. The mica being rolled it is inserted so that the lapping edges come under one of the copper strips, *k k*. When the ends of the copper strips are bent down and pressed tight so as to secure the mica in place: one frame will outlast many mica chimneys.

Fig. 4. *i*, india-rubber cloth bag and weight *j*, for oxygen gas, when a gasometer is not at hand.

When the lamp is to be used, the reservoir is charged with alcohol at 90° strength, and if oxygen gas is to be employed, a little "spirit gas" may be added, but good alcohol is preferable. The cup is unscrewed from the bottom of the burner and the lower orifice closed by a good cork. The blast tube is raised or depressed as required to produce the best effect on the flame. The platinum crucible is heated to full redness by the natural current of air; then, having raised the wick, on urging a blast by means of bellows, a very intense heat will be obtained.

This lamp is very powerful when used with oil and a blast of hot air, the air being heated in a copper tube over a charcoal fire in a wire grate; all the smoke is consumed. With this lamp a piece of lime or magnesia may be as intensely ignited as in Drummond's apparatus (251).

By throwing a current of oxygen gas outside the flame, a more perfect combustion of oil takes place, but the wick will then require to be elevated by means of a rack and pinion. The outside current is, however, not wanted, a sufficiently high temperature for most purposes being obtained without it.

These lamps are manufactured by Hooper and Blake, Boston.

Fig. 5, represents an air pump constructed by Chamberlain, of Boston, for Harvard College. The internal length of the barrel is 13 inches, and the diameter 4 inches. The piston rod passes through an air-tight collar, the upper part of which is concave, to receive oil, and into which the oil that is thrown out when the piston is elevated, is conveyed by a small bent tube passing out of the upper flange over the upper valve. The lower valve is formed by 6 small holes covered with leather, and there is a similar valve in the upper flange opening upwards. By this arrangement the atmospheric pressure is cut off, and after the first stroke by which the air above the piston is removed, the pump can be worked with great ease and rapidity. Within the receiver on the pump-plate, is represented a section of an improved method of exposing water to sulphuric acid (195). The glass dish has an opening in its centre, on the elevated edge of which the small dish containing the water is securely supported. Fig. 6 and 8 represents the arrangement for covering the water with a brass plate, (see note page 60,) while the exhaustion is making. The plate is then raised by means of the rod which passes through an air-tight cap, and the water freezes.

The piston is constructed of two plates of brass and one piece of leather; the lower plate being of the same diameter as the barrel, the upper plate is small enough to admit the leather turning up between it and the barrel; the whole piston is only one half or five eighths of an inch thick. Fig. 6 is an enlarged section of the barrel and piston of the pump.

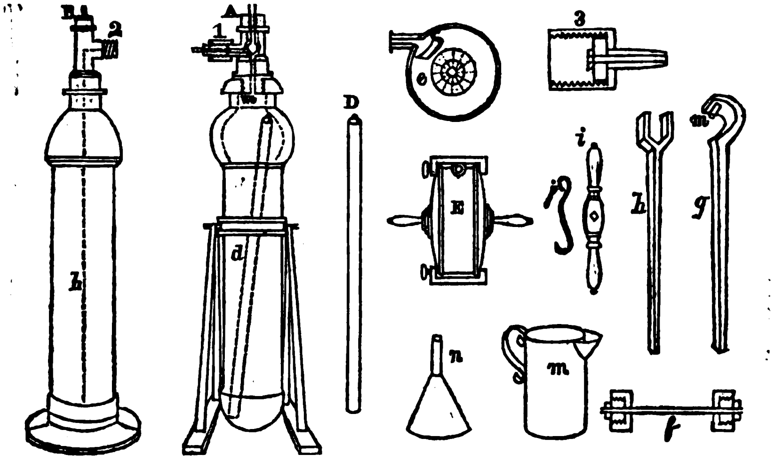
Fig. 7, represents De Luc's electrical columns, consisting of many hundred discs of silver-leaf and thin discs of zinc, alternating with writing paper, or silvered paper and zinc, or silvered paper and oxide of manganese, so arranged within the vertical and parallel glass tubes, that the dissimilar metals are in contact, and each pair thus formed, is separated by the paper. The tubes are terminated by small bells in metallic connexion with the upper discs. The series commences with silver in one tube and is terminated by zinc, or the other metal employed, while, in the other tube, the order of the discs is reversed. A delicate metallic clapper suspended between the columns, on a glass support, will be attracted and repelled. See page 92.

Fig. 9, is a representation of Clarke's electro-magnetic machine. A, horse-shoe magnets confined to the upright support by a clamp and screw. B is the armature, with coils of silked copper wire, which revolves in front of the poles of the magnets, motion being communicated by the wheel C, which is turned by the hand. D H, brake-pieces. The terminations of the coils are soldered to a brass cylinder, being insulated by a piece of hard wood attached to the brass stem. O O, iron wire springs pressing against the cylinder F, at one end. Q Q, a metal spring that rubs upon the brake-piece H. T, a bent copper wire connecting brass straps, on the block L. Thus E, H, Q, P, N, are in connexion with the commencements of each coil, and F, O, M, with the terminations.

Fig. 10 shows the arrangement for decomposing water by means of the above. Water is placed in a glass tube B, in a glass vessel A, through the bottom of which the platinum wires pass. To the glass vessel a brass cup is attached, from which proceed stout wires passing into holes in the brass straps on M and N. The wire Q rubs on the break-piece H. When the armature is made to revolve the decomposition of the water takes place. For a more particular description see Clarke's account of the instrument, &c. in *Amer. Jour.* vol. xxx. 100.

Fig. 11 represents a new self-registering thermometer, which was exhibited at the last meeting of the British Association. A is a glass tube filled with pure spirit of wine. B is a continuation of the same, but much smaller, which is to be about half full of quicksilver to support the spirit in the long tube. Upon the quicksilver at G, is a float supporting the wire C, which wire has a knee or bend in it, with a small eye, which runs upon the fixed wire D, carrying an index or pointer; E is the scale which must be made experimentally. If any change takes place in the bulk of the spirit, the quicksilver is also affected, and with the silver the ivory float G, carrying the index or pointer, which shows at once the degree of temperature upon the scale; this is the simple action of the thermometer· To make it register, the two light indexes or pointers F, move upon the wire D, their own friction keeping them wherever they are placed. To set it, the pointer F, below the thermometer's index, must be pushed close up to it, and the pointer F, above, pushed down it; and it is evident that if any change of temperature takes place, the thermometer's index will move the registering index either above or below, and leave it there, thereby showing the extreme rise and fall of the thermometer in any given time. The action of the air upon the quicksilver is also provided against. *Eighth Rep. Brit. Assoc.* 1839.

PLATE I.



CARBONIC ACID APPARATUS.

PLATE II.

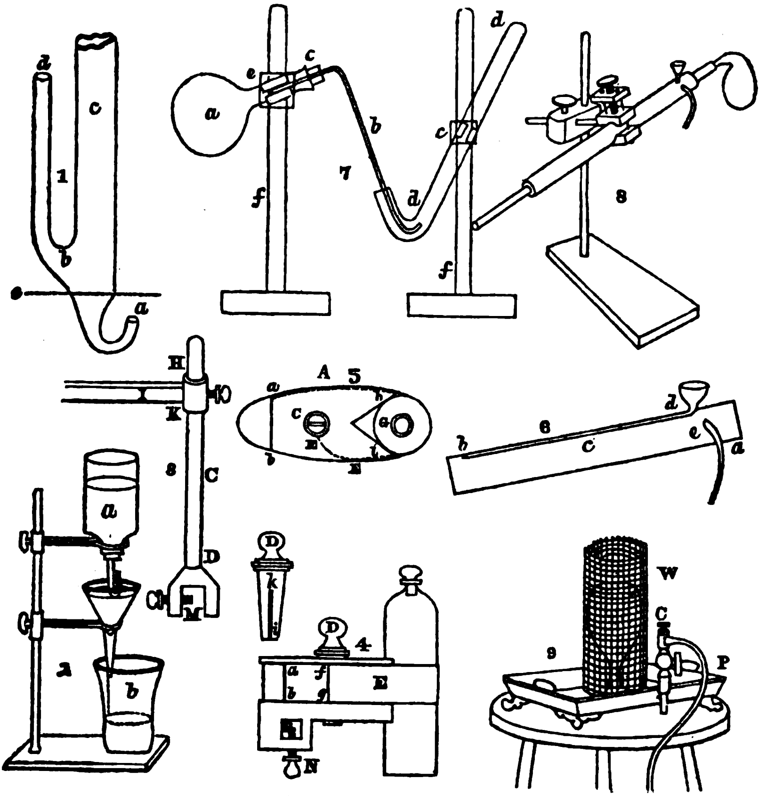


Plate I. *Apparatus for the Solidification of Carbonic Acid.*

Fig. 1. A. A cylinder of wrought iron, 23 inches in length, 4 in diameter, terminated by cast iron hemispheres; supported by two gudgeons on an iron frame, upon which it revolves.

d. A copper tube closed at bottom, for holding acid.

D. The same *j.* brass hook for removing the acid holder.

Fig. 2. B. Cylinder of wrought iron to receive the gas. Of the same size as A.

h. A small tube passing down to within a short distance from the bottom, up which the liquefied gas is forced by the pressure of the gas above.

E. A brass box, 4 inches in diameter 4 in depth, to receive the solidified gas.

e. The same without the cover, shewing the interior; the horizontal pipe, (the mouth of which is also seen in E, under the upper clamp by which and the one below, the cover is confined when the box is used,) fits upon a short jet 3. The centre of each part of the box is pierced with several small holes communicating with the wooden handles, which are hollow and open to allow of the escape of the expanding gas. In front of the inner mouth of the horizontal pipe is a short curved slip of sheet brass for the purpose of preventing the solidified gas being too rapidly driven out of the handles.

f. A copper pipe 16 inches in length and ¼ inch in diameter, terminated by connecting pieces, by means of which the two iron cylinders can be connected, for the transfer of the gas.

g. A hold-fast of iron with a small projection that fits into the hole W in fig. 1., By this the cylinder can be secured from turning when the plug or valve is opened.

h. A wrench for turning the plug.

i. Small brass wrench for turning the steel screw of the valve-plugs in the upper parts of the cylinders A. B.

m. A vessel of zinc, holding the quantity of water required for each charge.

n. A funnel of zinc for introducing the carbonate of soda into the cylinder A.

Fig. 3. Section of one of the connecting screws and pipe; the small projecting part on the flange of the pipe fits into the outlet of the screws of the valve plugs 1 and 2.

The cylinder A may be called the *Generator*, B the *Receiver*. The materials employed for each charge of the Generator, are, Bicarbonate of Soda in powder 2¾ lbs.; Water at 100° 6¼ lbs.; Sulphuric acid 1 lb. 7½ oz.

The valve plugs are of brass and alike, but a section of one only is represented (in Fig. 1. A.) with a double cone of steel, which is accurately ground to its seat; the stem is cut into a fine screw and passes through the upper part of the valve-plug, it is screwed up or down by means of the wrench *i* having a square hole into which the square end of the stem fits. It will be seen that when the cone is screwed up there is an outlet for any gas from the cylinder through the horizontal branch of the valve-plug, and when it is screwed down the passage is closed. The opening under the cone, through the lower part of the valve-plug, is one tenth of an inch diameter. When the cone is screwed up no gas can escape *above it*, as the upper part is also well ground to a conical cavity.

To charge the generator. Unscrew the valve plug and remove it from the end of the cylinder; through the funnel *n* pour in the soda salt: add the warm water, remove the funnel, and with a stick stir the salt and water, breaking down any lumps. Pour the sulphuric acid into the copper acid holder D, and with the hook *j* introduce it into the generator. Remove the hook and having carefully cleaned all the screws with a tooth brush (not with a cloth) and oiled them, screw in the valve plug making it secure by the aid of the wrench and holdfast. Screw down the steel valve firmly. Turn the generator and cause it to revolve several times, that the acid may be thrown upon the soda; repeat this and occasionally allow the cylinder to remain with the valve downward. Let the generator remain 5 or 10 minutes in the position represented in the plate, until the gas has disengaged itself and collected in the upper part of the cylinder. Having previously cooled the receiver in iced water (in which it should be immersed up to the valve) connect it with one end of the pipe *f* securing the screw with a wrench. Connect the other end of the pipe with the valve plug of Fig. 2. B also very firmly. Open the steel valve of the receiver by screwing it up entirely—then, slowly, and partially, open that of the generator. The gas will pass over and in about two minutes the pressure will be equalized, no more gas then passing; close the steel valve of the receiver and *then* that of the generator. Disconnect the generator, open the valve to allow the remaining gas to escape, having a vessel ready to receive the liquid which soon follows. When no more liquid passes out, remove the valve-plug, place it in a basin of clear water; and having lifted out the acid holder, pour out the sulphate of soda and wash out the inside of the generator with water. Repeat the charges in the same manner as long as any gas is *heard* to pass from the generator to the receiver. Nine charges I have usually found sufficient, which, if well managed, will completely fill the box E with solid gas several times.

To obtain the solid. Having previously cooled the box in ice, wipe it dry and secure the top on with the clamps. Screw the coupling and short jet (3) upon the valve plug (as represented 1) of the Receiver. Place the receiver between the knees, and the box upon the jet. Open the steel valve, slowly, until a white vapour issues from the handles of the box; gradually enlarge the opening, and when the brass box has become thickly covered with the condensed and frozen vapour of the apartment, the farther escape of the gas may be stopped by closing the valve. On removing the box and opening it, the white solid acid will be found within.

The greatest care is necessary to avoid introducing any dirt, fibres of wood, cloth, &c. into the vessels, as they are liable to be forced under the valves and into the small tubes and thus defeat the process.

Plate II.

Figs. 1 and 2 represent a method of washing precipitates: which will be often found useful. By this arrangement a column of pure water can be made continually to pass through a powder or precipitate. A flask, or bottle *a*, fig. 2, is filled with water and is closed by a cork, having a glass tube of the shape, fig. 1, passed through it. This tube may be about four inches in length and half an inch in diameter. When the flask or bottle is inverted as in fig. 2 *a*, the water will run out only till the air within it is expanded to a certain degree, the capillarity of the tube *a* fig. 1, not allowing the escape of any water into the air. But if the tube *a* is plunged into a liquid, the water from the flask or bottle will flow into the liquid. As the air expands the water is forced down the tube *d* and a bubble of air passes from *d* through *b* and ascends into the bottle. A correponding quantity of water is forced down, and every successive bubble of air has the same effect. This water flows out at the point *a*, and if that point is dipped into a liquid contained in a funnel, the level of the water in the latter is kept at the same point, as for example at the line *e*, fig. 1. Fig. 2 exhibits the arrangement, with a vessel below to receive the filtered liquid.

Fig. 3, 4, 5. Gahn's cylinder holder for flasks, cylinders, jars, &c. 5 represents the principal portion of this apparatus (seen from above). Fig. 4, exhibits the same in profile. The instrument is made of wood. A slit ⅛th of an inch deep is made in the block at *a b*, and in this slit a strong band or ribbon of the same width, is placed, the end of it being secured by a thick edge or seam down the side *b*. The end of this band is then carried round from *a*, in the direction A *h* G *i* E and through the slit *f g*, (fig. 4.) into the conical hole C, where it is fastened in another slit *k i*, cut in the conical peg D. The band is wound up round the conical peg and fixed, when necessary, by pressing the peg into the conical hole. The band can be loosened by slackening the conical peg. If a glass cylinder as G (fig. 5) is placed in the triangular opening *h i* it can be held fast or let loose at pleasure. The other part of this apparatus consists of a frame (fig. 3) I H M, which can be screwed to the side of a pneumatic trough by the screw at M. The upright rod D is cylindrical, the arm I square and adapted to the square hole F in fig. 4. The screws N and K permit any required adjustment.

Fig. 6 represents a convenient apparatus for condensing vapours. *a b*, A tube of tin 2 inches wide 17 inches long. *c*, A leaden pipe passing along inside to within an inch of each extremity of the tin tube, it is open at the lower end, but passes through the wide tube near the top terminating in a funnel. *e*, A pipe entering the upper side of the larger tube, close to where the other pipe passes out, and hanging down an inch or two below the wide tube. This short tube is open at both ends. A glass tube, 25 inches in length, is placed into the tin tube through corks at *a* and *b* which fit the latter and prevent the passage of water. The glass tube should be somewhat tapering, about an inch wide at the upper end and rather less than half an inch at the lower end. The upper end should be bordered or have a rim, so as to permit the insertion of a cork. Water poured into the funnel *d* can only escape after traversing the tube at *c* and thus the glass tube can be kept surrounded by cold water.

Fig. 7. Cooper's mercurial receiver. *d d*, The receiver to be filled with mercury; a basin is placed below the mouth to receive what may be displaced by the gas as it passes in from the flask *a*.

Fig. 8 represents Seffstroem's support, made entirely of wood. The pieces can be adjusted by means of the screws, to grasp a vessel or tube and support it at any desired height or angle.

Fig. 9. *Hare's apparatus for exploding hydrogen and chlorine.* A flask is half filled with chlorine and transferred to the pan P with its orifice over that of a pipe communicating with the cock C and flexible pipe extending to a self-regulating reservoir (Fig. 120, page 123) of hydrogen. The flask is surrounded with a cylinder of wire gauze. Just before the explosion is desired hydrogen is admitted to displace the water left in the flask. The pan should contain water sufficient to cover the mouth of the flask. A mirror is used to reflect the solar rays upon the flask. See *Amer. Jour.* xxix. 243.

CONTENTS.

CHAPTER I.

Of the Powers and Properties of Matter, and of the General Laws of Chemical Changes.

CHAPTER II.

CHAPTER III.

Inorganic Chemistry.

Compounds of Simple Non-Metallic Acidifiable Combustibles with each other.

CHAPTER IV.

Metals.

CHAPTER V.

SECTION I. SALTS.

CHAPTER VI.

Organic Chemistry.

II. VEGETABLE ACIDS.

CHAPTER VII.

CHAPTER VIII.

CHAPTER IX.

Products of the Destructive Distillation of Vegetable Substances.

CHAPTER X.

Animal Substances.

ADDENDA.

APPENDIX.

ERRATA.

Page 10. Line 17, for "system" read systems.
" 10. Line 20, for "square prismatic" read double oblique prismatic.
" 50. After "176," insert 7.
" 50. Before "A curious" insert 8.
" 64. Foot note, for "Hares's" read Hare's.
" 65. Third line for "11°" read 41°.
" 79. 5th line, for ελεκτϛον read ηλεκτϛον.
" 95. 4th line, for "smaller" *similar*.
" 107. Top of page for "Gasometers" read *Graduated vessels*.
" 115. Line 28, for "substract" read subtract.
" 115. Line 29, ditto.
" 120. Foot note, the reference should be to Frontispiece.
" 125. For "Doebereiner" read Dobereiner.
" 161. In margin, for "sodidum" read sodium.
" 166. 5th line, for "sulphurious" read sulphurous.
" 184. 12th line, for "sodium" read salts.
" 209. Paragraph 732 for "ammonical" read ammoniacal.
" 213. In the Formula for Olefiant gas, add 2 after the second H.
" 219. Last line, for "mercury" read Hydrocyanic acid.
" 257. 5th line for Fe read $\dot{Fe}$.
" 272. In margin, dele "Poisonous effects."
" 388. Line 29, for "whortleberry" read bear-berry.
" 468. Line 29, for "benzoly" read benzoyl.

MANUAL OF CHEMISTRY.

CHAPTER I.

OF THE POWERS AND PROPERTIES OF MATTER AND OF THE GENERAL LAWS OF CHEMICAL CHANGES.

Object of chemistry.

1. It is the object of Chemistry to investigate all changes in the constitution of matter, whether effected by heat, mixture or other means.*

Most of the substances belonging to our globe are constantly undergoing alterations in sensible qualities, and one variety of matter becomes as it were transmuted into another. Such changes, whether natural or artificial, whether slowly or rapidly performed, are called chemical.† The ends of this branch of knowledge are the application of natural substances to new uses, for increasing the comforts and enjoyments of man, and the demonstration of the order, harmony, and intelligent design of the system of the earth.

Foundations.

2. The foundations of chemical philosophy are observation, experiment, and analogy. By observation, facts are distinctly and minutely impressed on the mind. By analogy, similar facts are connected. By experiment, new facts are discovered; and in the progression of knowledge, observation, guided by analogy, leads to experiment, and analogy, confirmed by experiment, becomes scientific truth. D. 1, 2.

Origin of the term.

* The word *Chemistry* seems to be of Egyptian origin, and to have been originally equivalent to our phrase *natural philosophy* in its most extensive sense. In process of time it seems to have acquired a more limited signification, and to have been confined to *the art of working metals*. In the third century, we find it used in a much more limited sense, signifying the *art of making gold and silver*. Those who professed this art gradually assumed the form of a sect, under the name of Alchemists; a term which is supposed to be merely the word *chemist*, with the Arabian article *al* prefixed. The great object of the alchemists was to find out the means of converting the baser metals to gold, and the grand instrument by which this was to be effected was the philosopher's stone. T. i. 19.

Definitions.

† Chemistry is the science which treats of those events and changes in natural bodies, which are not accompanied by sensible motions. T. i. 18.

It is the object of Chemistry to discover and explain the changes of composition that occur among the integrant and constituent parts of different bodies. H. i. 12.

Arrangement. 3. In the present state of our knowledge, it will be most convenient to begin the study of chemistry with the discussions relating to the general powers or properties of matter, and afterwards to proceed to the examination of individual substances, and to the phenomena which they offer when presented to each other under circumstances favorable to the exertion of their mutual chemical agencies.

The powers and properties of matter, connected with chemical changes, may be considered under the heads of 1, Attraction; 2, Heat; 3, Electricity; 4, Light.

SECTION I. *Attraction.*

Attraction at sensible distances. 4. ALL bodies composing the material system of the universe have a mutual tendency to approach each other. The operation of this force extends to the remotest parts of the planetary system. The smaller bodies, that are under our more immediate observation, are influenced by the same power, and fall to the earth's surface, when not prevented by the interference of other forces. From these facts the existence of a property has been inferred, which has been called *attraction*, or more specifically, the *attraction of gravitation*. Its nature is entirely unknown to us. The attraction between these bodies takes place at sensible distances; it exists in all known forms of matter; and it acts upon them directly as the mass, and inversely as the square of the distance.

Weight. 5. The force required to separate a body from the surface of the earth, or prevent it from descending towards it, is called *its weight*.

Particles of bodies. 6. Of the nature of the particles of which bodies are composed, we have no satisfactory evidence. In simple bodies they must be all of the same nature, or *homogeneous*. In compound bodies, we understand by the term *particles*, the smallest parts into which bodies **Atoms.** can be resolved without decomposition. The word *atom*[*] denotes both these kinds of particles. When two atoms of different kinds unite to form a third or compound atom, we may term the two first *component* atoms; and if these have not been decomposed, they may be called *elementary* or *primary atoms*. H. 1, 28.

Contiguous attraction. 7. The attraction exerted between these minute particles, or atoms, when they are placed in apparent contact, and which is effective only at insensible distances, has been called *contiguous attraction*, and has been distinguished as it is exerted between particles of matter of the *same* kind, or between particles of a *different* kind. When the par- **Cohesion.** ticles of the same kind are united to form an aggregate or mass, they are sometimes said to be united by the *affinity of aggregation*, *the cohesive affinity*, or *cohesion*.

Effects of attraction at insensible distances. 8. This attraction preserves the form, and modifies the texture of solids, gives a spherical figure to fluids, causes the adhesion of surfaces, and influences the mechanical characters of bodies. Its force is exerted with the greatest intensity in solids;[†] in liquids it acts with much less energy; and in aëriform bodies it is doubtful if it exists at

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[*] From *a* privative, and τεμνειν to cut.

[†] The force of cohesion in solids is measured by the weight necessary to break them, or rather to pull them asunder.

all. Of this, water offers a good example in its different states of ice, water, and steam.

Its effects in liquids.

9. To cohesion is owing the spherical form which liquids assume, when suffered to form drops; as also their property of remaining heaped above the brims of the vessels that contain them. The force of cohesion varies in different liquids and hence the size of their drops must vary.

Heterogeneous, or chemical attraction.

10. When attraction operates upon *dissimilar* particles, and produces their union, it gives rise to new and infinitely varied productions. It is this kind of attraction which is distinguished as *heterogeneous;* it is also called *chemical attraction*, or *affinity*.

Results.

11. The results of attraction, as relating to the texture and forms of matter, are influenced by the circumstances under which it has taken place. Sometimes the particles are, as it were indiscriminately collected; and at others they are beautifully arranged, giving rise to regular and determinate figures.

Crystals.

12. The regular polyhedral solids thus resulting from the influence of attraction upon certain kinds of matter, are usually called *crystals;** and the bodies are said to be susceptible of *crystallization.*

Conditions for crystallization in general.

13. To enable the particles of bodies to assume that regular form which crystals exhibit, they must have freedom of motion; and accordingly the first step towards obtaining a body in its crystalline form, is usually to confer upon it either the liquid or aëriform state. This is effected by solution, or by exposure to heat.

Solution.

14. The term *solution*, is applied to a very extensive class of phenomena. When a solid disappears in a liquid, we have an example of solution. The expression is applied both to the *act* of combination, and to the *result* of the process. Solution is always the result of an attraction or affinity, between the fluid and the solid which is acted upon, feeble it is true, yet sufficient in force to overcome the cohesion of the solid. The affinity continues to act until at length a certain point is attained, where the affinity of the solid and fluid for each other is overbalanced by the cohesion of the solid, and the solution cannot be carried farther. This point is called *saturation*, and the fluid obtained is termed a *saturated solution.*

Saturation.

How the particles are disposed.

15. The particles of the solid may be regarded as disposed at regular distances throughout the fluid; and if the quantity of solvent be considerable, the particles will be too far asunder to exert reciprocal attraction; in other words, they will be more powerfully attracted by the solvent than by each other. If we now slowly get rid of a portion of the solvent, the solid particles will gradually approach each other, and they will aggregate according to certain laws, producing a regular form.

Other objects of solution.

16. There are two other great and general objects to be gained by solution, which render it a process of constant occurrence in the laboratory. The first is that of preparing substances for the exertion of chemical action. The second is that of separating one substance from another; this being continually effected by the use of such fluids as have a solvent power over one or more of the substances

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* From Κρύσταλλος, Ice.

present. Water is the great solvent whose aid is first to be called in; others are to be resorted to only when that is insufficient. So general and important is its use, that in speaking simply of the solubility of a body, water is always understood to be referred to.*

Evaporation.

The figure influenced by rapidity of evaporation.

Time for stopping artificial evaporation.

17. To recover a salt from its solution, if its solubility does not vary with the temperature of the solvent, as in the instance of common salt, it is necessary to expel a portion of the fluid by heat. This constitutes the process of *evaporation.*† The regularity of the figure (12) obtained will be influenced by the rapidity of the evaporation; if the process be slowly conducted, the particles unite with great regularity; if hurried, the crystals are irregular and confused. In common cases the evaporation may be continued till a pellicle forms upon the surface of the solution. The formation of a superficial pellicle is the common criterion of the fitness of a solution for crystallization; but where the object is to obtain very regular and very large crystals, the evaporation must be much slower, and carried to much less extent; even spontaneous evaporation, or that which takes place at common temperatures, must be resorted to.

Crystals formed by fusion.

18. There are certain bodies which may be dissolved or liquefied by heat, and during slow cooling, may be made to crystallize. This is the case with many of the metals, with spermaceti, sulphur, &c. Some other substances, when heated, readily assume the state of vapour or are *sublimed,* and during condensation, present regular crystalline forms; such as iodine, benzoic acid, camphor, &c.: and crystals of snow are produced by the condensation and cooling of aqueous vapour.

Crystallization of substances whose composition is feeble.

19. Some substances are so easily decomposed by heat, and at the same time retain water with such avidity, that it is impossible to crystallize them by any of the above processes; in these cases crystallization may sometimes be effected by placing the solution under

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Solubility, how tried.

* The solubility of a body may be tried by suspending a piece of it in a glass of clean undisturbed water; if it be soluble a descending current will be seen to fall from it, and be visible upon looking through the water horizontally. If it fall rapidly and in dense striæ, it will indicate rapid solubility, and the formation of a dense solution; if it fall in a very narrow stream, it will indicate only moderate or slight solubility; and by its descending rapidly or in a slow broad stream, or by resting about the substance, a judgment may be made of the comparative density of the solution produced. If no descending current appear, nor any fluid round the substance of a refractive power or colour different to that of the water, then the body must be very nearly if not quite insoluble at common temperatures.

If the substance appear to be insoluble, or if it be necessary to know whether it be soluble in alcohol, ether, oils, or any other body, for the purpose of selecting a solvent from among them, a portion should be pulverized finely, and introduced into a small tube with a little of the fluid to be tried, and heated; if the substance disappear, it is of course soluble. But if it be supposed to be a mixed body, and partly soluble, though not altogether so, then the presumed solution should be poured from the tube into an earthenware or platinum capsule, and evaporated carefully and slowly; if any substance remain, it of course indicates a degree of solubility. F. 168.

Method of obtaining a cold saturated solution.

A solution saturated when cold, may be often obtained much more speedily by the aid of heat, as by boiling the substance with water, leaving it to cool, and afterwards filtering it, when a saturated solution will be at once obtained. If the solution while cooling deposits any portion of the solid, it proves the saturation, if it does not, there is reason to doubt it, and heat with more of the solid substance in powder should again be applied. The solution may also be tested while hot by dipping into it a glass rod, and thus transferring a drop to a cold glass plate; if crystals or solid substance appear in a few moments, the solution will be saturated when cold. Sometimes this effect will not take place until the drop is stirred. F.

† Performed in shallow vessels exposing a large surface of the liquid.

the receiver of an air-pump, over the surface of sulphuric acid, and exhausting the air; the acid, by absorbing the vapour as it rises, causes rapid evaporation.

Water of crystallization.

20. In the act of separating from the water in which they were dissolved, the crystals of almost all salts carry with them a quantity of water. It is termed their *water of crystallization*, the quantity of which is very variable in different saline bodies, but it is uniform in the same salt.

21. The hardness, brilliancy, and transparency of crystals, often depend upon their containing this water, which sometimes exists in them in large quantities. Thus, sulphate of soda, in the state of crystals, contains more than half its weight. Gypsum, in its crystallized form, contains about 20 per cent. of water, which it loses at a red heat, and the crystals crumble down into the white powder called Plaster of Paris. Some salts part with it by simple exposure to dry air, when they are said to *effloresce;* but there are other salts which *deliquesce*, or attract water from the atmosphere.*

Efflorescence and deliquescence.

22. The water of crystallization is retained by a very feeble affinity, as is proved by the facility with which such water is separated from the saline matter by a moderate heat, or by exposure to the vacuum of an air-pump at common temperatures. A portion of the water is sometimes retained with such obstinacy, that it cannot be expelled by a temperature short of that at which the salt is totally decomposed. This water is considered to act the part of a base, and is called *basic water*. From the observations of Graham,† the water thus retained does not always appear to act this part, but to be in a peculiar state of combination. This he calls *constitutional* water; being that which is essential to the existence of the salt. It differs from basic water, by not being removed even by the most powerful alkalies, but is readily removed, and its place assumed, by certain anhydrous salts. The character of water in these different states of combination will be understood from the following example. Crystals of phosphate of soda are composed of 1 proportion phosphoric acid, 2 soda, and 25 water. At the temperature of 212°, 24 proportions of the water are expelled; but the 25th proportion is retained, and a red heat is required for its complete separation. By the loss of the 24 proportions the crystalline form and texture of the salt are destroyed, but the residual mass has all the properties of the common phosphate; whereas, by the loss of the 25th proportion, an entirely different salt, the pyrophosphate of soda, is produced.

Basic water.

Constitutional water.

23. In some cases the proportion of water is removed by an equivalent of any base that supplies its place in the compound; in others it is not affected by bases, but may be removed by certain anhydrous salts which occupy its place, and give rise to the formation of double salts. The former, as acting the part of a base, is the *basic water;* the latter, as influencing the constitution of a salt, is the *constitutional water*.

Water removed.

24. The difference is denoted in symbols, by writing the basic

Denoted by symbols.

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* Those crystals which effloresce by exposure to air, may often be conveniently preserved, by slightly oiling their surfaces. The best method is to soak the crystals in oil for a few hours, and then to wipe them and put them up in bottles.

† *Phil. Trans. Edin.*, xii. 297.

water, as is the case with all bases, on the left side of the acid with which it is combined, and the constitutional water on the right. Hence the symbol of the crystals of phosphate of soda is $2NaO: HO, P^2O^5+24Aq$.

Decrepitation.

25. Salts, in crystallizing, frequently enclose mechanically within their texture particles of water, by the expansion of which, when heated, the salt is burst with a crackling noise into smaller fragments. This phenomenon is called *decrepitation.* Those crystals in which the water of crystallization is so abundant, as to liquefy them when its temperature is raised, are sometimes said to undergo the *watery fusion.*

Watery fusion.

Crystallization promoted

26. Some salts, in consequence probably of their strong attraction for the water that retains them in solution, cannot be brought to crystallize in the ordinary way. In such cases, crystallization may be effected by the addition of substances having a strong affinity for water, by which its attraction for the dissolved matters is weakened; thus alcohol, added to certain aqueous saline solutions, (as solution of nitre,) produces a separation of crystals, but they are generally small and indistinct.

By a nucleus.

27. Crystallization is accelerated by introducing into the solution a nucleus, or solid body, upon which the process begins; and manufacturers often avail themselves of this circumstance. Thus we see sugar-candy crystallized upon strings, and verdigris upon sticks. There are cases in which it is particularly advantageous to put a few crystals of the dissolved salt into the solution, which soon cause a crop of fresh crystals. In some instances, if there be two salts in solution, that will most readily separate of which the crystals have been introduced.

Method of obtaining perfect crystals.

28. By placing a crystal of the same nature in a saturated solution of a salt, and turning it daily, so that the different sides shall be successively exposed to the liquid, very large and perfect crystals may be obtained.

29. When two salts of different solubilities are present in the same solution, they often may be separated by crystallization, that which is least soluble constituting the earlier crop of crystals.

Crystallization affected by circumstances,

30. Sometimes crystallization is *not* effectual for the separation of salts. When the sulphates of iron and copper are in solution together, crystals will be obtained resembling those of sulphate of iron, but with very variable proportions of sulphate of copper in them, the latter salt being at times present in great quantity; on other occasions triple salts are formed. F. 254.

By pressure.

31. The pressure of the atmosphere has been said to have considerable influence on crystallization. Thus a concentrated solution of sulphate of soda (Glauber's salt), excluded from the air while hot, does not crystallize on cooling; but will generally crystallize when the air is admitted.* The theory of this phenomenon is not very ap-

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* The best method of exhibiting this, is to place several pounds of Glauber's salt in a suitable vessel, and to pour upon it two parts of water to three of salt; boil it, and while hot strain the solution through a coarse cloth, into a tall, wide, thin glass jar, previously warmed; over the mouth of the jar a piece of wet bladder is to be securely tied, and the whole left to cool. When quite cold, a puncture of the bladder with the point of a knife will often be followed by crystallization of the salt—if it should not commence, the introduction of a fragment of the salt will be required. The tempera-

parent. It does not depend upon atmospheric pressure, for the solution may be cooled in open vessels, without becoming solid, provided its surface be covered with a thin film of oil; and Turner succeeded with the same experiment without the use of oil, by causing the air of the vessel to communicate with the atmosphere by means of a narrow tube. It appears from some experiments of Graham,* that the influence of the air may be ascribed to its uniting chemically with water; for he has proved that gases which are more freely absorbed than atmospheric air, act more rapidly in producing crystallization.

By light.

32. The presence of light also influences the process of crystallization. Thus we see the crystals collected in camphor bottles in druggists' windows always most copious upon the surface exposed to light; and if we place a solution of nitre in a room which has the light admitted only through a small hole in the window shutter, crystals will form most abundantly upon the side of the basin most exposed to the aperture through which the light enters, and often the whole mass of crystals will turn towards it. Many saline solutions form arborescent crystalline pellicles, when left to spontaneous evaporation, which slowly travel up the sides of the basin, and gradually proceed down upon the outside;† this process also always begins on the side nearest the light, and is often confined to it.

Assume one form rather than another.

33. It is commonly observed, that crystallized bodies affect one form in preference to others. The fluor spar of Derbyshire crystallizes in cubes: so does common salt. Nitre assumes the form of a six-sided prism, and sulphate of magnesia that of a four-sided prism. These forms are liable to vary. Fluor spar and salt crystallize sometimes in the form of octohedrons; and there are so many forms of carbonate of lime, that it is difficult to select that which most commonly occurs.

Primitive nuclei.

34. Romé de Lisle referred these variations of form to certain truncations of an invariable primitive nucleus; and Gahn afterwards observed, that when a piece of calcareous spar was carefully broken, all its particles were of a rhomboidal figure. This induced Bergman to suspect the existence of a primitive nucleus in all crystallized bodies.‡ This subject was more extensively prosecuted by Haüy. He determined the primary forms of minerals, and showed how secondary forms could be derived from them by simple laws of decrement.§

Haüy's primitive forms.

35. Haüy obtained his primary forms by mechanical division: thus by the skilful division of a six-sided prism of calcareous spar, he reduced it to a rhomb, precisely resembling that which is known under the name of Iceland crystal. Other forms of calcareous spar were subjected to the same operation; and, however different at the outset, finally agreed in yielding, as the last product, a rhomboidal solid.

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ture of the jar will rise during the change from the fluid to the solid state. If a globular vessel, as a matrass, is employed, it will often be broken during the crystallization. The crystallization will often take place on slight agitation without the access of air.

* *Phil. Trans. Edin.* 1828. See also *N. Edin. Jour.* xiii. 309.

† This may be prevented by smearing the edge of the vessel with oil.

‡ *Phys. and Chem. Essays*, Vol. II. p. 1.

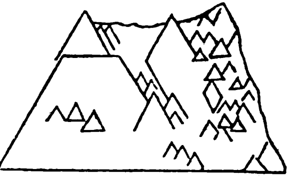
§ *Traité de Min.* Paris; 1801.

It was discovered also by Haüy, that if we take a crystal of another kind (the cubic fluor spar, Derbyshire spar, for instance,) the nucleus obtained by its mechanical division, will have a different figure, viz. an octohedron.*

Daniell's method.

36. A method of developing the structure of crystals, has been described by Daniell.† It consists in exposing any moderately soluble salt to the slow and regulated action of a solvent. Thus if a lump of alum is placed in water, after some days, octohedrons and sections of octohedrons will be seen in relief upon its lower part. (Fig. 7.) The crystalline forms of metals may be in a similar manner developed by immersion in dilute acids.

Fig. 7.



Wollaston's theory.

37. From the imperfect explanation of many of the appearances of crystals, afforded by the theory of Haüy, Wollaston proposed to consider the primitive particles as spheres, which, by mutual attraction, have assumed that arrangement which brings them as near as possible to each other. By the due application of spheres to each other, he has shown that a variety of crystalline forms may be produced.‡

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* The primary forms of Haüy are reducible to six; the parallelopiped, fig. 1, which includes the cube, the rhomb, and all the solids which are terminated by six faces, parallel two and two; the tetrahedron, fig. 2; the octohedron, fig. 3; the regular hexahedral prism, fig. 4; the dodecahedron with equal and similar rhomboidal planes, fig. 5; and the dodecahedron with triangular planes, fig. 6.

Fig. 1.

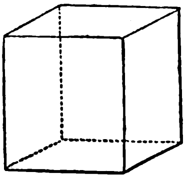


Fig. 2.

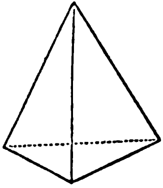


Fig. 3.

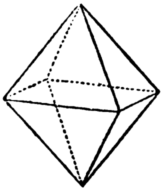


Fig. 4.

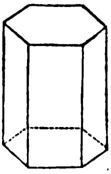


Fig. 5.

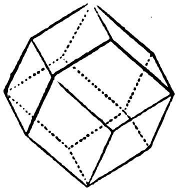
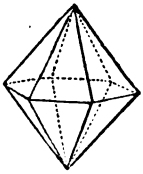


Fig. 6.



The instruments used for measuring the angles at which the planes of crystals meet, or incline to each other, are called *goniometers*. For the description of these and the method of using them see Cleaveland's *Mineralogy*, chap. 2d. (edit. 1822.) Brooke's *Crystallography*, p. 25.

† *Jour. of Sci. and Arts*, I. 24.

‡ *Philos. Trans.* 1813, p. 51. Other and very different views of the subject of primitive forms, have been taken by Brooke, Mohs and others. For more ample information on this subject consult the "*Familiar introduction to Crystallography*, by H. J. Brooke"; Mohs' *Treatise on Mineralogy*; "*Elements of Crystallography*," by G. Rose; or Whewell's *Essay in the Phil. Trans. Lond.*, 1825; "Shepard's *Mineralogy*," and "*A System of Mineralogy including an extended Treatise on Crystallography*," by James D. Dana, M. D. New Haven; 1837.

Sect. I.

Simple and compound forms.

38. The forms of crystals may be divided into simple and compound; a simple form has all its faces equal and similar to each other, while a compound form is bounded by at least two different classes of faces; thus figs. 8, 9, 10 are simple forms. Figs. 11, 12, 13 are compound, for fig. 11 is composed of eight hexagonal and six square faces; fig. 13 contains three classes of faces, eight hexagonal, six octagonal, and twelve quadratic. The lines round which the different parts of crystals are grouped, are called crystalline axes. It will be observed that in the figures 8, 9, 10, three right lines, which are equal in length and perpendicular to each other, may pass through the centre of the crystal; in fig. 8 by joining the opposite angles, in fig. 9 by joining the centres of the opposite faces, and in fig. 10 by connecting the opposite angles formed by the meeting of four edges. These forms are thus connected by having the same axes of crystallization, and proceeding from these three equal and rectangular axes, either the octohedron, the cube, or the rhombic dodecahedron may be constructed, the resulting form depending solely on the law according to which planes are symmetrically arranged around the axes.

Axes.

Fig. 8.

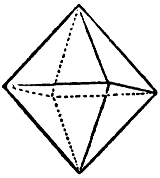


Fig. 9.

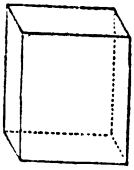


Fig 10.

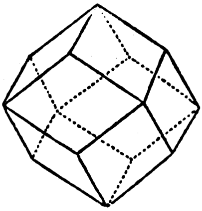


Fig. 11.

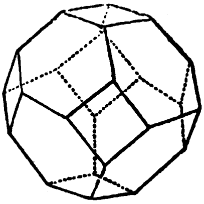


Fig. 12.

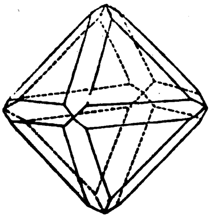
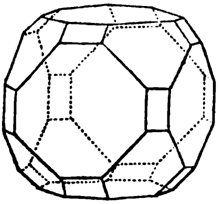


Fig. 13.



Laws.

39. From the law *that every plane shall pass through an extremity of each axis*, results the octohedron fig. 8. This law limits the number of faces to eight, and as these intersect in the lines joining the extremities of the axes, each face is an equilateral triangle, and the resulting form is the regular octohedron. From the law *that each plane shall pass through an extremity of one axis and be parallel to the other two*, results the cube fig. 9. As each axis has two extremities, only six planes can be grouped around them, and by their intersection the hexahedron, or cube, is produced. In a similar manner may the rhombic dodecahedron, fig. 10, be shown to be formed according to the law that *each plane shall pass through the extremities of two axes, and be parallel to the third.*

40. Simple forms thus associated by being reducible from the same

Systems of crystallization,

axes, constitute what is termed a *system of crystallization.* Thus the octohedron, cube, and rhombic dodecahedron are three forms of the octohedral or regular system. Such forms are connected still more intimately by the remarkable fact, that any substance which in crystallizing assumes one form of a system, may, and frequently does, assume other forms belonging to that system; and what is still more remarkable, the same substance is not only capable of assuming different forms of the same system, but during the act of crystallization, the faces of two, three, four, and in some cases even more, of these forms are simultaneously developed, whereby compound crystals of the greatest diversity of form and appearance are produced.*

41. A knowledge of all the simple forms of a system, as being those in which the same substance may occur, and which alone can give rise to compound crystals, is highly important. Haüy first proved the existence of a mathematical connexion between them; but we are indebted to Weiss, of Berlin, for the distinction of the systems of crystallization. He has shown that all crystalline forms may be brought under one of the six following systems, which may be distinguished as [illegible]

1. The octohedral, or regular system.
2. The square prismatic system.
3. The right prismatic system.
4. The oblique prismatic system.
5. The square prismatic system.
6. The rhombohedral system.

Octohedral system.

42. The *octohedral system* is characterized by the three equal and rectangular axes already described. If we suppose that two of the axes are horizontal, and the third vertical (figs. 8, 9, and 10), the law of symmetry is such, that if a face of a crystal be observed to bear a certain relation to one of the horizontal axes, other faces must fulfil the same condition to the other equal axes. From the perfect symmetry in the different parts of the crystal, this group is often called the regular system of crystallization. It consists of but few simple forms, the number being necessarily limited to the number of different ways in which a plane can intersect the three axes. These are only seven.

Number of forms.

1. The plane may cut each at an equal distance from the centre, as in the octohedron (fig. 8).
2. The plane may cut two axes at an equal, and the third at a greater distance from the centre. The resulting form is called the Triakisoctohedron.
3. The plane may cut two axes at an equal, and the third at a less distance from the centre. The resulting form is the Ikositetrahedron.
4. The plane may cut all three axes unequally. The resulting form is the Herakisoctohedron.
5. The plane may cut two axes at unequal distances from the centre, and be parallel to the third. The resulting crystal is the Tetrakishexahedron.
6. The plane may cut two axes in points equally distant from the

---

* Thus alum may crystallize in the form of a cube, or octohedron, but the compound crystal, fig. 11, is more common, where the faces of the cube truncate the angles of the octohedron. Fig. 12, is another form of the alum, where, in addition to the octohedron, the faces of the rhombic dodecahedron are also developed. Fig. 13 represents a combination of all three forms.

centre, and be parallel to the third. The form is the rhombic dodecahedron (fig. 10).

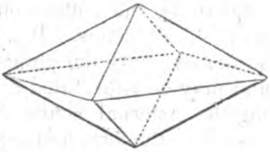
7. The plane may cut one axis, and be parallel to the other two. The form is the cube or hexahedron (fig. 9).

Of these forms, 1, 6, and 7 are of frequent occurrence; the others are usually found in combination.

Square prismatic system.

43. The *square prismatic system.* The forms of this system are also characterized by three axes which intersect each other at right angles; but they differ from those of the first system by two only out of the three, being equal. Let the third axis be supposed in a vertical position (fig. 14), the octohedron formed is either longer or shorter in the direction of this axis, than in that of its horizontal axis. These octohedrons may be compared to a double four sided pyramid on a square base. The parts about the base are similar to each other, but differ from those about its upper or lower extremity; and this character distinguishes the system.

Fig. 14.



Right prismatic system.

44. The *right prismatic system.* The crystals of this system are like the preceding, characterized by three rectangular axes, and are distinguished from both by no two of these axes being equal.

Fig. 15.

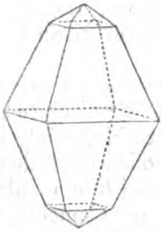


Fig. 16.

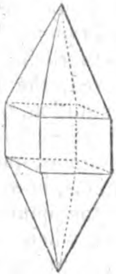
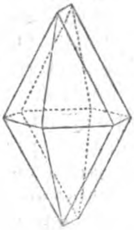


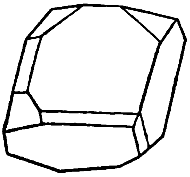
Fig. 17.



Oblique.

45. The *oblique prismatic system.* The crystals of this system (fig. 18), differ from those of the last by the front and back parts being dissimilar. This is owing to two of the axes intersecting each other obliquely, while the third still remains perpendicular to both.

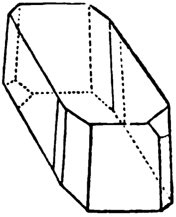
Fig. 18.



Double oblique.

46. The *double oblique system* is readily recognized by the complete absence of all symmetry in its crystalline forms. This results from all three axes intersecting each other obliquely; owing to which the left and right sides, as well as the back and front, are of different crystalline values. Hence no two faces are connected except those which are parallel, and all symmetry of form disappears.

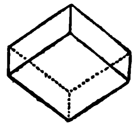
Fig. 19.



Rhombohedral.

47. The *rhombohedral system.* The forms of this system are, like the octohedral, characterized by three equal and similar axes; but these axes intersect each other at equal, but not at right angles. Its most simple form is the rhombohedron (fig. 20), which is bounded by six equal and similar rhombic faces. The axes are obtained by joining the centre of the opposite faces.*

Fig. 20.



Discovery of Mitscherlich.

48. In the year 1819, a discovery, extremely important both to mineralogy and chemistry, was made by Mitscherlich of Berlin, relative to the connexion between the crystalline form and composition of bodies. It appears from his researches,† that certain substances have the property of assuming the same crystalline form, and may be substituted for each other in combination without affecting the external character of the compound. Thus crystals possessed of the form and aspect of alum may be made with sulphates of potassa and sesquioxide of iron, without a particle of aluminous earth; and a crystal composed of selenic acid and soda will have a perfect resemblance to Glauber's salt.

Isomorphism.

49. To the new branch of science laid open by this discovery, the term *isomorphism* (from *ισος* equal, and *μοϱφὴ* form) is applied: and those substances which assume the same figure, are said to be *isomorphous.* Of these isomorphous bodies, several distinct groups have been described by Mitscherlich.‡

50. From the facts observed, the form of crystals is inferred to depend on their atomic constitution, and they at first induced Mitscherlich to suspect that crystalline form is determined solely by the number and arrangement of atoms, quite independently of their nature. Subsequent observations, however, induced him to abandon this view; and to incline to the opinion that certain elements, which are themselves isomorphous, when combined in the same manner with the same substance, communicate the same form.

Crystallization and separation of isomorphous substances.

51. Isomorphous substances crystallize together with great readiness, and are separated from each other with difficulty. Thus a weak solution of lime, which in pure water would be instantly indicated by oxalate of ammonia, is very slowly affected by that test when much sulphate of magnesia is present;§ and Turner found that chloride of manganese cannot be purified from lime by oxalate of ammonia.

The sulphates of zinc and copper, of copper and magnesium, of copper and nickel, of zinc and manganese, and of magnesium and manganese crystallize together, and have the same form as green vitriol, without containing a particle of iron. These mixed salts may be crystallized over and over again without the ingredients being separated from each other. T. 418.

Advantages from isomorphism,

52. The tendency of isomorphous bodies to crystallize together,

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[*] For more minute details see Turner's *Elements*, 6th edit. p. 409.

[†] *Ann. de Ch. et de Phys.*, vol. xiv. 172, xix. 350, and xxiv. 264 and 355.

[‡] For a table of isomorphous substances see Johnston's *Report on Chemistry*, in vol. 1st of *Reports of British Association*, 1831—2.

[§] Daubeny, in *Edin. Phil. Jour.* vii. 108.

accounts for the difficulty of purifying mixtures of isomorphous salts by crystallization. The same property sets the chemist on his guard against the occurrence of isomorphous substances in crystallized minerals. It is a useful guide in discovering the atomic constitution of compounds. For example, from the composition of the oxides of iron, and the compounds which this metal forms with other bodies, it is known that the sesquioxide consists of two atoms of iron and three atoms of oxygen; and, therefore, it is inferred that alumina, which is isomorphous with sesquioxide of iron, has a similar constitution.*

Connexion of crystallization with chemistry.

53. In connexion with chemistry, the theory of crystallization opens a new avenue to the science, and frequently enables us to ascertain directly, that which, independent of such aids, could only be arrived at by an indirect and circuitous route. We frequently read the chemical nature of substances, in their mechanical forms. In the arts, the process of crystallization is turned to very valuable account, in the separation and purification of a variety of substances.

SECTION II. *Heterogeneous Attraction, or Affinity.*

Chemical attraction or affinity.

54. Having considered attraction as disposing the particles of bodies to adhere so as to form masses or aggregates; and in many instances, to arrange themselves according to peculiar laws, and to assume regular geometrical figures—we are now to regard this power as operating upon dissimilar particles; as presiding over the composition of bodies; and as producing their chemical varieties. This is CHEMICAL ATTRACTION, or AFFINITY.

Distinguished from cohesive attraction. Result of this attraction.

55. Chemical affinity, like the cohesive attraction, is effective only at insensible distances; but it is distinguished from the latter force, in being exerted between the particles or atoms of bodies of *different kinds.* The result of its action is a new compound, in which the properties of the components have either entirely or partly disappeared, and in which new qualities are also apparent.

Thus, a piece of marble is an aggregate of smaller portions of marble attached to one another by *cohesion*, and the parts so attached are the integrant particles; each of which, however minute, is as perfect marble as the mass itself. But the integrant particles consist of two substances, lime and carbonic acid, which are different from one another as well as from marble, and are united by *chemical attraction.*

The integrant particles of a body are therefore aggregated together by cohesion; the component parts are united by affinity.

Instances.

56. The most simple instance of the exercise of chemical attraction is afforded by the mixture of two substances with one another. Water and sulphuric acid, or water and alcohol combine readily. So when potassa is added to sulphuric acid chemical affinity is exerted, and they combine together. If the two last substances are examined before being presented to each other, each will be found to be distinguished by peculiar properties. The potassa will convert the

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* *Plesiomorphism* (from the Greek πλησιος, near) is the term proposed by Miller to indicate the forms of substances that *approximate* but are not *identical;* such have been brought forward by Brooke against the doctrine of isomorphism. See his essay, and the reply of Whewell, in *Philos. Mag. and Ann.* N. S. X. 161 & 401.

Chap I. blue colour of vegetable infusions* to green, the acid will turn them red. But if we gradually add the potassa to the acid, we shall obtain a liquid which will have neither the properties of the potassa or of the acid; and which will no longer change the colour of the vegetable infusion, and the taste of which will have been converted into a bitter one.

Neutralization, 57. In cases of this kind where chemical combination takes place, and the qualities of the component parts of a compound are no longer to be detected in it; the bodies combined are said to *neutralize* each other.

Distinguished from saturation. 58. Neutralization is to be distinguished from saturation, (14) by which we express those weaker combinations where there is no remarkable alteration of qualities, as in cases of *solution*.—Water, for example, will dissolve successive portions of common salt, or sugar, until at length it refuses to take up more; or is *saturated;* the solution retaining the saline or sweet taste and some other qualities of the salt or sugar. The only physical quality that is changed being that of cohesion.†

The compound may have distinct properties. 59. In many cases, the properties of the compounds resulting from chemical affinity differ essentially from those of their component parts, and a series of new bodies, possessed of distinct and peculiar characters, is produced.

Exp. 1. Thus when two volumes of nitric oxide gas (Deutoxide of Nitrogen) are mixed with one of oxygen, an orange-coloured gas results, very sour, and soluble in water, whereas, the gases before mixture were colourless, tasteless, and insoluble in water.

Exp. 2. If into a glass vessel, exhausted of air, be introduced sulphur, and copper filings, and heat be applied so as to melt the former, it will presently combine with the latter.

Exp. 3. If we mix a quantity of iron filings and sulphur, and melt them in a crucible, we obtain a brittle mass which has properties different from those of either of its constituent parts.

Results. 60. We observe as the results of this attraction between these substances, 1, that the substances produced have not the intermediate properties of their elements but that they present new characters;

Test liquid. * An infusion of purple cabbage affords an economical and convenient liquid for this and similar purposes. For its preparation, one or more red cabbages should be cut into strips, and boiling water poured upon the pieces, a little dilute sulphuric acid is to be added, and the whole well stirred: it is then to be covered and kept hot as long as possible, or if convenient, should be heated nearly to boiling for an hour or two in a copper or earthen vessel. The quantity of water to be added at first should be sufficient to cover the cabbage, and the sulphuric acid should be in the proportion of about half an ounce of strong oil of vitriol by measure to each good sized plant. This being done, the fluid should be separated and drained off, and as much more hot water poured on as will cover the solid residue, adding a very little sulphuric acid. The whole is to be closed up, and suffered to stand until cooled, and then the liquid poured off and added to the former infusion. The *infusion* is to be evaporated to one half or one third its first bulk, poured into a jar, allowed to settle, and the clear red fluid decanted and preserved in bottles. This solution will keep a year. When required for use, the acid of a small portion of it should be neutralized by caustic potassa or soda, (not by ammonia,) when it will assume an intensely deep blue colour, and will in most cases, require dilution with twelve or fourteen parts of water. *Faraday.*

Neutralization how effected. † Neutralizations are best effected with the assistance of heat, especially if a carbonate be used, or if precipitation occur during the operation. The carbonic acid in the first case is dissipated, and in the latter the combination is more rapidly and perfectly effected. Evaporating basins are highly useful for these purposes, their contents being easily stirred, and the rod used for that purpose also applied to moisten the test paper when required. The solution to be neutralized should not be very strong, and the substance added should be diluted upon approaching the point of neutralization, if it be accurately required. F. 274.

Sect. II.

2, that in the second experiment much heat and light are evolved during the mutual action; 3, that the substances will unite in certain proportions only.

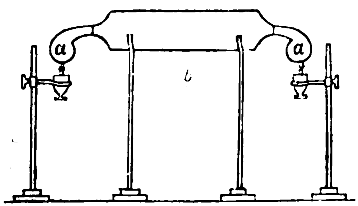
61. In liquids and gases, similar changes of properties may be exhibited, and, in many cases, a change of form or state results. Thus the combination of aëriform bodies produces a solid.

Solid products.

Exp. 1.

Into a retort (fig. 21, *a*,) introduce a small quantity of liquid ammonia (volatile alkali,) and into another a little hydrochloric (muriatic) acid; insert the beaks of the retorts into the extremities of a glass cylinder, *b*. The gases arising from the acid and ammonia, pass into the cylinder and unite to form a new solid compound, hydrochlorate of ammonia (sal ammoniac.)

Fig. 21.



Exp. 2.

If to a concentrated solution of hydrochlorate of lime, sulphuric acid or a saturated solution of carbonate of potassa be gradually added, a white solid will result.

Gaseous.

62. In other cases the solids are converted into aëriform matter, of which the combustion of gunpowder is a familiar instance.—Gases also, form a liquid; as when olefiant gas is mixed with chlorine.

When certain liquids are presented to each other, gases are the result, as when to two parts of alcohol we add one part of nitric acid, an effervescence ensues, and aëriform matter is copiously evolved.

Liquid.

Solids also produce liquids.

Exp.

Rub together in a mortar a few crystals of Glauber's salt with nitrate of ammonia, the two solids will become fluid.

Such operations are not confined to art. Nature presents them on an extended scale; and in connexion with the functions of life, renders them subservient to the most exalted purposes.

63. The new chemical powers that bodies thus acquire in consequence of combination, are often extremely remarkable, and can only be learned by *experiment*. It frequently happens that inert bodies produce inert compounds, and that active substances remain active when combined; but the reverse often occurs: thus oxygen, sulphur, and water, in themselves tasteless and comparatively inert, produce sulphuric acid when chemically combined; and potassa, which is a powerful caustic, when combined with sulphuric acid, forms a *salt** possessing little activity.

Changes produced by chemical action.

64. The colours of bodies are altered by chemical action.

Exp.

Into a weak solution of nitrate of copper, drop liquid ammonia, a rich blue colour will be produced. Add gradually, on the end of a glass rod, a little sulphuric acid, the liquid will become colourless.

Exp.

To an infusion of purple cabbage add a few drops of an acid, the colour will be changed to red.—The addition of liquid potassa, in quantity just sufficient to neutralize the acid, will restore the original colour.

Exp.

The addition of potassa alone, produces a green colour.

Exp.

Into a small jar of chlorine gas, confined by water, introduce a piece of litmus paper, the colour will be wholly destroyed.

Exp.

When sulphate of copper (blue vitriol,) and acetate of lead (sugar of lead) are rubbed together in a mortar; the new compound has a green colour.

Exp.

Calomel and potassa, both colourless, when rubbed in a mortar form a *black* compound.

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* The term *salt* in chemistry is not confined to those substances called salts in ordinary discourse.

Exp. Iodine, whose vapour is of a violet hue, forms a beautiful red compound with mercury, and a yellow one with lead.

Change of specific gravity, 65. The specific gravity of bodies is altered by chemical action. Two bodies rarely occupy the same space after combination which they did separately. In general their bulk is diminished, so that the specific gravity of the new body is greater than the mean of its components. Thus a mixture of 100 equal measures of water and an equal quantity of sulphuric acid does not occupy the space of 200 measures, but considerably less. A similar contraction frequently attends the combination of solids. Gases often experience a remarkable condensation when they unite. But there are exceptions. The reverse happens in some metallic compounds; and there are examples of combination between gases without any change in bulk.

And of temperaature. 66. A change of temperature generally accompanies chemical action. Caloric is evolved either when there is a diminution in the bulk of the combining substances without a change of form, or when a gas is condensed into a liquid, or when a liquid becomes solid (61. Exp. 2); and as when water is poured upon quicklime.

Exp. When equal parts of sulphuric acid and water are mixed, the temperature is so much increased that if the mixture be made in a phial about which tow is wrapped containing a few pieces of phosphorus, the phosphorus will be inflamed.[*]

Ignition. 67. Ignition is a frequent attendant upon chemical action, (59. Exp. 2.)

Exp. Mix, cautiously, a small quantity of sugar with about half its weight of the salt called chlorate of potassa, form the mixture into a heap upon a plate of iron, and drop upon it from the extremity of a glass rod, a little sulphuric acid, it will be inflamed.

Exp. Drop a small piece of potassium into water, or upon ice, hydrogen gas will be disengaged and take fire.

Chemical action promoted by mechanical division, 68. As chemical action takes place among the ultimate or constituent elements of bodies, it must obviously be opposed by the cohesion of their particles, and chemical attraction is often prevented by mechanical aggregation.

Exp. Introduce a piece of the metal antimony into a jar of chlorine gas, it will be only slowly and superficially acted upon; but if the mechanical aggregation be previously diminished, by reducing the metal to powder, it in that state rapidly unites with the gas, and burns the instant that it is introduced.

The influence of mechanical division in promoting the action of chemical affinity, and in favouring solution, will be obvious, if into a vessel containing dilute hydrochloric acid we drop a lump of marble; and into another vessel containing the same acid we pour an equal weight of marble reduced to powder.

By heat, 69. The chemical energies of bodies, are increased by heat.

Exp. To four ounce-measures of water, at the temperature of the atmosphere, add three ounces of sulphate of soda in powder, only part of the salt will be dissolved, even after being agitated some time. Apply heat, and the whole of the salt will disappear.

To this law, however, there are several exceptions; for many salts are equally, or nearly equally, soluble in cold as in hot water; as will be seen hereafter.

The effects of heat are sometimes only referable to the diminution of adhesion by expansion, or liquefaction; but in other cases they

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[*] As the phial is often broken, it should be placed upon a plate.

are peculiar and complicated, and probably concerned in modifying the electrical energies of the acting substances.

And by Mechanical agitation.

70. Mechanical agitation, also favours the chemical action of bodies.

Exp. Into a wine glass full of water, tinged blue with the infusion of cabbage let fall a small lump of solid tartaric acid. The acid, if left at rest, even during some hours, will only change to red that portion of the infusion, which is in immediate contact with it. Stir the liquid, and the whole will immediately become red.

Exp. Sulphuric acid poured into alcohol will subside to the bottom, and chemical action will take place only at the touching surfaces of the two substances—but it will be brought on through the whole mixture by agitation.

Some bodies evince no affinity.

71. Some bodies evince no affinity for each other.

Exp. Oil and water, or powdered chalk and water, may be agitated together, but they will not combine. On allowing the vessels containing them to remain at rest, the oil or water rises to the surface, and the chalk falls to the bottom.

Union promoted by a third body,

72. The intervention of a third body will sometimes promote the union of two other bodies which have no affinity for each other.

Exp. Thus oil and water unite immediately on adding an alkali, as caustic potassa.

Or destroyed.

73. It very frequently happens, on the contrary, that the tendency of two bodies to unite, or remain in combination together, is weakened or destroyed by the addition of a third. Thus alcohol unites with water in such a manner as to separate most salts from it.

Exp. A striking instance of this is seen in a saturated or strong solution of nitre in water. If to this there be added an equal measure of alcohol, the greater part of the nitre instantly falls down.

Exp. Or, if to a solution of camphor in alcohol, water be added, the water will unite with the alcohol and the camphor will be separated.

Exp. Oil has an affinity for the volatile alkali, ammonia, and will unite with it, forming a soapy substance called a liniment. But the ammonia has a still greater attraction for sulphuric acid; and hence if the acid be added to the liniment, the alkali will quit the oil, and unite by preference with the acid.

Affinity how inferred.

74. The affinity existing between any two bodies, is inferred from their entering into chemical combination, and that this has happened, we have a proof in the change of properties.

75. From a great number of facts, it appears that some bodies have a stronger tendency to unite than others, and that the union of a substance with another will often exclude, or even bring about the separation of a third substance which may have been previously united with one of them. This preference of uniting, exhibited with regard to other bodies, has been called *Elective Affinity*. Thus

Elective affinity,

Exp. 1. To a solution of camphor in alcohol add water; the camphor will be separated, and the water and alcohol will unite.

Exp. 2. Add to water a few drops of sulphuric acid; the addition of a solution of baryta will cause the separation of the acid. The white substance that will subside will be a new compound of sulphuric acid and baryta.

In these and many similar cases combination and decomposition occur.

Single,

76. When a compound is decomposed and but one substance is separated, or brought into combination, the affinity has been called *Single Elective*. But the phenomena are often more complex.

Double.

77. When two compounds, each consisting of two ingredients, are decomposed and two new compounds formed, we have an instance of *Double Elective Affinity*.

Exp.

Mix together a solution of carbonate of ammonia and hydrochlorate of lime; carbonate of lime and hydrochlorate of ammonia will be formed.

Decomposition.

78. The knowledge of the affinities which bodies have for each other, enables us to separate them when united, or to perform the process of *decomposition*. Thus,

Exp.

In a solution of nitrate of silver (common lunar caustic) place a piece of polished copper; it will soon be covered with metallic silver. The solution will have been *decomposed*, and the silver *precipitated*.

Tables of affinity,

79. The order in which decompositions take place has been expressed in tables, of which the following, drawn up by Geoffroy, is an example :—

SULPHURIC ACID.

Baryta,
Strontia,
Potassa,
Soda,
Lime,
Ammonia,
Magnesia.

This table signifies, first, that sulphuric acid has an affinity for the substances placed below the horizontal line, and may unite separately with each; and, secondly, that the base of the salts so formed will be separated from the acid by adding any of the alkalies or earths which stand above it in the column. Thus ammonia will separate magnesia, lime ammonia, and potassa lime; but none can withdraw baryta from sulphuric acid, nor can ammonia or magnesia decompose sulphate of lime, though strontia or baryta will do so. Bergmann conceived that these decompositions are solely determined by chemical attraction, and that consequently the order of decomposition represents the comparative forces of affinity; and this view, from the simple and natural explanation it affords of the phenomenon, was for a time very generally adopted. But it does not necessarily follow, because lime separates ammonia from sulphuric acid, that the lime has a greater attraction for the acid than the volatile alkali. Other causes are in operation which modify the action of affinity to such a degree, that it is impossible to discover how much of the effect is owing to that power.

Objections to.

80. Berthollet was the first to show that the relative forces of chemical attraction cannot always be determined by observing the order in which substances separate each other when in combination, and that the tables of Geoffroy are merely tables of decomposition, not of affinity. He likewise traced all the various circumstances that modify the action of affinity, and gave a consistent explanation of the mode in which they operate. He denied the existence of elective affinity as an invariable force, capable of effecting the perfect separation of one body from another; he maintained that all the instances of complete decomposition attributed to elective affinity are in reality determined by one or more of the collateral circumstances that influence its operation. But here this acute philosopher went too far. Bergmann erred in supposing the result of chemical action to be in every case owing to elective affinity; but Berthollet ran into the opposite extreme in declaring that the effects formerly ascribed to that power are never produced by it.

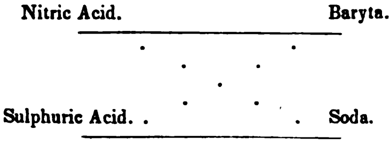
Diagrams.

81. The chemical changes are often illustrated by diagrams,

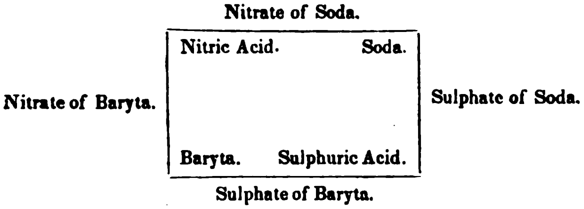
which may either be constructed so as merely to show the result of the change, or may exhibit the composition of the acting bodies.

Exp. The addition of sulphate of soda to nitrate of baryta (both in solution), will be attended with the formation of sulphate of baryta and nitrate of soda.

The following diagram exhibits the substances before mixture, on parallel lines; after mixture, by diagonal lines:



Or a more complete view of the change is given in the following diagram, where the bodies before mixture are placed upon the outside of the perpendicular lines; their component parts are shown within them; and the new results on the outside of the horizontal lines.*



Circumstances influencing affinity. 82. Chemical affinity is influenced by various extraneous circumstances and forces. Of these the most important are, cohesion, elasticity, quantity of matter, and gravity. To these may be added the agency of the imponderables.

Cohesion, 83. The first obvious effect of cohesion is to oppose affinity, by impeding or preventing that mutual penetration and close proximity of the particles of different bodies, which is essential to the successful exercise of their attraction. For this reason, bodies seldom act chemically in their solid state. Liquidity, on the contrary, favours chemical action; it permits the closest possible approximation, while the cohesive power is comparatively so trifling as to oppose no appreciable barrier to affinity.

How diminished, 84. Cohesion may be diminished in two ways, by mechanical division, or by the application of heat. The former is useful by increasing the extent of surface. Heat acts with greater effect, and never fails in promoting combination, whenever the cohesive power is a barrier to it. Its intensity should always be so regulated as to produce liquefaction. The fluidity of one of the substances frequently suffices for effecting chemical union, as is proved by the facility with which water dissolves many salts and other solid bodies. The reduction of both substances to the liquid state is the best me-

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* Various methods have been made use of to express chemical changes, and the results of chemical actions, by means of diagrams, for which the student may consult Henry's and Brande's *Chem.*, the *Medical Chemistry* of Paris, and Ure's *Dictionary*, Art. *Attraction*.

thod for ensuring chemical action. The slight degree of cohesion possessed by liquids does not appear to cause any impediment to combination. It seems fair to infer, that very little, if any, affinity exists between two bodies which do not combine when they are intimately mixed in a liquid state.

Agency in crystallization,

85. The phenomena of crystallization are owing to the ascendancy of cohesion over affinity. When a large quantity of salt has been dissolved in water by the aid of heat, part of the saline matter generally separates as the solution cools, because the cohesive power of the salt then becomes comparatively too powerful for chemical attraction. Its particles begin to cohere together and are deposited in crystals, the process of crystallization continuing till it is arrested by the affinity of the liquid. A similar change happens when a solution made in the cold is gradually evaporated. The cohesion of the saline particles is no longer counteracted by the affinity of the liquid, and the salt, therefore, assumes the solid form.

Affects results.

86. Cohesion plays a still more important part. It sometimes determines the result of chemical action, probably even in opposition to affinity.

Exp.

Thus, on mixing together a solution of two acids and one alkali, of which two salts may be formed, one soluble, and the other insoluble, the alkali will unite with that acid with which it forms the insoluble compound, to the exclusion of the other. This is one of the modifying circumstances employed by Berthollet to account for the phenomena of single elective attraction, and is certainly applicable to many of the instances to be found in the tables of affinity.

Its action in particular cases.

87. To comprehend the manner in which cohesion acts in some instances, it is necessary to consider what takes place when in the same liquid two or more compounds are brought together, which do not give rise to an insoluble substance.

Exp.

Thus on mixing solutions of sulphate of potassa and nitrate of soda, no precipitate ensues; because the salts, capable of being formed by double decomposition, sulphate of soda and nitrate of potassa, are likewise soluble. In this case it is possible either that each acid may be confined to one base, so as to constitute two neutral salts: or that each acid may be divided between both bases, yielding four neutral salts. It is difficult to decide this point in an unequivocal manner: but judging from many chemical phenomena, it is probable that the arrangement last mentioned is the most frequent, and is probably universal whenever the relative forces of affinity are not very unequal. When two acids and two bases meet together in neutralizing proportion, it may, therefore, be inferred, that each acid unites with both the bases in a manner regulated by their respective forces of affinity, and that four salts are contained in solution. In like manner the presence of three acids and three bases will give rise to nine salts; and when four of each are present, sixteen salts will be produced. This view affords the most plausible theory of the constitution of mineral waters, and of the products which they yield by evaporation. T.

Influence of insolubility,

88. The influence of insolubility in determining the result of chemical action may be readily explained on this principle. If nitric acid, sulphuric acid, and baryta, are mixed together in solution, the base may be conceived to be at first divided between the two acids, and nitrate and sulphate of baryta to be generated. The latter being insoluble is instantly removed beyond the influence of the nitric acid, so that for an instant nitrate of baryta and free sulphuric acid remain in the liquid; but as the base left in solution is again divided between the two acids, a fresh quantity of the insoluble sulphate is generated; and this process of partition continues, until either the baryta or the

sulphuric acid is withdrawn from the solution. Similar changes ensue when nitrate of baryta and sulphate of soda are mixed.*

Of efflorescence,

89. The efflorescence of a salt is sometimes attended with a similar result. If carbonate of soda and chloride of calcium are mingled together in solution, the insoluble carbonate of lime subsides. But if carbonate of lime and sea-salt are mixed in the solid state, and a certain degree of moisture is present, carbonate of soda and chloride of calcium are slowly generated, and since the former, as soon as it is formed, separates itself from the mixture by efflorescence, its production continues progressively. The efflorescence of carbonate of soda, which is sometimes seen on old walls, or which in some countries is found on the soil, appears to have originated in this manner.

Of elasticity,

90. From the obstacle which cohesion puts in the way of affinity, the gaseous state, in which the cohesive power is wholly wanting, might be expected to be peculiarly favourable to chemical action. The reverse, however, is the fact. Bodies evince little disposition to unite when presented to each other in the elastic form. Combination does indeed sometimes take place in consequence of a very energetic attraction; but examples of an opposite kind are much more common. This want of action seems to arise from the distance between the particles preventing that close approximation which is so necessary to the successful exercise of affinity. Hence many gases cannot be made to unite directly, which nevertheless combine readily while in their *nascent* state; that is while in the act of assuming the gaseous form by the decomposition of some of their solid or fluid combinations.

Elasticity operates likewise as a decomposing agent. If two gases, the reciprocal attraction of which is feeble, suffer considerable condensation when they unite, the compound will be decomposed by very slight causes. Chloride of nitrogen affords an apt illustration of this principle, being distinguished for its remarkable facility of decomposition.

Of heat.

91. Many familiar phenomena of decomposition are owing to elasticity. All compounds that contain a volatile and a fixed principle, are liable to be decomposed by a high temperature. The expansion occasioned by heat removes the elements of the compound to a greater distance from each other, and thus by diminishing the force of chemical attraction, favours the tendency of the volatile principle to assume the form which is natural to it. The evaporation of water from a solution of salt is an instance of this kind.

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* The separation of salts by crystallization, from mineral waters or other saline mixtures, is explicable by a similar mode of reasoning. Thus on mixing nitrate of potassa and sulphate of soda, four salts, according to this view, are generated, namely, the sulphates of soda and potassa, and the nitrates of those bases; and if the solution be allowed to evaporate gradually, a point at length arrives when the least soluble of these salts, the sulphate of potassa, will be disposed to crystallize. As soon as some of its crystals are deposited, and thus withdrawn from the influence of the other salts, the constituents of these undergo a new arrangement, whereby an additional quantity of sulphate of potassa is generated; and this process continues until the greater part of the sulphuric acid and potassa has combined, and the compound is removed by crystallization. If the difference in solubility is considerable, the separation of salts may be often rendered very complete by this method. T.

Many solid substances, which contain water in a state of intimate combination, part with it in a strong heat in consequence of the volatile nature of that liquid. The separation of oxygen from some metals, by heat alone, is explicable on the same principle.

Heat may favour or oppose affinity.

92. It appears that the influence of heat over affinity is variable; for at one time it promotes chemical union, and opposes it at another. Its action, however, is always consistent. Whenever the cohesive power is an obstacle to combination, heat favours affinity either by diminishing the cohesion of a solid, or by converting it into a liquid. As the cause of the gaseous state, on the contrary, it keeps at a distance particles which would otherwise unite; or, by producing expansion, it tends to separate from one another substances which are already combined.

Influence of elasticity on decompositions,

93. Some of the decompositions, which were attributed by Bergmann to the sole influence of elective affinity, may be ascribed to elasticity. If three substances are mixed together, two of which can form a compound which is less volatile than the third body, the last will, in general, be completely driven off by the application of heat. The decomposition of the salts of ammonia by the pure alkalies or alkaline earths, may be adduced as an example.

On results of chemical action,

94. The influence of elasticity in determining the result of chemical action in these instances, seems owing to the same cause which enables insolubility to be productive of similar effects. Thus, on mixing hydrochlorate of ammonia with lime, the acid is divided between the two bases; some ammonia becomes free, which, in consequence of its elasticity, is entirely expelled by a gentle heat. The acid of the remaining hydrochlorate of ammonia is again divided between the two bases; and if a sufficient quantity of lime is present, the ammoniacal salt will be completely decomposed.

Of quantity of matter.

95. The influence of quantity of matter over affinity, is universally admitted. If one body A unites with another body B in several proportions, that compound will be most difficult of decomposition which contains the smallest quantity of B. Of the three oxides of lead, for instance, the peroxide parts most easily with its oxygen by the action of heat; a higher temperature is required to decompose the red oxide; and the protoxide will bear the strongest heat of our furnaces without losing a particle of its oxygen.

Example.

96. The influence of quantity over chemical attraction, may be further illustrated by the phenomena of solution. When equal weights of a soluble salt are added in succession to a given quantity of water, which is capable of dissolving almost the whole of the salt employed, the first portion of the salt will disappear more readily than the second, the second than the third, the third than the fourth, and so on. The affinity of the water for the saline substance, diminishes with each addition, till at last it is weakened to such a degree as to be unable to overcome the cohesion of the salt. The process then ceases, and a saturated solution is obtained.*

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* Quantity of matter is employed advantageously in many chemical operations. If, for instance, a chemist is desirous of separating an acid from a metallic oxide by means of the superior affinity of potassa for the former, he frequently uses rather more of the alkali than is sufficient for neutralizing the acid. He takes the precaution of employing an excess of alkali, in order the more effectually to bring every particle of the substance to be decomposed in contact with the decomposing agent.

Berthollet's views.

97. But Berthollet attributed a much greater influence to quantity of matter. It was the basis of his doctrine, developed in the *Statique Chimique*, that bodies cannot be wholly separated from each other by the affinity of a third substance for one element of a compound; and to explain why a superior chemical attraction does not produce the effect which might be expected from it, he contended that quantity of matter compensates for a weaker affinity.

Berthollet confounded two things, namely, force of attraction and neutralizing power, which are really different, and ought to be held distinct. M. Dulong has also found that the principle of Berthollet is not in accord with the results of experiment. T. 133.

Influence of gravity,

98. The influence of gravity is perceptible when it is wished to make two substances unite, the densities of which are different. In a case of simple solution, a larger quantity of saline matter is found at the bottom than at the top of the liquid, unless the solution shall have been well mixed subsequently to its formation. In making an alloy of two metals, which differ from one another in density, a larger quantity of the heavier metal will be found at the lower than in the upper part of the compound; unless great care be taken to counteract the tendency of gravity by agitation. This force obviously acts, like the cohesive power, in preventing a sufficient degree of approximation.

Of pressure,

99. Pressure has an important influence upon chemical action. It appears to operate both by bringing the particles into closer contact, and by inducing elevation of temperature. As when chlorate of potassa and phosphorus are ignited by percussion.

Of imponderables.

100. The chemical agency of galvanism, and the effects of light and electricity, will be most conveniently stated in other parts of the work. T. 128.

Measure of affinity,

101. As the order of decomposition is not always a satisfactory measure of the force of affinity, when no disturbing causes operate, the phenomena of decomposition afford a sure criterion; but when the conclusions obtained in this way are doubtful, assistance may be derived from other sources. The surest indications are procured by observing the tendency of different substances to unite with the same principle, under the same circumstances, and subsequently by marking the comparative facility of decomposition by the same decomposing agent. Thus, on exposing silver, lead, and iron, to air and moisture, the iron soon rusts, the lead is oxidized in a slight degree only, and the silver resists oxidation altogether. It is hence inferred that iron has the greatest affinity for oxygen, lead next, and silver the least. It is inferred from the action of heat on the carbonate of potassa, baryta, lime, and oxide of lead, that potassa has a stronger attraction for carbonic acid than baryta, baryta than lime, and lime than oxide of lead.

Of acids and alkalies.

102. Of all chemical substances, our knowledge of the relative degrees of attraction of acids and alkalies for each other is the most uncertain. Their action on one another is affected by so many circumstances, that it is in most cases impossible, with certainty, to refer any effect to its real cause. T.

Substances unite in certain proportions,

· 103. Substances which unite chemically have been found to do so in certain proportions. In some cases they are united in a great many proportions, in others only in a few. In a few instances combi-

Unlimited, nation takes place unlimitedly in all proportions; in others it occurs in every proportion within a certain limit. The union of water with alcohol and the liquid acids, such as the sulphuric, hydrochloric, and nitric acids, affords instances of the first mode of combination; the solutions of salts in water are examples of the second. One drop of sulphuric acid may be diffused through a gallon of water, or a drop of water through a gallon of the acid; or they may be mixed together in any intermediate proportions; and in each case they appear to unite perfectly with each other. A hundred grains of water, Limited, on the contrary, will dissolve any quantity of sea-salt which does not exceed forty grains. Its solvent power then ceases, because the cohesion of the solid becomes comparatively too powerful for the force of affinity. The limit to combination is in such instances owing to the cohesive power; and but for the obstacle which it occasions, the salt would most probably unite with water in every proportion.

Character of compounds of many proportions, 104. All the substances that unite in many proportions, give rise to compounds which have this common character, that their elements are united by a feeble affinity, and preserve, when combined, more or less of the properties which they possess in a separate state.

Of few. 105. The most interesting series of compounds is produced by substances which unite in a few proportions only; and which, in combining, lose more or less completely the properties that distinguish them when separate. Of these bodies, some form but one combination. Others combine in two proportions. Others again unite in three, four, five, or even six proportions, which is the greatest number of compounds that any two substances are known to produce, except perhaps carbon and hydrogen, and those which belong to the first division.

Laws. 106. The combination of substances that unite in a few proportions only, is regulated by the three following remarkable laws:—

First law. 1. The first law is, that the composition of bodies is fixed and invariable. A compound substance, so long as it retains its characteristic properties, always consists of the same elements united together in the same proportion. Water is formed of 1 part* of hydrogen and 8 of oxygen; and were these two elements to unite in any other proportion, some new compound, different from water, would be the product. The same observation applies to all other substances, however complicated, and at whatever period they were produced. This law is universal and permanent. Its importance is equally manifest: it is the essential basis of chemistry.

How accounted for. 107. Two views have been proposed by way of accounting for this law. The explanation now universally given, is confined to a mere statement, that substances are disposed to combine in those proportions to which they are so strictly limited, in preference to any others; it is regarded as an ultimate fact, because the phenomena are explicable on no other known principle.

The tendency of bodies to unite in definite proportions only, is so great as to excite a suspicion that all substances combine in this way; and that the exceptions thought to be afforded by the phenomena of solution, are rather apparent than real.

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* By the expression "parts" is meant parts by weight.

Second law.

108. The second law of combination is, that the relative quantities in which bodies unite may be expressed by proportional numbers. Thus, 8 parts of oxygen unite with 1 part of hydrogen, 16.1 of sulphur, 35.42 of chlorine, 39.6 of selenium, and 108 parts of silver. Such are the quantities of these five bodies which are disposed to unite with 8 parts of oxygen; and it is found that when they combine with one another, they unite either in the proportions expressed by those numbers, or in multiples of them according to the third law of combination.

Equivalents, &c.

109. From the occurrence of such proportional numbers has arisen the use of certain terms, as *Proportion*, *Combining Proportion*, *Proportional*, and *Chemical Equivalent*, or *Equivalent*, to express them. The latter term, introduced by Wollaston, was suggested by the circumstance that the combining proportion of one body is, as it were, equivalent to that of another body, and may be substituted for it in combination.

Equivalents of compounds.

110. This law does not apply to elementary substances only, since compound bodies have their combining proportions or equivalents, which may likewise be expressed in numbers. Thus, since water is composed of one equivalent or 8 parts of oxygen, and one equivalent or 1 of hydrogen, its combining proportion or equivalent is 9. The equivalent of sulphuric acid is 40.1, because it is a compound of one equivalent or 16.1 parts of sulphur, and three equivalents or 24 parts of oxygen. The equivalent number of potassium is 39.15, and as that quantity combines with 8 of oxygen to form potassa, the equivalent of the latter is $39.15+8=47.15$. Now when these compounds unite, one equivalent of the one combines with one, two, three, or more equivalents of the other, precisely as the simple substances do. The equivalent of sulphate of potassa will therefore be $40.1+47.15=87.25$.

Examples.

111. The composition of the salts affords a very instructive illustration of this subject; and to exemplify it still further, a list of the equivalents of a few acids and alkaline bases is annexed:—

Hydrofluoric acid	19.68	Lithia	14.44
Phosphoric acid	71.4	Magnesia	20.7
Hydrochloric acid	36.42	Lime	28.5
Sulphuric acid	40.1	Soda	31.3
Nitric acid	54.15	Potassa	47.15
Arsenic acid	115.4	Strontia	51.8
Selenic acid	63.6	Baryta	76.7

It will be seen at a glance that the neutralizing power of the different alkalies is very different; for the equivalent of each base expresses the quantity required to neutralize an equivalent of each of the acids. Thus 14.44 of lithia, 31.3 of soda, and 76.7 of baryta, combine with 54.15 of nitric acid, forming the neutral nitrates of lithia, soda, and baryta. The same fact is obvious with respect to the acids; for 71.4 of phosphoric, 40.1 of sulphuric, and 115.4 of arsenic acid unite with 76.7 of baryta, forming a neutral phosphate, sulphate, and arseniate of baryta.

Neutral compounds.

112. These circumstances afford a ready explanation of a curious fact, first noticed by the Saxon chemist Wenzel; namely, that when two neutral salts mutually decompose each other, the resulting compounds are likewise neutral. The cause of this fact is now obvious. If 71.4 parts of neutral sulphate of soda are mixed with 130.85 of

nitrate of baryta, the 76.7 parts of baryta unite with 40.1 of sulphuric acid, and the 54.15 parts of nitric acid of the nitrate combine with the 31.3 of soda of the sulphate, not a particle of acid or alkali remaining in an uncombined condition.

Sulphate of Soda.		*Nitrate of Baryta.*	
Sulphuric acid .	40.1	54.15	Nitric acid,
Soda . . .	31.3	76.7	Baryta,
	71.4	130.85	

It matters not whether more or less than 71.4 parts of sulphate of soda are added; for if more, a small quantity of sulphate of soda will remain in solution; if less, nitrate of baryta will be in excess; but in either case the neutrality will be unaffected.

Third law.

113. The third law of combination is, that when one body A unites with another body B in two or more proportions, the quantities of the latter, united with the same quantity of the former, bear to each other a very simple ratio. The progress of chemical research, in discovering new compounds and ascertaining their exact composition, has shown that these ratios of B may be represented by one or other of the two following series:—

Ratios.

1st Series. A unites with 1, 2, 3, 4, 5, &c. of B.
2d Series. A unites with 1, 1½, 2, 2½, &c. of B.

The first series is exemplified by the subjoined compounds:

Whole numbers.

Water is composed of .	Hydrogen	1	. Oxygen	8	1
Binoxide of hydrogen .	Do.	1	. Do.	16	2
Carbonic oxide . .	Carbon	6.12	. Do.	8	1
Carbonic acid . .	Do.	6.12	. Do.	16	2
Nitrous oxide . .	Nitrogen	14.15	. Do.	8	1
Nitric oxide . .	Do.	14.15	. Do.	16	2
Hyponitrous acid . .	Do.	14.15	. Do.	24	3
Nitrous acid . .	Do.	14.15	. Do.	32	4
Nitric acid . .	Do.	14.15	. Do.	40	5

It is obvious that in all these compounds the ratios of the oxygen are expressed by whole numbers. In water the hydrogen is combined with half as much oxygen as in the binoxide of hydrogen, so that the ratio is as 1 to 2. The same relation holds in carbonic oxide and carbonic acid. The oxygen in the compounds of nitrogen and oxygen is in the ratio of 1, 2, 3, 4, and 5. In like manner the ratio of sulphur in the two sulphurets of mercury, and that of chlorine in the two chlorides of mercury, is as 1 to 2. So, in bicarbonate of potassa, the alkali is united with twice as much carbonic acid as in the carbonate; and the acid of the three oxalates of potassa is in the ratio of 1, 2, and 4.

The following compounds exemplify the second series:—

Half equivalents.

Protoxide of iron	consists of	Iron	28	Oxygen	8	1
Sesquioxide or Peroxide .	.	Do.	28	Do.	12	1½
Protoxide of manganese .	.	Manganese	27.7	Do.	8	1
Sesquioxide* .	.	Do.	27.7	Do.	12	1½
Binoxide .	.	Do.	27.7	Do.	16	2
Arsenious acid .	.	Arsenic	37.7	Do.	12	1½
Arsenic acid .	.	Do.	37.7	Do.	20	2½
Hypophosphorous acid .	.	Phosphorus	15.7	Do.	4	½
Phosphorous acid .	.	Do.	15.7	Do.	12	1½
Phosphoric acid .	.	Do.	15.7	Do.	20	2½

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* The Latin *sesqui*, one and a half, is used when the elements of an oxide, chloride, &c., are as 1 to 1½ or as 2 to 3.

Both of these series, which together constitute the third law of combination, result naturally from the operation of the second law. The first series arises from one equivalent of a body uniting with 1, 2, 3, or more equivalents of another body. The second series is a consequence of two equivalents of one substance combining with 3, 5, or more equivalents of another. Thus if two equivalents of phosphorus unite both with 3 and with 5 equivalents of oxygen, we obtain the ratio of 1½ to 2½; and should one equivalent of iron combine with one of oxygen, and another compound be formed of two equivalents of iron to three of oxygen, then the oxygen united with the same weight of iron would have the ratio, as in the table, of 1 to 1½. Still more complex arrangements will be readily conceived, such as 3 equivalents of one substance to 4, 5, or more of another. But it is remarkable that combinations of the kind are very rare; and even their existence, though theoretically possible, has not been decidedly established.*

More complex arrangements.

Advantages of these laws.

114. The utility of being acquainted with these important laws is almost too manifest to require mention. Through their aid, and by remembering the equivalents of a few elementary substances, the composition of an extensive range of compound bodies may be calculated with facility. Thus, by knowing that 6.12 is the equivalent of carbon and 8 of oxygen, it is easy to recollect the composition of carbonic oxide and carbonic acid; the first consisting of 6.12 parts of carbon + 8 of oxygen, and the second of 6.12 carbon + 16 of oxygen. The equivalent of potassium is 39.15; and potassa, its protoxide, is composed of 39.15 of potassium + 8 of oxygen. From these few data, we know at once the composition of carbonate and bicarbonate of potassa; the former being composed of 22.12 parts of carbonic acid + 47.15 potassa, and the latter of 44.24 carbonic acid + 47.15 potassa. This method acts as an artificial memory, the advantage of which, compared with the common practice of stating the composition in 100 parts, will be manifest by inspecting the following quantities, and attempting to recollect them.

	Carbonic Oxide.	*Carbonic Acid.*
Carbon	42.86	27.27
Oxygen	57.14	72.73

	Carbonate of Potassa.	*Bicarbonate of Potassa.*
Carbonic acid	31.43	47.83
Potassa	68.57	52.17

From the same data, calculations, which would otherwise be difficult or tedious, may be made rapidly and with ease, without refer-

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* The merit of establishing the first law of combination seems justly due to Wenzel, a Saxon chemist; and the second law is also deducible from his experiments on the composition of the salts. His work, entitled *Lehre der Verwandtschaft*, was published in 1777. The late Mr Higgins, also, in 1789, speculated on the atomic constitution of compound bodies; but it is to Dalton* that we are indebted for a theory of chemical union, embracing the whole science, and giving it a consistency and form which before his time it had never possessed. Of all who have successfully laboured in establishing the laws of combination, the most splendid contribution is that of the celebrated Berzelius.

* *New System of Chem. Philos.* 1808.

Uses,

ence to books, and frequently by a simple mental process. The exact quantities of substances required to produce a given effect may be determined with certainty, thus affording information which is often necessary to the success of chemical processes, and of great consequence both in the practice of the chemical arts, and in the operations of pharmacy.

In analysis.

115. The same knowledge affords a good test to the analyst by which he may judge of the accuracy of his result, and even sometimes correct an analysis which he has not the means of performing with rigid precision. Thus a powerful argument for the accuracy of an analysis is derived from the correspondence of its result with the laws of chemical union. On the contrary, if it form an exception to them, we are authorized to regard it as doubtful; and may hence be led to detect an error, the existence of which might not otherwise have been suspected. If an oxidized body be found to contain one equivalent of the combustible with 7.99 of oxygen, it is fair to infer that 8, or one equivalent of oxygen, would have been the result, had the analysis been perfect.

The composition of a substance may sometimes be determined by a calculation, founded on the laws of chemical union, before an analysis of it has been accomplished.

Numbers how determined.

116. The method of determining equivalent numbers will be anticipated from what has already been said. The commencement is made by carefully analyzing a definite compound of two simple substances which possess an extensive range of affinity. Thus water, a compound of oxygen and hydrogen, is found to contain 8 parts of the former to 1 of the latter; and if it be assumed that water consists of one equivalent of oxygen and one of hydrogen, the relative weights of these equivalents will be as 8 to 1. The chemist then selects for analysis such compounds as he believes to contain one equivalent of each element, in which either oxygen or hydrogen, but not both, is present. Carbonic oxide and hydrosulphuric acid are suited to his purpose: as the former consists of 8 parts of oxygen and 6.12 of carbon, and the latter of 1 part of hydrogen and 16.1 of sulphur, the equivalent of carbon is inferred to be 6.21, and that of sulphur 16.1. The equivalents of all the other elements may be determined in a similar manner.*

Essential point.

117. Since the equivalents merely express the relative quantities of different substances which combine together, it is in itself immaterial what figures are employed to express them. The only essen-

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* In researches on chemical equivalents there are two kinds of difficulty, one involved in the processes for ascertaining the exact composition of compounds, and the other in the selection of the compounds which contain single equivalents. Important general precautions in the experimental part of the subject are the following:—1, to exert scrupulous care about the purity of materials; 2, to select methods which consist of a few simple operations only; 3, to repeat experiments, and with materials prepared at different times; 4, to arrive at the same conclusion by two or more processes independent of each other. In the selection of compounds of single equivalents, there are several circumstances calculated to direct the judgment; for which see Turner's *Elements of Chemistry*, p. 139. The ready decomposition by galvanism, observed by Faraday, of compounds which consist of single equivalents, and the resistance to the same agent of many others not so constituted, promises to become an indication of great value in determining equivalent numbers.

tial point is, that the relation should be strictly observed. Thus, the equivalent of hydrogen may be assumed as 10; but then oxygen must be 80, carbon 61.2 and sulphur 16.1. We may call hydrogen 100 or 1000; or, if it were desirable to perplex the subject as much as possible, some high uneven number might be selected, provided the due relation between the different numbers were faithfully preserved. But such a practice would effectually do away with the advantage above ascribed to the use of equivalents; and it is the object of every one to employ such as are simple, that their relation may be perceived by mere inspection. Thomson makes oxygen 1, so that hydrogen is eight times less than unity, or 0.125, carbon 0.75, and sulphur 2. Wollaston, in his scale of chemical equivalents, estimated oxygen at 10; and hence hydrogen is 1.25, carbon 7.5 and so on. According to Berzelius, oxygen is 100. And lastly, several other chemists, such as Dalton, Davy, Henry, and others, selected hydrogen as their unit; and, therefore, the equivalent of oxygen is 8. One of these series may be reduced to either of the others by an obvious and simple calculation. The numbers adopted in this work refer to hydrogen as unity. T. 141.

Unit.

Wollaston's scale.

118. These equivalent numbers, when once well ascertained and arranged in a tabular form, become a safe and invaluable source of information to the chemist. By adapting a table of this sort to a moveable scale, on the principle of Gunter's sliding rule, Wollaston constructed a *logometric scale of chemical equivalents*, which is capable of solving with great facility many problems of chemistry.*

Atomic theory.

119. To account for the laws observed with regard to the definite combinations of bodies, Dalton proposed what may be termed, the *atomic theory of the chemical constitution of bodies*. The laws themselves are the deductions from experiment, the mere expression of the facts, and are not necessarily connected with any speculation.

Atoms, what,

120. Two opposite opinions have long existed concerning the ultimate elements of matter. It is supposed, according to one party, that every particle of matter, however small, may be divided into smaller portions, provided our instruments and organs were adapted to the operation. Their opponents contend, on the other hand, that matter is composed of certain ultimate particles or molecules, which by their nature are indivisible, and are hence termed *atoms* (from *α not* and *τεμνειν to cut*). These opposite opinions have from time to time been keenly contested, and the progress of modern chemistry has revived attention to this controversy. We have only to assume with Dalton, that all bodies are composed of ultimate atoms, the weight of which is different in different kinds of matter, and we explain at once the foregoing laws of chemical union; and this mode of reasoning is, in the present case, almost decisive, because the phenomena do not appear explicable on any other supposition.

121. According to the atomic theory, every compound is formed

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* For description of this instrument, and a table of chemical equivalents of elementary substances, see Appendix. See also Faraday's *Chemical Manipulation*.

Form compounds.

of the atoms of its constituents. An atom of A may unite with one, two, three, or more atoms of B. Thus supposing water to be composed of one atom of hydrogen and one atom of oxygen, binoxide of hydrogen will consist of one atom of hydrogen and two atoms of oxygen. If carbonic oxide is formed of one atom of carbon and one atom of oxygen, carbonic acid will consist of one atom of carbon and two atoms of oxygen.

If, in the compounds of nitrogen and oxygen enumerated at (page 26,) the first or protoxide consist of one atom of nitrogen and one atom of oxygen, the four others will be regarded as compounds of one atom of nitrogen to two, three, four, and five atoms of oxygen. From these instances it will appear, that the law of multiple proportions is a necessary consequence of the atomic theory. There is also no apparent reason why two or more atoms of one substance may not combine with two, three, four, five, or more atoms of another; but, on the contrary, these arrangements are necessary in explanation of the not unfrequent occurrence of half equivalents, as formerly stated. (Page 27.) Such combinations will also account for the complicated proportion noticed in certain compounds, especially in many of those belonging to the animal and vegetable kingdom.

Use of the term atom.

122. In consequence of the satisfactory explanation which the laws of chemical union receive by means of the atomic theory, it has become customary to employ the term *atom* in the same sense as combining proportion or equivalent. For example, instead of describing water as a compound of one equivalent of oxygen and one equivalent of hydrogen, it is said to consist of one atom of each element. In like manner sulphate of potassa is said to be formed of one atom of sulphuric acid and one atom of potassa; the word in this case denoting as it were a compound atom, that is, the smallest integral particle of the acid or alkali,—a particle which does not admit of being divided, except by the separation of its elementary or constituent atoms. The numbers expressing the proportions in which bodies unite, must likewise indicate, consistently with this view, the relative weights of atoms; and accordingly these numbers are often called *atomic weights*. Thus, as water is composed of 8 parts of oxygen and 1 of hydrogen, it follows, on the supposition of water consisting of one atom of each element, that an atom of oxygen must be eight times as heavy as an atom of hydrogen. If carbonic oxide be formed of an atom of carbon and an atom of oxygen, the relative weight of their atoms is as 6.12 to 8; and in short the chemical equivalents of all bodies may be considered as expressing the relative weights of their atoms.

Atomic weight.

Arguments in support of the theory.

123. The arguments in favour of the atomic constitution of matter become much stronger, when we trace the intimate connexion which subsists, among many substances, between their crystalline form and chemical composition. The only mode of satisfactorily accounting for the striking identity of crystalline form observable, first, between two substances, and secondly, between all their compounds, which have an exactly similar composition, is by supposing them to consist of ultimate particles, possessed of the same figures, and arranged in precisely the same order. The phenomena presented by isomor-

phous bodies (50), afford a powerful argument in favour of the atomic theory.* T. 418.

Theory of volumes.

124. Soon after the publication of Dalton's views of the atomic constitution of bodies,† a paper appeared by Gay-Lussac,‡ in which he proved that gases unite together by volume in very simple and definite proportions. It was found that water is composed precisely of 100 measures of oxygen gas and 200 measures of hydrogen; and Gay-Lussac, being struck by this peculiarly simple proportion, was induced to examine the combinations of other gases, with the view of ascertaining if any thing similar occurred in other instances.

The first compounds which he examined were those of ammoniacal gas with hydrochloric, carbonic, and fluoboric acid gases. 100 volumes of the alkali were found to combine with precisely 100 volumes of hydrochloric acid gas, and they could be made to unite in no other ratio. With both the other acids, on the contrary, two distinct combinations were possible. These are

100	Fluoboric acid gas, with	100	Ammoniacal gas.
100	do.	200	do.
100	Carbonic acid gas	100	do.
100	do.	200	do.

Various other examples were quoted, both from his own experiments and from those of others, all demonstrating the same fact.

Union of gases.

125. From these and other instances Gay-Lussac established the fact, that gaseous substances unite in the simple ratio of 1 to 1, 1 to 2, 1 to 3, &c.; and this original observation has been confirmed by a multiplicity of experiments. Nor does it apply to gases merely, but to vapours also.

Of compound gases.

126. Another remarkable fact established by Gay-Lussac in the same essay is, that the volumes of compound gases and vapours always bear a very simple ratio to the volumes of their elements. Thus,

Volumes of Elements.			*Volumes of resulting Compounds.*
100 Nitrogen gas	+	300 Hydrogen gas yield	200 Ammoniacal gas.
50 Oxygen "	+	100 Hydrogen " . . .	100 Water.
50 Oxygen "	+	100 Nitrogen " . . .	100 Protoxide of nitrogen gas.
100 Chlorine "	+	100 Hydrogen " . . .	200 Hydrochloric acid "
100 Iodine "	+	100 Hydrogen " . . .	200 Hydriodic acid "
100 Oxygen "	+	100 Nitrogen " . . .	200 Binoxide of nitrogen "

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* Dalton supposes that the atoms of bodies are spherical; and he has invented certain symbols to represent the mode in which he conceives they may combine together, as illustrated by the following figures:

⊙ Hydrogen.	○ Oxygen.
⦶ Nitrogen.	● Carbon.

BINARY COMPOUNDS.

○ ⊙ Water.
○ ● Carbonic oxide.

TERNARY COMPOUNDS.

○ ⊙ ○ Binoxide of hydrogen.
○ ● ○ Carbonic acid.
&c. &c. &c.

All substances containing only two atoms he called binary compounds; those composed of three atoms, ternary compounds; of four, quaternary, &c. For a more full account of the doctrine of atoms, see Daubeny *on the Atomic Theory*, and Prout's *Bridgewater Treatise*.

† *New System of Chem. Philos.* 1808.

‡ *Mem. d'Arcueil.*

Combining volumes.

The law of multiples (page 26) is equally demonstrable by means of combining volumes as by combining weights. Thus,

Volumes of Elements.				*Resulting Compounds.*
100 Nitrogen	+	50 Oxygen	yield	Protoxide of nitrogen.
100 do.	+	100 do.		Binoxide of nitrogen.
100 do.	+	150 do.		Hyponitrous acid.
100 do.	+	200 do.		Nitrous acid.
100 do.	+	250 do.		Nitric acid.
100 Hydrogen	+	50 do.		Water.
100 do.	+	100 do.		Binoxide of hydrogen.
100 Carbon vapour	+	50 do.		Carbonic oxide.
100 do.	+	100 do.		Carbonic acid.

It thus appears that the laws of combination may equally well be deduced from the volumes as from the weights of the combining substances, and that the composition of gaseous bodies may be expressed as well by measure as weight.

Table of equivalent weights, &c.

127. The following table exhibits a view of equivalent weights and volumes, to which are added the respective specific gravities in relation both to air and hydrogen.

GASES AND VAPOURS.	Specific Gravities.		Chemical Equivalents.	
	Air as 1.	Hydrogen as 1.	By Vol.	By Weight.
Hydrogen,	0.0689	1.00	100	1.
Nitrogen,	0.9727	14.15	100	14.15
Chlorine,	2.4700	35.42	100	35.42
Carbon, (hypothetical),	0.4215	6.12	100	6.12
Iodine,	8.7020	126.30	100	126.3
Bromine,	5.4017	78.40	100	78.4
Water,	0.6201	9.00	100	9.
Alcohol,	1.6009	23.24	100	23.24
Sulphuric ether,	2.5817	37.48	100	37.48
Light carburetted hydrogen,	0.5593	8.12	100	8.12
Olefiant gas,	0.9808	14.24	100	14.24
Carbonic oxide,	0.9727	14.12	100	14.12
Carbonic acid,	1.5239	22.12	100	22.12
Protoxide of nitrogen,	1.5239	22.15	100	22.15
Sulphurous acid,	2.2117	32.10	100	32.1
Sulphuric acid, (anhydrous)	2.7629	40.10	100	40.1
Cyanogen,	1.8157	26.39	100	26.39
Hydrosulphuric acid,	1.1782	17.10	100	17.1
Binoxide of nitrogen,	1.0375	15.75	200	30.15
Mercury,	6.9589	101.00	200	202.
Ammonia,	0.5897	8.75	200	17.15
Hydrochloric acid,	1.2694	18.21	200	36.42
Hydriodic acid,	4.3854	63.65	200	127.3
Hydrobromic acid,	2 7353	39.70	200	79.4
Hydrocyanic acid,	0.9423	13.95	200	27.39
Arseniuretted hydrogen,	2.7008	39.20	200	78.4
Sesquichloride of arsenic,	6.3025	90.83	200	181.66
Sesquiodide of arsenic,	15.6505	227.15	200	454.3
Protochloride of mercury,	8.1939	118.71	200	237.42
Bichloride of mercury,	9.4289	136.42	200	272.84
Bromide of mercury,	9.6597	140.20	200	280.4
Bibromide of mercury,	12.3606	179.40	200	358.8
Biniodide of mercury,	15.6609	227.30	200	454.6
Oxygen,	1.1024	16.00	50	8.
Arsenious acid,	13.6972	198.80	50	99.4
Phosphorus,	4.3269	62.80	25	15.7
Arsenic,	10.3901	150.80	25	37.7
Sulphur,	6.6558	96.60	16.66	16.1
Bisulphuret of mercury,	5.3788	78.06	300	234.2

Ratios of combining volumes.

128. From the examination of the table it will be seen, 1st, that the combining volumes are either equal, or in the simple ratio of 1 to 2, 1 to 3, &c. The same simplicity rarely exists among the equivalent weights. 2. The specific gravities and weights of the 18 first substances are seen to be identical. As these have the same uniting volume as hydrogen, the assumed unit, and as the specific gravities are merely the weights of equal volumes, the numbers in the column of specific gravities and those in the column of weights coincide. 3. The identity in the equivalent volumes of the elementary gases, hydrogen, nitrogen, and chlorine, led to the notion that the equivalent volumes of most other elements might also be identical. *Assuming* that identity, the specific gravity, for example, of the elements hydrogen, carbon, and sulphur, in a gaseous state, may easily be calculated. Thus, taking 1, 6.12, and 16.1 as the equivalents of hydrogen, carbon, and sulphur, their specific gravities in the gaseous state, supposing combining volumes equal, will be in the same ratio of 1, 6.12 and 16.1. But such hypothetical numbers cannot be always confided in; the real specific gravity of a vapour is, in some cases, as much greater than the hypothetical, as its equivalent volume is less than that of hydrogen.*

Identity of specific gravities and weights.

Specific gravity calculated.

Specific gravity of compound gases calculated.

129. The tables supply materials for calculating the specific gravity of compound gases, and of verifying the accuracy of other conclusions respecting their composition. The specific gravities of certain gases being known, together with their uniting proportions by volumes, and the resulting volume, we can easily deduce the weight of 100 volumes of the compound gas that may be formed.

130. We can assume the specific gravity as the weight of 100 volumes, or the weight of 100 volumes as the specific gravity when the number of volumes is 100; then 50 volumes may be indicated by one half, 25 by a fourth, and 16.66 by a sixth of the specific gravity of 100 volumes. Thus the specific gravity of hydrosulphuric acid gas will be that of its constituents, viz. of 100 volumes of hydrogen + $\frac{1}{6}$th of 100 volumes of the vapour of sulphur.†

131. As vapours are easily condensed by cold, and in many cases exist as such only at high temperatures, their specific gravities may often be obtained by calculation more accurately than by experiment.

Chemical Symbols.

132. The impracticability of contriving convenient names expressive of the constitution of chemical compounds, suggested the employment of symbols as an abbreviated mode of denoting the composition of bodies. The symbols contrived by Berzelius are now extensively used by chemists and mineralogists. These are also called *chemical formulæ*, and it is important that the chemical student should not be unacquainted with them. The following table includes the symbols of the elementary substances according to Berzelius.

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* The identity in the equivalent volumes of hydrogen, nitrogen, and chlorine, suggested the idea that the atoms of all the elements are of the same magnitude, and equal volumes of the elements in a gaseous state were supposed to contain an equal number of atoms. The late researches of Dumas and Mitscherlich have shown that this is not the fact.

† For further examples see Turner's *Chemistry*, 147.

TABLE OF SYMBOLS.

Elements.	Symb	Elements.	Symb.	Elements.	Symb.
Aluminium	Al	Gold (Aurum)	Au	Potassium (Kalium)	K
Antimony (Stibium)	Sb	Hydrogen	H	Rhodium	R
Arsenic	As	Iodine	I	Selenium	Se
Barium	Ba	Iridium	Ir	Silicium	Si
Bismuth	Bi	Iron (ferrum)	Fe	Silver (Argentum)	Ag
Boron	B	Lead (Plumbum)	Pb	Sodium (Natrium)	Na
Bromine	Br	Lithium	L	Strontium	Sr
Cadmium	Cd	Magnesium	Mg	Sulphur	S
Calcium	Ca	Manganese	Mn	Tellurium	Te
Carbon	C	Mercury (Hydrargy-		Thorium	Th
Cerium	Ce	rum)	Hg	Tin (Stannum)	Sn
Chlorine	Cl	Molybdenum	Mo	Titanium	Ti
Chromium	Cr	Nickel	Ni	Tungsten (Wolfram)	W
Cobalt	Co	Nitrogen	N	Uranium	U
Columbium (Tanta-		Osmium	Os	Vanadium	V
lum)	Ta	Oxygen	O	Yttrium	Y
Copper (Cuprum)	Cu	Palladium	Pd	Zinc	Zn
Fluorine	F	Phosphorus	P	Zirconium	Zr
Glucinium	G	Platinum	Pt		

Explanation. The foregoing symbols are intended to represent the chemical equivalents of the elements. Thus, the letters H, I, and Ba, stand for one equivalent of hydrogen, iodine, and barium; and 2H, 3H, and 4H, for 2, 3, and 4 equivalents of hydrogen. Two equivalents of an element are often denoted by placing a dash *through*, or more commonly under its symbol: thus, $\underline{H}$ means 2H, and $\underline{P}$ signifies 2P. Certain compounds are often, for the sake of brevity, denoted by single symbols in the same manner as the elements; thus, an equivalent of water, ammonia, and cyanogen, is sometimes expressed by Aq, Am, and Cy; but in general the formulæ for compound bodies are so contrived as to indicate the elements they contain, and the mode in which they are united. This may be done in several ways; but that which first suggests itself, is to connect together the symbols by the same signs as are used in Algebra. Thus the formulæ $K+O$, $Ca+O$, $Ba+O$, $Mn+O$, $Fe+O$, $2Fe+3O$, $3H+N$, $2H+2C$, $C+2O$, $N+5O$, $S+3O$, and $H+Cl$, denote single equivalents of potassa, lime, baryta, protoxide of manganese, protoxide of iron, sesquioxide of iron, ammonia, olefiant gas, carbonic acid, nitric acid, sulphuric acid, and hydrochloric acid. The formula $K+N+6O$ indicates the elements which are contained in an equivalent of nitrate of potassa: in order to express further that the potassium is combined with only one equivalent of oxygen, the remaining oxygen with the nitrogen, and the potassa with nitric acid, the symbols are placed thus,—$(K+O)+(N+5O)$, the brackets containing the symbols of those elements which are supposed to be united. A number placed on the outside of a bracket, multiplies the compound within it: thus $(K+O)+(S+3O)$ is sulphate of potassa, and $(K+O)+2(S+3O)$ is the bisulphate. All the elements contained in a compound are thus visibly represented, and the chemist is able readily to trace all possible modes of combination, and to select that which is most in harmony with the facts and principles of his science. He may, and often does, thereby detect relations which might otherwise have escaped notice.

Advantage of formulæ.

133. Another advantage attributable to such formulæ is, that they facilitate the comprehension of chemical changes. If hydrosulphuric acid acts upon the protoxide of lead, it is easy to say that the sulphur combines with the lead, and the hydrogen with the oxygen; but the exact adaptation of the quantities for mutual interchange appears to be more clearly shown by symbols than by a description or a diagram. In the simple instance alluded to, $H+S$ reacts on $Pb+O$, and the products are $Pb+S$ and $H+O$. When hydrosulphuric acid acts on bicyanuret of mercury, the result is bisulphuret of mercury and hydrocyanic acid; the substances which interchange elements are $2(H+S)$ and $Hg+2Cy$; and the products are $Hg+2S$, and $2(H+Cy)$. In more complicated changes the advantage of chemical formulæ is still more manifest, examples of which kind will be found in other parts of this volume.

Abbreviated.

134. Useful as the algebraic chemical formulæ are for the purpose of studying chemical changes, they are sometimes found inconveniently long where the object is merely to express the composition of bodies, and accordingly Berzelius has introduced several abbreviations. For instance, he indicates degrees of oxidation by dots placed over the symbol, writing $\dot{K}$, $\ddot{C}$, $\overset{\cdot\cdot}{\dddot{N}}$, instead of $K+O$, $C+2O$, $N+5O$, for potassa, carbonic acid, and nitric acid. In like manner he denotes compounds of sulphur by commas, writing $\overset{,}{K}$, $\overset{,,}{Hg}$, $\overset{,}{H}$ instead of $K+S$, $Hg+2S$, $H+S$, for sulphuret of potassium, bisulphuret of mercury, and hydrosulphuric acid. When the ratio is that of two to three he employs the symbol for two equivalents above stated; thus, $\underline{\dddot{Fe}}$, $\underline{\overset{\cdot\cdot}{\dddot{P}}}$, $\underline{\overset{\cdot\cdot}{\dddot{As}}}$ is used instead of $2Fe+3O$, $2P+5O$, $2As+5O$, for an equivalent of sesquioxide of iron, phosphoric acid, and arsenic acid; and similarly we have $\underline{\overset{,,,}{As}}$, $\underline{\overset{,,}{\overset{,,,}{As}}}$ instead of $2As+3S$, $2As+5S$ for the sesquisulphuret and persulphuret of arsenic. These last formulæ are sometimes used to indicate two equivalents instead of one; but as, agreeably to the atomic theory, the smallest possible molecule of sesquioxide of iron consists of 2 atoms of iron and 3 of oxygen, the formula $2Fe+3O$ ought to stand for one equivalent only.

Berzelius often dispenses with the sign +, and writes combined elements side by side, the sign of addition being understood instead of expressed. Thus he uses $\dot{K}\dddot{S}$, $\dot{C}a\ddot{C}$, $\dot{B}a\overset{\cdot\cdot}{\dddot{N}}$, $\dot{K}\dddot{S}+\dot{N}i\dddot{S}$, instead of $\dot{K}+\dddot{S}$, $\dot{C}a+\ddot{C}$, $\dot{B}a+\overset{\cdot\cdot}{\dddot{N}}$, $(\dot{K}+\dddot{S})+(\dot{N}i+\dddot{S})$, for sulphate of potassa, carbonate of lime, nitrate of baryta, and the double sulphate of potassa and oxide of nickel. Two or more equivalents of one constituent of a compound are denoted by numbers placed in the same position as the indices of powers in algebra: thus NH^3, NC^2, $\underline{\dddot{F}e}^2\,\dot{H}^3$ is the abbreviation of $N+3H$, $N+2C$, $2\underline{\dddot{F}e}+3\dot{H}$, for ammonia, cyanogen, and sesquihydrate of iron, a compound of 2 equiva-

Chap. I.

lents of sesquioxide of iron and 3 of water. A number used before symbols, like coefficients in algebra, multiplies all the following symbols not separated from it by a + sign. Thus in $8\,\dot{C}a\,Si^3+\dot{K}\,\dot{S}i^6+16\,Aq$ (which is the formula for the mineral called apophyllite), the 8 dènotes 8 equivalents of $\dot{C}a\,\dot{S}i^3$, or tersilicate of lime, which are united with 1 equivalent of sexsilicate of potassa, and 16 of water.

Berzelius also expresses the vegetable and animal acids by the first letter of their name, with a dash over it. Thus $\overline{T}$, $\overline{A}$, $\overline{C}$, $\overline{B}$, $\overline{G}$, $\overline{F}$, are the symbols for tartaric, acetic, citric, benzoic, gallic, and formic acids.

Isomeric bodies.

135. It was formerly thought that the same elements united in the same ratio must always give rise to the same compound; but examples have been discovered of two or even more substances containing the same elements in the same ratio, and yet exhibiting chemical properties distinct from each other. For such compounds Berzelius has suggested the general appellation of *isomeric*, from *ισος equal*, and *μερος part*, expressive of equality in the ingredients.

Isomerism is quite consistent with our theories of chemical union; insomuch as the same elements may be grouped or combined in different ways, and give rise to compounds essentially distinct.*

Some bodies consist of the same elements in the same ratio, and yet differ in their equivalents. The nature of these compounds is at once detected by their equivalents being unlike, and by the volume which they occupy as gases compared with the volumes of the elements of which they consist. Isomeric bodies of this kind are obviously much less intimately allied than those above described. T. 153.

Modes of ascertaining the composition of bodies.

136. The proof which establishes the nature of chemical compounds, is of two kinds, *synthesis* and *analysis*. Synthesis consists in effecting the chemical union of two or more bodies; and analysis, in separating them from each other, and exhibiting them in a separate state. The composition of sulphate of copper (blue vitriol) is *synthetically* demonstrated by *uniting* sulphuric acid to oxide of copper. When we have a compound of two or more ingredients, which are themselves compounded also, the separation of the compounds from each other may be called the *proximate analysis* of the body; and the farther separation of these compounds into their most simple principles, its *ultimate analysis*.

Ultimate and Proximate analysis.

Thus the sulphuric acid of the sulphate of copper consists of sulphur and oxygen, and oxide of copper consists of copper and oxygen; consequently we should say that the *ultimate* component parts of blue vitriol are copper, sulphur, and oxygen.

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* Thus the elements of sulphate of potassa may perhaps be united indiscriminately with each other, as expressed by the formula KSO^4; or they may form $KO+SO^3$; or $KS+O^4$; or KO^2+SO^2; and other combinations might be made. The second of these is doubtless the real one; but no one can say that the others are impracticable. Again, the elements of peroxide of tin, Sn and 2O, may either form SnO^2, or $SnO+O$; and those of the sesquioxide of iron, 2Fe and 3O, may either be Fe^2O^3, or $FeO+FeO_2$, not to mention other possible combinations. The elements of alcohol are 2C, 3H, and O, which may be united indiscriminately as H^3C^2O, or H^3C^2+O, or as H^2C^2+HO, besides others; it is commonly considered a compound of olefiant gas and water, as indicated by the last formula. T.

The proximate analysis of sulphate of potassa consists in resolving it into potassa and sulphuric acid; and its ultimate analysis is effected by decomposing the potassa into potassium and oxygen, and the sulphuric acid into oxygen and sulphur.

When the analysis of any substance has been carried as far as possible, we arrive at its most simple principles or *elements;* by which expression we are to understand, not a body that is *incapable* of further decomposition, but only one which *has not yet been decomposed.*

SECTION III. *Heat or Caloric.*

Sensations of heat and cold.

137. No sensations are more familiar to us than those of heat and cold. They are excited by bodies applied to our organs, and at different times very different degrees of sensation are excited by the same body. The power of inducing these sensations does not depend upon the matter itself, which is applied to our organs; for every shade of sensation is produced, without the qualities of that matter being permanently changed; it is considered as depending on the operation of a certain subtle principle, present in bodies, and which, according to its quantity, gives rise to the power of exciting different sensations.

Has received various names.

138. This principle, or power, has been distinguished by various appellations, as Fire, Heat, the matter of Heat, or the Igneous fluid; terms which are either ambiguous, or which involve some hypothesis, and which are superseded by the unexceptionable appellation of Caloric. M. I. 183.*

May be considered under two views.

139. Caloric, so far as its chemical agencies are concerned, may be chiefly considered under two views—as an antagonist to the cohesive attraction of bodies—and as concurring with, and increasing elasticity. By removing the particles of any solid to a greater distance, from each other, their cohesive attraction is diminished; and one of the principal impediments to their union with other bodies is overcome. On the other hand, caloric may be infused into bodies in such quantity, as not only to overcome cohesion, but to place their particles beyond the sphere of chemical affinity.

In many cases, when two bodies are combined together, one of which is fixed, and the other becomes elastic by union with caloric, we are able, by its interposition alone, to effect their disunion. Thus carbonate of lime gives up its carbonic acid by the mere application of heat.

The state of bodies influenced by caloric.

140. We may consider, then, all bodies in nature as subject to the action of two opposite forces, the mutual attraction of their particles on the one hand, and the repulsive power of caloric on the other; and bodies exist in the solid, liquid, or elastic state, as one or the other of these forces prevails.

Water, by losing caloric, has its cohesion so much increased, that it assumes the solid form of ice; adding caloric, we diminish again its cohesion, and render it fluid; and finally, by a still farther addition of caloric, we change it into va-

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* Or we may define caloric as the agent to which the phenomena of heat and combustion are ascribed. U.

pour, and give it so much elasticity, that it may be rendered capable of bursting the strongest vessels. In many liquids, the tendency to elasticity is even so great, that they pass to the gaseous form by the mere removal of the weight of the atmosphere; as is the case with ether in the exhausted receiver of the air pump.

It expands bodies.

141. Expansion is the most obvious and familiar effect of caloric and it takes place, though in different degrees, in all forms of matter. When a body which occasions the sensation of heat on our organs, is brought into contact with another body which has no such effect, the result of their mutual action is that the hot body contracts, and loses to a certain extent its power of communicating heat, and the other body expands, and in a degree acquires this power.

Proved by experiments.

The expansion of solids may be made apparent by heating a rod of iron, of such a length as to be included, when cold, between two points, and the diameter of which is such, as barely to allow it to pass into an iron ring. When heated, it will have become sensibly larger; and it will be found incapable of passing through the ring.

Principle upon which pyrometers are made.

142. This property of metals has been applied to the construction of an instrument for measuring temperature, called a *pyrometer*.*

Expansion of solids,

143. The expansion of solids has engaged the attention of several experimenters,† and the following results have been obtained:—1. Different solids do not expand to the same degree from equal additions of heat. 2. A body which has been heated from the temperature of freezing to that of boiling water, and again allowed to cool to 32° F., recovers precisely the same volume which it possessed at first. 3. The dilatation of the more permanent or infusible solids is very uniform within certain limits; their expansion, for ex-

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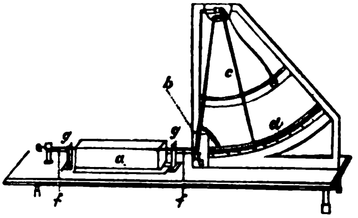
Fig. 22.



* An instrument of this kind is repreresented by fig. 22, which will be found very convenient for showing the expansibilities of bars of different metals, at temperatures not exceeding that of boiling water. Upon a flat piece of mahogany are fixed brass studs, *g g*, on which the metallic bar, *f f*, is placed. One end of this bar bears against a lever *b* at a point very near its fulcrum; the other end of this lever, which is bent, bears against another lever *c*, the lower extremity of which is an index. Beneath this index is a graduated arc *d*. When we wish to immerse the bar in hot water, or to apply heat gradually through the medium of water, the bar is passed through the brass box *a*, which has an aperture at each end. An opening is left in the board immediately under the box, to allow the application of a lamp. The small expansion of the metallic bar is magnified by the first lever in the proportion of the distances of the point of pressure from its plane, and from its other extremity; and this magnified effect is again magnified by the other lever, so that an expansion of the 400th part of an inch corresponds to a whole inch on the scale. This pyrometer is liable to the objection that the distance of the points of pressure from the fulcrum and extremity of each lever is variable during the experiment. (*See Ferguson's Lect.*)

Daniell's pyrometer.

Daniell's pyrometer is susceptible of great precision. Its indications result from a difference in the expansion and contraction of a platinum bar, and a tube of black lead ware, in which it is contained. These differences are made available by connecting an index with the platinum bar, which traverses a circular scale fixed on to the tube. See a description of this instrument in *Turner's Elements* p. 26, *Quart. Jour of Sci.* xi. 309, *and Philos. Trans.* 1830–1.

† The Philosophical Transactions contain various dissertations on the subject by Ellicot, Smeaton, Troughton, and General Roy; and M. Biot, in his *Traité de Physique*, has given the results of experiments performed with great care by Lavoisier and Laplace.

ample, from the freezing point of water to 122°, is equal to what takes place betwixt 122° and 212°. The subsequent researches of Dulong and Petit,* prove that solids do not dilate uniformly at high temperatures, but expand in an increasing ratio; that is, the higher the temperature beyond 212° the greater the expansion for equal additions of heat. It is manifest, indeed, from their experiments, that the rate of expansion is an increasing one even between 32° and 212°; but the differences which exist within this small range are so inconsiderable as to escape observation, and, therefore, for most practical purposes may be disregarded.

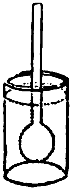
The subjoined table includes the most interesting results of Lavoisier and and Laplace. (*Biot*, vol. 1. p. 158.)

Names of Substances.	*Elongation when heated from 32° to 212°*
Glass tube without lead, a mean of three specimens - - -	$\frac{1}{1115}$ of its length.
English flint glass - - - -	$\frac{1}{1248}$
Copper - - - -	$\frac{1}{581}$
Brass—mean of two specimens - -	$\frac{1}{532}$
Soft iron forged - - - -	$\frac{1}{819}$
Iron wire - - - -	$\frac{1}{812}$
Untempered steel - - - -	$\frac{1}{927}$
Tempered steel - - - -	$\frac{1}{807}$
Lead - - - - -	$\frac{1}{351}$
Tin of India - - - -	$\frac{1}{516}$
Tin of Falmouth - - - -	$\frac{1}{462}$
Silver - - - - -	$\frac{1}{524}$
Gold—mean of three specimens - -	$\frac{1}{662}$
Platinum, determined by Borda - -	$\frac{1}{1167}$

Of liquids,

144. The expansion of liquids is seen by putting a common thermometer, made with mercury or alcohol, into warm water, Fig. 23, when the dilatation of the liquid will be shown by its ascent in the stem. The experiment is indeed illustrative of two other facts. It proves, first that the dilatation increases with the temperature; for if the thermometer be plunged into several portions of water heated to different degrees, the ascent will be greatest in the hottest water, and least in the coolest portions. It demonstrates, secondly, that liquids expand more than solids. The glass bulb of the thermometer is itself expanded by the hot water, and, therefore, is enabled to contain more mercury than before; but the mercury being dilated to a much greater extent, not only occupies the additional space in the bulb, but likewise rises in the stem. Its ascent marks the difference between its own dilatation and that of the glass, and is only the apparent, not the actual, expansion of the liquid.

Fig. 23.



Their relative expansibilities different.

145. Liquids differ also in their relative expansibilities: ether is more expansible than spirit of wine, and spirit more than water, and water more than mercury. Those liquids are generally most expansible which boil at the lowest temperature.

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* *An. de. Chim. et de Phys.* vii.

This may be rendered evident by partially filling several glass tubes of equal diameters, furnished with bulbs, with the different liquids, and placing them in hot water; as the liquids expand, they will rise to different heights in the tubes. To render this more apparent the liquids may be tinged with some colouring matter. The tubes may be placed in a light frame, having a thin copper trough to contain water, which may be heated by a lamp. Fig. 24. Or they may be suspended as in Fig. 25.

Fig. 24.

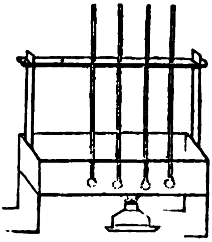
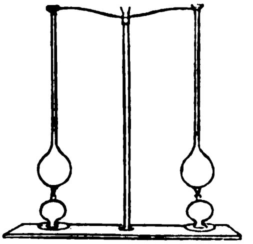


Fig. 25.



Of mercury,

146. From the frequency with which mercury is employed in philosophical experiments, it is important to know the exact amount of its expansion. This subject has been investigated by several philosophers, but the experiments of Lavoisier and Laplace, and especially of Dulong and Petit, are entitled to the greatest confidence. According to the former, the actual dilatation of mercury, in passing from the freezing to the boiling point of water, amounts to $\frac{100}{5412}$ of its volume; but the result obtained by Dulong and Petit, who found it, $\frac{100}{5550}$ is probably still nearer the truth. Adopting the last estimate, this metal dilates, for every degree of Fahrenheit's thermometer, $\frac{1}{9990}$ of the bulk which it occupied at the temperature of 32°. If the barometer, for instance, stand at 30 inches when the thermometer is at 32°, we may calculate what its elevation ought to be when the latter is at 60°, or at any other temperature. The apparent expansion of mercury contained in glass is of course less than the absolute expansion.*

Liquids expand in increasing ratio.

147. All experimenters agree that liquids expand in an increasing ratio, or that equal increments of heat cause a greater dilatation at high than at low temperatures. Thus, if a fluid is heated from 32° to 122°, it will not expand so much as it would do in being heated from 122° to 212°, though an equal number of degrees is added in both cases. The nearer a liquid approaches its boiling point, the greater is its expansibility; hence those liquids appear most equably expansible which have the highest boiling points, and hence one of the great advantages of mercury in constructing thermometers.

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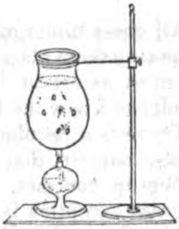
* Between the limits of 32° and 212° F. Lavoisier and Laplace estimate the apparent expansion at $\frac{1}{63}$ and Dulong and Petit at $\frac{1}{64.8}$ of its volume, being $\frac{1}{11664}$ for each degree of Fahrenheit's thermometer. Dulong and Petit state, that the mean total expansion of mercury from 32° to 572° F. for each degree is $\frac{1}{9540}$; and that the mean apparent expansion in glass from 32° to 572° F. for each degree is $\frac{1}{11372}$. The temperature in their experiments was estimated by an air thermometer, which they consider more uniform in its rate of expansion than one of mercury. The temperature of 572° F. on the air thermometer corresponds to 586° in the mercurial one. T. 19.

148. The expansion of air may be shown by inverting a tube terminated by a bulb, and partly filled with water (Fig. 26); the air confined in the bulb will expand when heated, and expel the water from the tube.

Fig. 26.

Fig. 27.



Specific gravity altered by a change of temperature,

Of liquids,

149. As heat increases the bulk of all bodies, it is obvious that change of temperature is constantly producing changes in their density or specific gravity, as may be easily demonstrated in fluids where there is freedom of motion among the particles. If we apply heat to the bottom of a vessel of water, that portion of the fluid, which is nearest to the source of heat, is expanded, and becoming specifically lighter, ascends, and is replaced by a colder portion from above. This, in its turn, becomes heated and dilated, and gives way to a second colder portion; and thus the process goes on, as long as the fluid is capable of imbibing heat. (Fig. 27.)

Of air,

150. In air, similar currents are continually produced, and the vibratory motion observed over chimney pots, and slated roofs which have been heated by the sun, depends upon this circumstance: the warm air rises, and its refracting power being less than that of the circumambient colder air, the currents are rendered visible by the distortion of objects viewed through them. This is easily illustrated by placing a spiral of pasteboard upon a wire over an Argand lamp, or at the side of a stove pipe.*

Ventilation.

The ventilation of rooms and buildings can only be perfectly effected by suffering the heated and foul air to pass off through apertures in the ceiling, while fresh air, of any desired temperature, is admitted from below.†

Fig. 28.

Of gases.

151. As the particles of air and aëriform substances are not held together by cohesion, they are found to dilate from equal additions of heat much more than solids or liquids. Now, chemists are in the habit of estimating the quantity of the gases employed in their experiments by measuring them; and since the volume occupied by any

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*Advantage is taken of this in heating apartments by furnaces placed in cellars. Cold air being brought in contact with the surface of heated metal, and allowed to ascend through pipes into the apartments.

†Various contrivances have been resorted to, to prevent the passage of cold air from above downwards through the ventilator, which can only be completely effected by keeping the ventilating tubes at a higher temperature than the surrounding air; heating them, for instance, by steam; passing them through a fire; or placing a lamp beneath them, of sufficient dimensions to cause a strong current upwards.

Chap I. gas is so much influenced by temperature, it is essential to accuracy that a due correction be made for the variations arising from this cause; that they should know how much dilatation is produced by each degree of the thermometer, whether the rate of expansion is uniform at all temperatures, and whether that ratio is the same in all gases.

152. All gases undergo equal expansions by the same addition of heat, supposing them placed under the same circumstances; so that it is sufficient to ascertain the law of expansion observed by any one gas, in order to know the law for all.*

Peculiar effect of heat. 153. There is a peculiarity in the effect of heat upon the bulk of some fluids, namely, that at a certain temperature, increase of heat causes them to contract, and its diminution makes them expand. This singular exception is only observable in those liquids which acquire an increase of bulk in passing from the liquid to the solid state, and is remarked only within a few degrees of temperature above their point of congelation. Water is a noted example of it. Ice swims upon the surface of water, and, therefore, must be lighter than it, which is a convincing proof that water, at the moment of freezing, must expand. The increase is estimated by Boyle at about $\frac{1}{9}$th of its volume, which gives 900 as the specific gravity

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*It appears from the experiments of Gay Lussac, that 100 parts of air, in being heated from 32° to 212° F., expand to 137.5 parts. The increase for 180 degrees is, therefore, 0.375 or $\frac{37.5}{100}$ths of its bulk: and by dividing this number by 180, it is found that a given quantity of dry air dilates to $\frac{1}{480}$th of the volume it occupied at 32°, for every degree of Fahrenheit's thermometer.

This point being established, it is easy to ascertain what volume any given quantity of gas should occupy at any given temperature. Suppose a certain portion of gas to occupy 20 measures of a graduated tube at 32°, it may be desirable to determine what would be its bulk at 42°. For every degree of heat it has increased by $\frac{1}{480}$th of its original volume, and, therefore, since the increase amounts to ten degrees, the 20 measures will have dilated by $\frac{10}{480}$ths. The expression will, therefore, be $20+20\times\frac{10}{480}=20.416$. It must not be forgotten that the volume which the gas occupies at 32° is a necessary element in all such calculations. Thus, having 20.416 measures of gas at 42°, the corresponding bulk for 52° cannot be calculated by the formula $20.416+20.416\frac{10}{480}$; the real expression is $20+20.416\frac{10}{480}$, because the increase is only $\frac{10}{480}$ths of the space occupied at 32°, which is 20 measures.*

A similar remark applies to the formula for estimating the effect of heat on the height of the barometer.

The rate of expansion of atmospheric air at temperatures exceeding 212° has been examined by Dulong and Petit, and the following table contains the result of their observations. (*An. de Ch. et de Ph.* vii. 120.)

Temperature by the Mercurial Thermometer.		Corresponding volumes of a given volume of air.
Fahrenheit.	Centigrade.	
— 33	— 36	0.8650
32	0	1.0000
212	100	1.3750
302	150	1.5576
392	200	1.7389
482	250	1.8189
572	300	2.0976
Mercury boils 680	360	2.3125

* See Formulæ, Turner, 21.

Water, its maximum density,

of ice, that of water being 1000.[*] Dalton estimates the specific gravity of ice at 9.42. Water has attained its maximum of density at about 39°[†], and if it be cooled below 39° it expands as the temperature diminishes, as it does when heated above that point.

Exp.

Immerse two thermometer tubes, one containing spirits of wine and the other water, into melting snow; the former will sink till it indicates 32° F., but the latter, when it has nearly attained 39° F., will begin to expand, and continue to do so till it freezes. Or, fill a flask capable of holding three or four ounces, with water at the temperature of 60° F. and adapt a cork to it, through which passes a glass tube open at both ends, about the eighth of an inch wide, and ten inches long. After having filled the flask, insert the cork and tube, and pour a little water into the latter till the liquid rises to the middle of it. On immersing the flask in a mixture of pounded ice and salt, the water will fall in the tube, marking contraction; but in a short time an opposite movement will be perceived, indicating that expansion is taking place, while the water within the flask is at the same time yielding caloric to the freezing mixture on the outside of it.

An apparent object in this anomaly.

This anomaly in respect to water is productive of very important consequences, in preserving the depths of rivers and lakes of a temperature congenial to their inhabitants.

Expands forcibly,

154. The most remarkable circumstance attending this expansion, is the prodigious force with which it is effected. Boyle filled a brass tube, three inches in diameter, with water, and confined it by means of a moveable plug; the expansion, when it froze, took place with such violence as to push out the plug, though preserved in its situation by a weight equal to 74 pounds. The Florentine Academicians burst a hollow brass globe, whose cavity was only an inch in diameter, by freezing the water with which it was filled; and it has been estimated that the expansive power necessary to produce such an effect was equal to a pressure of 27,720 pounds weight. Major Williams gave ample confirmation of the same fact by some experiments which he performed at Quebec in the years 1784 and 1785.[‡] Glass bottles, lead and iron pipes, &c., in which water freezes, are often ruptured.

Other cases,

155. Water is not the only liquid which expands under reduction of temperature, as the same effect has been observed in a few others which assume a highly crystalline structure on becoming solid:—fused iron, antimony, zinc, and bismuth are examples of it. Mercury is a remarkable instance of the reverse; for when it freezes, it suffers a very great contraction (31 note.)

Cause,

156. The cause of the expansion of water at the moment of freezing is attributed to a new and peculiar arrangement of its particles. Ice is in reality crystallized water, and during its formation the particles arrange themselves in ranks and lines, which cross each other at angles of 60° and 120°, and consequently occupy more space than when liquid. This may be seen by examining the surface of water while freezing in a saucer. No very satisfactory reason can be assigned for the expansion which takes place previous to congelation.

Temperature

157. The state of a body with respect to its power of producing the effects which arise from the operation of caloric, is termed its

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[*] Experiments on Cold.

[†] Hallstrom *An. de Chim. et Phys.* xxviii, 90, whose experiments were made with great care. According to the more recent experiments of Stampfer 38.75 and to those of Crichton 38.97. Johnston's Report in 1st *Report of the British Association*.

[‡] *Phil. Trans. Ed.* ii, 23.

temperature. In every body the temperature depends on the quantity of caloric which it contains, and the temperature is said to be high or low as it respects another body, in proportion as it occasions an expansion or contraction of its parts.

Imperfectly known from sensation.

158. The temperature of bodies can be but imperfectly estimated by the sensation of heat or cold they produce, the sensation being modified by preceding impressions upon the sentient organ and other external circumstances. Hence the necessity of some common measure of temperature, as by means of the *Thermometer*.

Principle on which the thermometer indicates temperature.

159. The principle on which the thermometer indicates temperature, is, that caloric has a tendency always to preserve an equilibrium; so that if two bodies at different temperatures, be brought into contact, it will pass from the one at the higher into that at the lower temperature, until the temperature of both is the same. Thus, if we mix equal quantities of the *same* fluid at different temperatures, the cold portion will expand as much as the hot portion contracts, and the resulting temperature is the mean; so that it appears, that as much heat as is lost by the one portion is gained by the other.

Thermometer.

160. A common thermometer consists of a tube terminated at one end by a bulb, and hermetically closed at the other. The bulb and part of the tube are filled with an appropriate liquid, which when designed to measure very low temperatures, is spirit of wine; under other circumstances quicksilver is better adapted for the purpose.* A graduated scale† is attached to the stem; and whenever the instrument is applied to bodies of a higher temperature, the mercury or spirit expands and rises in the tube.

Graduation.

161. In dividing the scale of a thermometer, the two fixed points usually resorted to are the freezing and boiling of water, which always take place at the same temperature, when under the same atmospheric pressure. The intermediate part of the scale is divided into any convenient number of degrees; and it is obvious, that all thermometers thus constructed will indicate the same degree of heat when exposed to the same temperature. In the centigrade thermometer, this space is divided into 100°; the freezing of water being marked 0°, the boiling point 100°. In this country we use Fahrenheit's scale of which the 0° is placed at 32° below the freezing of water, which, therefore, is marked 32°, and the boiling point 212°, the intermediate space being divided into 180°. Another scale is Reaumur's; the freezing point is 0°, the boiling point 80°. These are the principal thermometers used in Europe and this country.‡

Fig. 29.

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* Quicksilver will indicate 500° F. but freezes at —39°.

† As the chemist will often have occasion to employ the thermometer for ascertaining the temperature of corrosive liquids, the graduated scale should be provided with a hinge, so as to double back, and leave the bulb exposed, as shown in Fig. 29.

‡ For the method of constructing thermometers see Faraday's *Manipulation*, and for those of great sensibility, *Quart. Jour. of Sci.* vii. p. 183.

Rules for comparing the ordinary thermometers.

162. Each degree of Fahrenheit's scale is equal to $\frac{4}{9}$ths of a degree on Reaumur's: if, therefore, the number of degrees on Fahrenheit's scale above or below the freezing of water be multiplied by 4 and divided by 9, the quotient will be the corresponding degree of Reaumur.

Fahrenheit.	*Reaumur.*
$68^\circ-32^\circ=36\times4=144\div9=16^\circ$	
$212^\circ-32^\circ=180\times4=720\div9=80^\circ$*	

Change of zero.

163. M. Bellain has observed that mercurial thermometers slowly change their point of zero, which uniformly becomes higher than at the time of graduation. This phenomenon appears owing to a diminished capacity of the bulb due to the atmosphere continually pressing on its exterior, while a vacuum exists in the interior of the tube; for it has not been noticed either in mercurial thermometers which are unsealed, or in thermometers made with alcohol. The principal contraction ensues soon after the tube is sealed, and hence some months should be permitted to elapse between the sealing and graduation of a thermometer.†

Air thermometers.

164. Air is sometimes resorted to as indicating very small changes of temperature. The instrument employed by Sanctorio, to whom the invention of the thermometer is generally ascribed, was of a very simple kind, and measured variations of temperature by the variable expansion of a confined portion

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* To reduce the degrees of Reaumur to those of Fahrenheit, they are to be multiplied by 9, and divided by 4.

Reaumur.	*Fahrenheit.*
$16^\circ\times9=144\div4=36^\circ+32^\circ=68$	
$80^\circ\times9=720\div4=180^\circ+32^\circ=212$	

Every degree of Fahrenheit's is equal to $\frac{5}{9}$ths of a degree on the centigrade scale; the reduction therefore is as follows:

Fahrenheit.	*Centigrade.*
$212-32=180\times5=900\div9=100^\circ$	

Centigrade.	*Fahrenheit.*
$100\times9=900\div5=180+32=212^\circ$	

Corresponding degrees

Fahr.	Cent.	Reaum.	Fahr.	Cent.	Reaum.	Fahr.	Cent.	Reaum.
212	100	80	113	45	36	14	-10	- 8
203	95	76	104	40	32	5	-15	-12
194	90	72	95	35	23	- 4	-20	-16
185	85	68	86	30	24	-13	-25	-20
176	80	64	77	25	20	-22	-30	-24
167	75	60	68	20	16	-31	-35	-28
158	70	56	59	15	12	-40	-40	-32
149	65	52	50	10	8			
140	60	48	41	5	4			
131	55	44	32	0	0			
122	50	40	23	-5	-4			

† *An. de. Ch. et de Ph.* xxi. 330.

of air. This instrument is represented in the margin. It consists of a glass tube, eighteen inches long, open at one end, and blown into a ball at the other. If a warm hand be applied to the ball, the included air will expand, and a portion be expelled through the open end of the tube. And if in this state the aperture is quickly immersed in a cup filled with some coloured liquid, it will ascend in the tube, as the air in the ball contracts by cooling; and its altitude will in every case depend upon the degree of expansion which the air has previously undergone. In this manner it is prepared for use, and will indicate increase of temperature by the descent of its fluid, and *vice versa*. These effects may be exhibited, alternately by applying the hand to the ball, and then blowing on it with a pair of bellows. The amount of the expansion or contraction is measured by a graduated scale attached to the stem of the instrument.

Fig. 30.

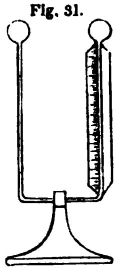
Advantages of.

165. The advantages of the *Air* Thermometer consist in the great amount of the expansion of air, when compared with that of any liquid; by which it is enabled to detect minute changes of temperature, which the mercurial thermometer would scarcely discover; for air is increased in volume by a given elevation of temperature, about twenty times more than quicksilver. The advantages, however, which attend this excessive delicacy are counterbalanced by several serious objections. It will be readily seen, for instance, that the air thermometer will not only be affected by changes of temperature, but by variations of atmospheric pressure.

Leslie's.

166. Leslie, under the name of the *Differential Thermometer*, employed a modification of the air thermometer invented by Sturmius.* It consists of two glass-tubes of unequal length, each terminating in a hollow ball, as represented in Fig. 31, which are united by a bent tube containing coloured sulphuric acid. Whenever a hot body approaches one of the bulbs, it must neessarily drive the fluid towards the other. It is evident then that this instrument cannot be employed to measure variations in the temperature of the surrounding atmosphere, because, as long as both balls are of the same temperature, whatever this may be, the air contained in both will have the same elasticity, and consequently, the included coloured liquor, being pressed equally in opposite directions, must remain stationary. If, however, any change of temperature is effected in one of the balls, the instrument will immediately indicate this *difference* with the greatest nicety. The amount of this effect is ascertained by a graduated scale, the interval between freezing and boiling being divided into 100 equal degrees. This thermometer is peculiarly adapted to ascertain the difference of the temperatures of two contiguous spots in the same atmosphere.

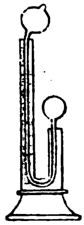
Fig. 31.



Howard's.

A differential thermometer has been contrived by Howard resembling the above in its general form, (Fig. 32) but in

Fig. 32.



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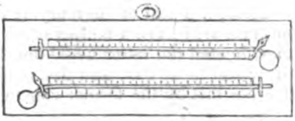
* See a description and sketch in his *Collegium Curiosum*, p. 54; published in 1676.

which the degree of heat is measured by the expansive force of the vapour of ether, or spirit of wine, *in vacuo*.* It is intended to be applied to the same purposes as that of Leslie, but is more sensible to changes of temperature, and the movement of the fluid follows instantaneously the application of the heating cause, whereas in the air thermometer some time is required before the effect takes place.

Self-registering thermometer.

167. Different methods have been recommended for ascertaining the highest or lowest temperature that may occur during any particular period, as during the night, when there is no one present to observe it. The simplest contrivance of this kind is the following:

Fig. 33.



It consists of two thermometers (Fig. 33), a spirit of wine and a mercurial one, the former for ascertaining the lowest, the latter the highest heat. In the tube of the former is placed a small piece of white enamel, which, as the fluid contracts, is brought along with it, but on its again expanding does not take it with it; it leaves it at the place to which it had carried it, and thus the lowest temperature that had happened is pointed out. In the tube of the latter is placed a small piece of a needle, so as just to rest on the mercury. As the fluid expands, it pushes the needle before it and on again contracting, it leaves it at that part to which it had carried it, so that in this way the highest temperature is ascertained. These thermometers are fixed on a board, with the balls at opposite sides, the mercurial one horizontally, the one with spirit of wine with the ball inclined downwards, so that, when we wish to set them, by raising the side next the spirit ball, the enamel and needle will come to the surfaces of the fluids.

Fig. 34.

Six's thermometer (Fig. 34), has the bulb in the form of a long cylinder, the tube is bent down parallel with the cylinder and passing under it, rises in a parallel direction to the top on the other side; the bulb is usually filled with spirits of wine, which is in contact with a portion of mercury occupying the lower part of the tube, and the mercury is succeeded by a second portion of spirit. The mercury carries an index upon each of its surfaces; when the fluid in the cylinder contracts by cold, the index on the left side will be pressed upwards, as long as the heat decreases, and will be retained at its greatest height by a weak spring. When the fluid in the cylinder expands by heat, it must press upon the surface of the mercury in the left side of the tube, forcing it to rise higher in the right side: as long as the heat continues to increase, the index will rise on the surface of the mercury in the right side of the tube, and will be retained at the greatest height by its spring: it must be obvious, therefore, that the index on the side opposite the left hand will indicate the greatest degree of cold, in any given time, and the one on the right, the greatest degree of heat. The indexes being of iron or steel, may be brought back to their places by a magnet, applied to the outside of the tube.

Amount of information from thermometer.

168. Though the thermometer is a most valuable instrument, the sum of information which it conveys is very small. It only indicates that condition of bodies in which they affect the senses with an impression of heat or cold, and which is expressed by the word *temperature*. It does indeed point out a difference in the temperature of two or more substances with great nicety; but it does not indicate how much heat any body contains. We learn by it whether the temperature of one body is greater or less than that of another; and if there is a difference, it is expressed numerically, namely, by the degrees of an arbitrary scale, selected for convenience, without any reference whatever to the actual quantity of heat present in bodies.

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* Directions for constructing it are given in the 8th vol. of the *Quart. Jour. of Sci.* p. 219.

Specific caloric.

169. The relative quantities of heat which different bodies in the same state require to raise them to the same thermometric temperature, is called their *specific* heat, and those bodies which require most heat are said to have the greatest *capacity* for heat. That the quantity of heat in different bodies of the same temperature is different, was first shown by Black, in 1762.

Exp.

Mix together equal quantities of water, one portion being at 100° and the other at 50°, the temperature of the mixture will be the arithmetical mean or 75°; that is, the 25 degrees lost by the warm water will exactly suffice to heat the cold water by the same number of degrees.

It is hence inferred, that equal weights or measures of water of the same temperature contain equal quantities of heat; and the same is found to be true of other bodies. But if equal weights or equal bulks of *different* substances are employed, the result will be different.

Exp.

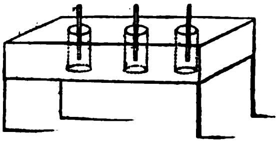
Thus, if a pint of mercury at 100° be mixed with a pint of water at 40°, the mixture will have a temperature of 60°, so that the 40 degrees lost by the former, heated the latter by 20 degrees only; and when, reversing the experiment, the water is at 100° and the mercury at 40°, the mixture will be at 80°, the 20 degrees lost by the former causing a rise of 40 in the latter.

The fact is still more strikingly displayed by substituting equal weights for measures.

Different quantities of heat required by bodies.

170. It appears that the same quantity of heat imparts twice as high a temperature to mercury as to an equal volume of water; a similar proportion is observed with respect to equal weights of spermaceti oil and water; and that the heat which gives 5 degrees to water will raise an equal weight of mercury by 115 degrees, being the ratio of 1 to 23. Hence if equal quantities of heat be added to equal weights of water, spermaceti oil, and mercury, their temperatures in relation to each other will be expressed by the numbers 1, 2, and 23; or, what amounts to the same, in order to increase the temperature of equal weights of those substances to the same extent, the water will require 23 times as much heat as the mercury, and twice as much as the oil. T. 29.

Fig. 35.



This may be illustrated by an ingenious apparatus contrived by Bache. Three vessels of sheet iron, (Fig. 35) to contain equal *weights* of mercury, alcohol, and water, are attached to a frame, by which they can be dipped into the same vessel containing hot water. An alcohol thermometer, with a large column of fluid, dips into each vessel. As the heat enters, the thermometer in the mercury rises with great rapidity, that in the alcohol more slowly, and that in the water still more so.*

171. The same knowledge may be obtained by reversing the process; by noting the relative quantities of caloric which bodies give out in cooling; for if water requires 23 times more caloric than mercury to raise its temperature 1 or more degrees, it must also lose 23 times as much in cooling. The *calorimeter*, invented and employed by Lavoisier and La Place, acts on this principle.†

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* Cylinders of copper, coated with a varnish of thickened linseed oil to protect the surface, may be substituted for the thermometers, phosphorus, placed on the top of each, will inflame first on the cylinder in the liquid having the least capacity for heat. *Amer. Jour.* xxviii. 324.

† See Lavoisier's *Elements of Chemistry.*

Cause.

172. The singular fact of substances of equal temperature, containing unequal quantities of heat, naturally excites speculation about its cause, and various attempts have been made to account for it. The explanation deduced from the views of Black is the following. He conceived that heat exists in bodies in two opposite states: in one it is supposed to be in chemical combination, exhibiting none of its ordinary characters, and remaining as it were concealed, without evincing any signs of its presence; in the other, it is free and uncombined, passing readily from one substance to another, affecting the senses in its passage, determining the height of the thermometer, and in a word giving rise to all the phenomena which are attributed to this active principle.*

Heating and cooling of bodies influenced by capacity.

173. The capacities of bodies for heat have considerable influence upon the rate at which they are heated and cooled. Those bodies which are most slowly heated and cooled, have generally the greatest capacity for heat. Thus, if equal quantities of water and quicksilver be placed at equal distances from the fire, the quicksilver will be more rapidly heated than the water, and the metal will cool most rapidly when carried to a cold place. Upon this principle, Leslie ingeniously determined the specific heat of bodies, observing their relative times of cooling a certain number of degrees comparatively with water, under similar circumstances.

Leslie's method.

Specific heat of gases.

174. The determination of the specific heat of gaseous substances is a problem of importance, and has accordingly occupied the attention of several experimenters of great science and practical skill; but the inquiry is beset with so many difficulties that, in spite of the talent which has been devoted to it, our best results can be viewed as approximations only, requiring to be corrected by future research.†

Circumstances to be noticed.

175. The circumstances which merit particular notice, concerning the specific heat of bodies, have been arranged by Turner under the eight following heads:—

1. Every substance has a specific heat peculiar to itself; whence it follows, that a change of composition will be attended by a change of capacity for heat.

2. The specific heat of a body varies with its form. A solid has a smaller capacity for heat than the same substance when in the state of a liquid.

3. When a given weight of any gas is made to vary in density and volume while its elasticity is unchanged, as when air confined in a tube over mercury is heated and suffered to expand without variation of pressure, the specific heat is believed to remain constant.

4. Of the specific heat of equal volumes of the same gas at a varying density and elasticity, as when air is forced into a bottle with different degrees of force, nothing certain has been established.

5. The specific heat of equal weights of the same gas varies as the density and elasticity vary.

6. The specific heat of solids and liquids was formerly thought to be constant at all temperatures, so long as they suffer no change of form or composition. Dalton, however, (*Chemical Philosophy*, part

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* For objections to this theory, see note by Bache, p. 30, Turner's *Elements*, Am. ed.

† For a view of the experiments of Crawford, Lavoisier, Dulong, and others, on this subject, see *Turner's Elements*, p. 31.

I. p. 50,) endeavours to show that the specific heat of such bodies is greater in high than at low temperatures; and Petit and Dulong have proved it experimentally with respect to several of them.

It is difficult to determine whether the increased specific heat observed in solids and liquids at high temperatures is owing to the accumulation of heat within them, or to their dilatation. It is ascribed in general to the latter.

Dilatation of air, &c.

176. Change of specific heat always occasions a change of temperature. Increase in the former is attended by diminution of the latter; and decrease in the former by increase of the latter.

Fig. 36.

Exp.

Thus when air, confined within a flaccid bladder, is suddenly dilated by means of the air-pump, a thermometer placed in it will indicate the production of cold. On the contrary, when air is compressed, the corresponding diminution of its specific heat gives rise to increase of temperature; nay, so much heat is evolved when the compression is sudden and forcible, that tinder may be kindled by it. This is illustrated by a brass syringe furnished at one end with a stop cock having a small chamber in which tinder, or what is better, a small piece of phosphorus wrapped in tow, is placed. By suddenly compressing the piston, the tinder takes fire on opening the stop cock. Or the tinder may be placed in a cavity, in the end of the piston.

The explanation of these facts is obvious. In the first case, a quantity of heat becomes insensible, which was previously in a sensible state; in the second, heat is evolved, which was previously latent.

Relation of specific heat and weight.

A curious relation between the specific heat of some elementary substances and their atomic weight was discovered by Dulong and Petit; namely, that the product of the specific heat of each element by the weight of its atom is a constant quantity.

Forms and states of bodies influenced by caloric.

177. Heat has great influence on the *forms* or *states* of bodies. When we heat a solid it becomes fluid or gaseous, and liquids are converted into aëriform bodies or vapours. Black investigated this effect of heat with singular felicity.* During the liquefaction of bodies, a quantity of heat, which is essential to the state of fluidity, and which is therefore often called the *heat of fluidity*, is absorbed, without increasing the sensible or thermometric temperature. Consequently, if a cold solid body, and the same body hot and in a liquid state, be mixed in known proportions, the temperature after mixture will not be the proportional mean, as would be the case if both were liquid, but will fall short of it; much of the heat of the hotter body being consumed in rendering the colder solid *liquid*, before it produces any effect upon its *sensible temperature*.

178. Equal parts of *water* at 32°, and of *water* at 212°, will produce on mixture a mean temperature of 122°. But equal parts of *ice* at 32°, and of water at 212°, will only produce (after the liquefaction of the ice) a temperature of 52°, the greater portion of the heat of the water being employed in thawing the ice, before it can produce any rise of temperature in the mixture. To heat thus *insensible* or

Latent caloric.

combined, Black applied the term *latent heat*. The actual loss of the thermometric heat in these cases was thus estimated; a pound of ice at 32° was put into a pound of water at 172°, the ice melted, and the temperature of the mixture was 32°. Here the water was

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* Black's *Lectures*.

cooled 140°, while the *temperature* of the ice was unaltered; that is, 140° of heat disappeared, their effect being not to increase temperature, but to produce fluidity.

Cold produced by rapid solution. 179. In all cases of liquefaction caloric is absorbed, and we produce artificial cold, often of great intensity, by the rapid solution of certain saline bodies in water.* Upon this principle the action of freezing mixtures depends, some of which may frequently be conveniently and economically applied to the purpose of cooling wine or water in hot climates, or where ice cannot be procured.

Exp. 1. Dilute a portion of nitric acid with an equal weight of water; and, when the mixture has cooled, add to it a quantity of light fresh-fallen snow. On immersing the thermometer in the mixture, a very considerable reduction of temperature will be observed. This is owing to the absorption, and intimate fixation of the free caloric of the mixture by the liquefying snow.

Exp. 2. Mix quickly together equal weights of fresh-fallen snow at 32°, and of common salt, cooled, by exposure to a freezing atmosphere, down to 32°. The two solid bodies, on admixture, will rapidly liquefy, and the thermometer will sink 32° or to 0°, or according to Blagden to 4† lower.

Theory. To understand this experiment, it must be recollected, that the snow and salt, though at the freezing temperature of water, have each a

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FRIGORIFIC MIXTURES WITH SNOW.

Mixtures.	Parts by weight.	Thermometer sinks		Degree of Cold produced.
Sea-salt,	1	from any temperature	to —5°	
Snow,	2			
Sea-salt,	2		to —12°	
Hydrochlorate of ammonia,	1			
Snow,	5			
Sea-salt,	10		to —18°	
Hydrochlorate of ammonia,	5			
Nitrate of potassa,	5			
Snow,	24			
Sea-salt,	5		to —25°	
Nitrate of ammonia,	5			
Snow,	12			
Diluted sulphuric acid,†	2	from +32° to —23°		55 degrees.
Snow,	3			
Concentrated hydrochloric acid,	5	from +32° to —27°		59
Snow,	8			
Concentrated nitrous acid,	4	from +32° to —30°		62
Snow,	7			
Chloride of calcium,	5	from +32° to —40°		72
Snow,	4			
Crystallized chloride of calcium,	3	from +32° to —50°		82
Snow,	2			
Fused potassa,	4	from +32° to —51°		83
Snow,	3			

But freezing mixtures may be made by the rapid solution of salts, without the use of snow or ice; and the following table, taken from Walker's Essay in the Philosoph-

† *Phil. Trans.* lxxviii. 281.

*The snow should be freshly fallen, dry, and uncompressed. If snow cannot be had, finely powdered ice may be substituted for it.

†Made of strong acid, diluted with half its weight of snow or distilled water.

considerable portion of uncombined caloric. Now salt has a strong affinity for water; but the union cannot take place while the water continues solid. In order, therefore, to act on the salt, the snow absorbs all the free caloric required for its liquefaction; and during this change, the free caloric, both of the snow and the salt, amounting to 32°, becomes latent, and is concealed in the solution. This solution remains in a liquid state at 0, or 4° below 0 of F.; but if a greater degree of cold be applied to it, the salt separates in a concrete form.

Most neutral salts, also, during solution in water, absorb much caloric; and the cold, thus generated, is sometimes so intense as to freeze water, and even to congeal mercury. The former experiment, however, (viz. the congelation of water,) may easily be repeated on a summer's day.

Exp. Add to 32 drachms of water, 11 drachms of hydrochlorate of ammonia, 10 of nitrate of potassa, and 16 of sulphate of soda, all finely powdered. The salts may

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ical Transactions for 1795, includes the most important of them. The salts must be finely powdered and dry.

MIXTURES.	Parts by weight.	Temperature falls	Degree of Cold produced.
Hydrochlorate of ammonia, Nitrate of potassa, Water,	5 5 16	from +50° to +10°	40 degrees.
Hydrochlorate of ammonia, Nitrate of potassa, Sulphate of soda, Water,	5 5 8 16	from +50° to +4°	46
Nitrate of ammonia, Water,	1 1	from +50° to +4°	46
Nitrate of ammonia, Carbonate of soda, Water,	1 1 1	from +50° to —7°	57
Sulphate of soda, Diluted nitrous acid,*	3 2	from +50° to —3°	53
Sulphate of soda, Hydrochlorate of ammonia, Nitrate of potassa, Diluted nitrous acid,	6 4 2 4	from +50° to —10°	60
Sulphate of soda, Nitrate of ammonia, Diluted nitrous acid,	6 5 4	from +50° to —14°	64
Phosphate of soda, Diluted nitrous acid,	9 4	from +50° to —12°	62
Phosphate of soda, Nitrate of ammonia, Diluted nitrous acid,	9 6 4	from +50° to —21°	71
Sulphate of soda, Hydrochloric acid,	8 5	from +50° to 0°	50
Sulphate of soda, Diluted sulphuric acid,†	5 4	from +50° to +3°	47

These artificial processes for generating cold are much more effectual when the materials are previously cooled by immersion in other frigorific mixtures.

* Composed of fuming nitrous acid two parts in weight, and one of water—the mixture being allowed to cool before being used.

† Composed of equal weights of strong acid and water, being allowed to cool before use.

be dissolved separately, in the order set down. A thermometer, put into the solution, will show, that the cold produced is at, or below freezing; and a little water, in a thin glass tube, being immersed in the solution, will be frozen in a few minutes. H. 1. 113.*

Method of freezing mercury. Crystallized chloride of calcium, when mixed with snow, produces a most intense degree of cold. This property was discovered by Lovitz, and has been since applied to the congelation of mercury on a very extensive scale.†

On a small scale, it may be sufficient to employ two or three pounds of the salt.

Exp. Let a few ounces of mercury, in a very thin glass retort, be immersed, first in a mixture of one pound of each; and, when this has ceased to act, let another similar mixture be prepared. The second will never fail to congeal the quicksilver.‡

Latent caloric made sensible. 180. When fluids are converted into solids, their *latent* heat becomes *sensible*. Water, if kept perfectly free from agitation, may be cooled down several degrees below 32°; but, on shaking it, it immediately congeals, and the temperature rises to 32°.

The evolution of caloric, during the congelation of water is well illustrated by the following experiment of Crawford.

Exp. 1. Into a round tin vessel put a pound of powdered ice; surround this by a mixture of snow and salt in a larger vessel; and stir the ice in the inner one, till its temperature is reduced to + 4° F. To the ice thus cooled add a pound of water at 32°. One fifth of this will be frozen; and the temperature of the ice will rise from 4° to 32°. In this instance, the caloric evolved, by the congelation of one fifth of a pound of water, raises the temperature of a pound of ice 28°. H. 1. 115.

Exp. 2. Dissolve sulphate of soda in water, in the proportion of one part to five, and surround the solution by a freezing mixture, it will cool gradually down to 31°. The salt, at this point, begins to be deposited, and stops the cooling entirely.

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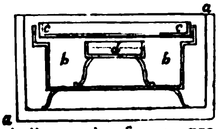
* The results of some of Walker's experiments on this subject, are given in the tables of freezing mixtures.

† The proportions, which answer best, are about equal weights of the salt finely powdered, and of fresh fallen and light snow. On mixing these together, and immersing a thermometer in the mixture, the mercury sinks with great rapidity. For measuring exactly the cold produced, a spirit thermometer, graduated to 50° below 0 of Fahrenheit, or still lower should be employed. A few pounds of the salt are sufficient to congeal a large mass of mercury. By means of 13 pounds of the chloride, and an equal weight of snow, Pepys and Allen froze 56 pounds of quicksilver into a solid mass. The mixture of the whole quantity of salt and snow, however, was not made at once, but part was expended in cooling the materials themselves.

‡ Fig. 37, a very simple and cheap apparatus may be employed to freeze mercury. The outer vessel of wood may be twelve and a half inches square, and seven inches deep. It should have a wooden cover, rabbeted in, and furnished with a handle. Within this is placed a tin vessel *b b*, standing on feet which are one and a half inches high, and having a projection at the top, half an inch broad and an inch deep, on which rests a shallow tin pan *c c*. Within the second vessel is a third *d*, made of untinned iron, and supported by feet two inches high. This vessel is four inches square, and is intended to contain the mercury. When the apparatus is used, a mixture of hydrochlorate of lime and snow is put into the outer vessel *a a*, so as completely to surround the middle vessel *b b*. Into the latter, the vessel *d*, containing the quicksilver to be frozen, previously cooled down by a freezing mixture, is put; and this is immediately surrounded by a mixture of snow and muriate of lime, previously cooled to 0° F. by an artificial mixture of snow and common salt. The pan *c c* is also filled with these materials, and the wooden cover is then put into its place. The vessels are now left till the quicksilver is frozen. A more elegant, but more expensive, apparatus, by Pepys, intended for the same purpose, is figured in an early volume of the Philosophical Magazine. H. 1. 114.

Fig. 37.



This evolution of caloric during the separation of a salt, is exactly the reverse of what happens during its solution.*

When a solution of Glauber's salt is made suddenly to crystallize, its temperature is considerably augmented; (31 note) and when water is poured upon quicklime, a great degree of heat is produced by the solidification which it suffers in consequence of chemical combination; congelation, therefore, is to surrounding bodies a heating process, and liquefaction a cooling process.

Conversion of liquids into the aëriform state.

181. When liquids are heated they acquire the gaseous form, and become invisible elastic fluids, possessed of the mechanical properties of common air. By a sufficiently intense heat every liquid and solid would probably undergo this change. A considerable number of bodies, however, resist the strongest heat of our furnaces without vaporizing. These are said to be *fixed* in the fire: those which, under the same circumstances, are converted into vapour, are called *volatile.* This effect of caloric is termed *Vaporization.*

Vapours.

182. Vapours are characterized by the readiness with which they are convertible into liquids or solids, either by a moderate increase of pressure, the temperature at which they were formed remaining the same, or by a moderate diminution of that temperature, without change of pressure. They retain this form or state as long as their temperature remains sufficiently high, but re-assume the liquid form when cooled again.

Exp. 1.

Fill a jar with water heated to 104° and invert it in a vessel of the same. Then introduce a little ether by means of a glass tube closed at one end. The ether will rise to the top of the jar, and, in its ascent will be changed into gas, filling the whole jar with a transparent, invisible, elastic fluid. On permitting the water to cool, the ethereal gas is condensed, and the inverted jar again becomes filled with water.

Exp. 2.

Or more beautifully thus. Fill a glass tube about thirty inches long and an inch in diameter, with quicksilver, and invert it in the mercurial trough. Pass up from a small bottle an ounce or more of ether; after it has collected upon the surface of the quicksilver in the tube, it may be made to boil by the heat of the hand by grasping the tube at that part where the ether stands; which will pass to the state of vapour and depress the mercurial column.

Difference of density.

183. The disposition of various substances to yield vapour is very different; and the difference depends doubtless on the relative power of cohesion with which they are endowed. Vapours occupy more space than the substances from which they were produced. According to the experiments of Gay Lussac, water, at its point of greatest density, in passing into vapour, expands to 1696 times its volume, alcohol to 659 times, and ether to 443 times, each vapour being at a temperature of 212° F. and under a pressure of 29.92 inches of mercury. This shows that vapours differ in density. Watery vapour is lighter than air at the same temperature and pressure, in the proportion of 1000 to 1604; or the density of air being 1000, that of watery vapour is 625. The vapour of alcohol, on the contrary, is half as heavy again as air; and that of ether is more than twice and a half as heavy.

Dilatation of vapours.

184. The dilatation of vapours by heat was found by Gay-Lussac to follow the same law as gases, that is, for every degree of Fahrenheit, they increase by $\frac{1}{480}$th of the volume they occupied at 32°. But the law does not hold unless the quantity of vapour con-

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* Blagden, *Phil. Trans.* lxxviii. 290.

tinue the same. If the increase of temperature cause a fresh portion of vapour to rise, then the expansion will be greater than $\frac{1}{480}$th for each degree; because the heat not only dilates the vapour previously existing to the same extent as if it were a real gas, but augments its bulk by adding a fresh quantity of vapour. The contraction of a vapour on cooling will likewise deviate from the above law, whenever the cold converts any of it into a liquid; an effect which must happen, if the space had originally contained its maximum of vapour.

Influenced by pressure.

The volume of vapour varies under varying pressure according to the same law as that of gases, provided always that the gaseous state is preserved. This law, discovered by Boyle and Mariotte, is more fully explained in the section on atmospheric air, and merely expresses the fact that the volume of gaseous substances at a constant temperature is inversely as the pressure to which they are subject.

Boiling point of liquids different.

185. The temperature at which vapour rises with sufficient freedom for causing the phenomena of ebullition, is called the boiling point. The heat requisite for this effect varies with the nature of the fluid. Thus, sulphuric ether boils at 96° F. alcohol at 173° and pure water at 212°; while oil of turpentine must be raised to 316°, and mercury to 662°, before either exhibits marks of ebullition. The appearance of boiling is owing to the formation of vapour at the bottom of the vessel, and it escapes through the heated fluid above it.

Boiling point constant under same circumstances.

186. The boiling point of the same liquid is constant, so long as the necessary conditions are preserved; but it is liable to be affected by several circumstances. The nature of the vessel has some influence upon it. Thus Gay Lussac observed that pure water boils precisely at 212° in a metallic vessel and at 214° in one of glass. It is likewise affected by the presence of foreign substances. Bostock found that ether, heated in a glass vessel, had its boiling point lowered nearly 50° by introducing a few chips from a cedar pencil, and alcohol of s. g. 849 had its boiling point reduced by a similar cause between 30° and 40°. The boiling point of water, heated in a glass vessel, was brought down 4° or 5° by the same means.* By putting coils of wire into liquids, heated in glass vessels with a view to distillation, they are made to boil readily, quietly and some degrees lower than they would otherwise do. It is of course necessary to use a metal which will not be acted upon by the liquid.

Effect of pressure.

187. A circumstance which has great influence over the boiling point and vaporization of fluids is variation of pressure. By the mere removal of atmospheric pressure, ether will be converted into vapour at the common temperature of the atmosphere.

Exp.

Into a glass tube, about six inches long, and half an inch in diameter, put a teaspoonful of ether, and fill up the tube with water; then, pressing the thumb on the open end of the tube, place it, inverted, in a jar of water. Let the whole be set under the receiver of an air-pump, and exhaust the air. The ether will be changed into gas, which will expel the water entirely from the tube. On re-admitting the air into the receiver, the gas is again condensed into a liquid form.

Boiling point in vacuo.

From the experiments of the late Prof. Robison it appears that liquids boil in a vacuum at a temperature 140° lower than in the open air.† Thus water boils at 72° F., alcohol at 36,° and ether at —44°. This proves that a liquid is not necessarily hot because it

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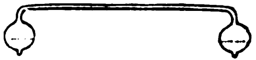
* *Ann. of Philos.* N. S. ix. 196.

† Black's *Lectures*, Vol. i. p. 161.

boils. The heat of the hand is sufficient to make ether boil in a vacuum, as is exemplified by the *Pulse Glass.*

Fig 38.



Effect of changes of density of the air. Altitudes determined by the boiling point.

188. Even the ordinary variations in the weight of the air, as measured by the barometer, are sufficient to make a difference in the boiling point of water of several degrees. When the barometer is at 28 inches, water will boil at the temperature of 208,43°, when at 30 inches at 212°, and when at 31 at 213,76°. At the top of Mount Blanc, Saussure found that it boiled at 187°, so that the heights of mountains, and even of buildings, may be calculated by reference to the temperature at which water boils upon their summits.*

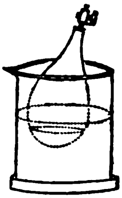
Example of diminished pressure facilitating ebullition.

The following apparently paradoxical experiment also illustrates the influence of diminished pressure in facilitating ebullition.

Exp.

Insert a stop cock securely into the neck of a Florence flask, Fig. 39, containing a little water, and heat it over a lamp till the water boils, and the steam freely escapes by the open stop cock; then suddenly remove the lamp and close the cock. The water will soon cease to boil; but if plunged into a vessel of cold water, ebullition instantly recommences, but ceases if the flask be held near the fire: the vacuum in this case being produced by the condensation of the steam.†

Fig. 39.



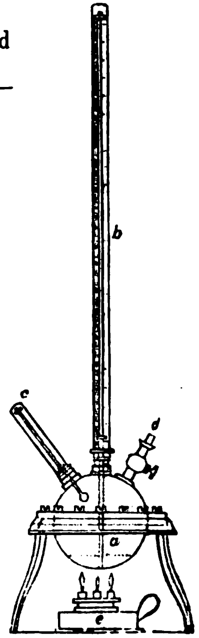
Example of the contrary effect of pressure.

189. Water cannot be heated under common circumstances beyond 212° F. because it then acquires such an expansive force as enables it to overcome the atmospheric pressure, and to fly off in the form of vapour. But if subjected to sufficient pressure, it may be heated to any extent without boiling. The elasticity of steam increases in a greater ratio than the temperature at which it is produced: thus if it be

1 at 212°	4 at 293.7	16 at 398.48
it is 2 " 250.5	8 " 341.78	24 " 435.57

Or steam at these temperatures, has 2, 4, 8, 16, and 24 times the elastic force of steam at 212°.‡

Fig. 40.



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[*] Wollaston has described the method of constructing a thermometer of extreme delicacy, applicable to these purposes.*

[†] The experiment may be varied by placing the flask in an inverted position in the ring of a retort-stand and blowing upon it with a pair of bellows.

Marcei's apparatus.

[‡] For making experiments on this subject, the apparatus, represented Fig. 40, contrived by Marcet, will be found extremely useful. *a* is a strong brass globe, composed of two hemispheres screwed together with flanches; a portion of quicksilver is introduced into it, and it is then about half filled with water. *b* is a barometer tube passing through a steam-tight collar, and dipping into the quicksilver at the bottom of the globe. *c* is a thermometer graduated to about 400°, and also passing through an air-tight collar. *d* is a stop cock, and *e* a large spirit lamp. The whole is supported upon the brass frame and stand *f*. Upon applying heat to this vessel, the stop cock being closed as soon as the water boils, it will be found that the temperature of the water and its vapour increases with the pressure, which is measured by the ascent of the mercury in the barometer tube. The thermometer under atmospheric pressure being at 212°, will be elevated to 217° under a pressure of five inches of mercury, and to 242° under a pressure of 30 inches, or thereabouts; each inch of mercury producing by its pressure a rise of about 1° in the thermometer. The barometer tube also serves the purpose of a safety-valve, the strength of the brass globe being such as to resist a greater pressure than that of one atmosphere.

[*] *Phil. Trans.* 1817.

Evaporation.

190. Evaporation as well as ebullition consists in the formation of vapour, and the only assignable difference between them is, that the one takes place quietly, the other with the appearance of boiling. Evaporation occurs at common temperatures. This fact may be proved by exposing water in a shallow vessel to the air for a few days, when it will gradually diminish, and at last disappear entirely. Most liquids, if not all of them, are susceptible of this gradual dissipation; and it may also be observed in some solids, as for example in camphor. Evaporation is much more rapid in some liquids than in others, and it is always found that those liquids, the boiling point of which is lowest, evaporate with the greatest rapidity. Thus alcohol, which boils at a lower temperature than water, evaporates also more freely; and ether, whose point of ebullition is yet lower than that of alcohol, evaporates with still greater rapidity.

The chief circumstances that influence the process of evaporation are extent of surface, and the state of the air as to temperature, dryness, stillness, and density.

Sensible, or free caloric made latent.

191. The conversion of a liquid into vapour is always attended with great loss of thermometric heat; and as liquids may be regarded as compounds of solids and heat, so vapours may be considered as consisting of a similar combination of heat with liquids; in other words, a great quantity of heat becomes latent during the formation of vapour.

Exp. 1.

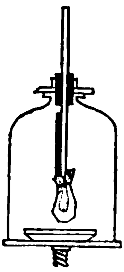
Moisten a thermometer with alcohol, or with ether, and expose it to the air, repeating these operations alternately. The mercury of the thermometer will sink at each exposure, because the volatile liquor, during the evaporation, robs it of its heat. In this way, (especially with the aid of an apparatus, described by M. Cavallo, in the Philosophical Transactions, 1781, p. 509,) water may be frozen, in a thin and small glass ball, by means of ether. The same effect may be obtained, also, by immersing a tube, containing water at the bottom, in a glass of ether, which is to be placed under the receiver of an air pump; or the ether may be allowed to float on the surface of the water. During the exhaustion of the vessel, the ether will evaporate rapidly, and, robbing the water of heat, will completely freeze it; thus exhibiting the singular spectacle of two fluids in contact with each other, one of which is in the act of boiling, and the other of freezing, at the same moment.

Exp. 2.

Marcet's method of freezing mercury.

By a little modification of the experiment, mercury itself, which requires for congelation a temperature of almost 40° below 0 of F., may be frozen, as was first shown by Marcet.*

Fig. 41.



* A conical receiver, (Fig. 41,) open at the top, is placed on the plate of an air-pump, and a small tube with a cylindrical bulb at its lower end, containing mercury, is suspended within the receiver, through the aperture, by means of a brass plate, perforated in its centre, and fitting the receiver air-tight, when laid upon its open neck. The tube passes through this plate to which it is fitted by a leather adjustment, or simply by a cork secured with sealing wax. The bulb is then wrapped up in a little cotton wool, or, what is better, in a small bag of fine fleecy hosiery, in which a small spirit thermometer graduated below 40° F., may also be included, and after being dipped into sulphuret of carbon or ether,* the apparatus is quickly placed under the receiver, which is exhausted as rapidly as possible. In two or three minutes, the temperature sinks to about 45° below 0, at which moment the quicksilver in the stem suddenly descends with great rapidity. If it be desired to exhibit the mercury in a solid state, common tubes may be used, which have originally been about an inch in diameter, but have been flattened by pressure, when softened by the blowpipe. The experiment succeeds, when the temperature of the room is as high as + 40° Fahrenheit. H. 126.

* In exhausting a vessel containing either of these fluids, the valves of the air pump should be metallic.

Chap. I.

Temperature of steam,

192. The loss of sensible heat attending the formation of vapour, is proved by the well known fact that the temperature of steam is precisely the same as that of the boiling water from which it rises; so that all the heat which enters into the liquid, is solely employed in converting a portion of it into vapour, without affecting the temperature of either in the slightest degree, provided the latter is permitted to escape with freedom. The heat which then becomes latent, to use the language of Black, is again set free when the vapour is condensed into water. The exact quantity of heat rendered insensible by vaporization, may, therefore, be ascertained by condensing the vapour in cold water, and observing the rise of temperature which ensues. From the experiments of Black and Watt, conducted on this principle, it appears that steam of 212°, in being condensed into water of 212°, gives out as much heat as would raise the temperature of an equal weight of water by 950 degrees, all of which had previously existed in the vapour without being sensible to a thermometer.

Latent heat of.

The latent heat of steam and several other vapours has been examined by Ure, whose results are contained in the following table. (*Phil. Trans.* 1818.)

	Latent Heat.
Vapour of water at its boiling point	967°
Alcohol	442
Ether	302.379
Petroleum	177.87
Oil of turpentine	177.87
Nitric acid	531.99
Liquid ammonia	837.28
Vinegar,	875*

193. The large quantity of heat, latent in steam, renders its ap-

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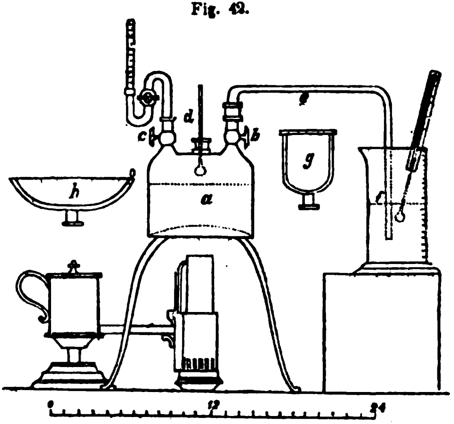
When a jet of liquid carbonic acid is directed upon mercury, it is so rapidly vaporized that the mercury is frozen. The pipes connected with the fountains from which soda water is drawn, are often closed by ice, formed on the sudden escape and expansion of the last portion of water and compressed gas.

Henry's apparatus.

* The small boiler, represented in Fig. 42, taken from Henry's *Elements of Chemistry*, may be conveniently employed in experiments on the latent heat of steam.

For this purpose the tube *e* must be screwed on the stop-cock *b*, and immersed into the glass of water *f*. The cock *c* being closed, the steam arising from the boiling water *a* will pass into the cold water *f*, the temperature of which will be much augmented by its condensation. Ascertain the increase of temperature and weight, and the result will show how much a given weight of water has had its temperature raised by a certain weight of condensed steam. To another quantity of water of the same weight and temperature as that in the jar at the outset of the experiment, add a quantity of water at 212°, equal in weight to the condensed steam; it will be found, on comparing the resulting temperatures, that a given weight of steam has produced, by its condensation, a much greater elevation of temperature than the same quantity of boiling water.

Fig. 42.



Economical use of steam,

plication extremely useful for practical purposes. Thus water may be heated at a considerable distance from the conducting pipe *e*. (Fig. 42.) This furnishes us with a commodious method of warming the water of baths, which, in certain cases of disease, it is of importance to have near the patient's bed-room; for the boiler, in which the water is heated, may thus be placed on the ground floor, or in the cellar of a house; and the steam conveyed by pipes into an upper apartment. Steam may also be applied to the purpose of heating or evaporating water, by a modification of the apparatus.* In breweries and other manufactories, where large quantities of warm and boiling water are consumed it is frequently heated by conveying steam into it, or by suffering steam-pipes to traverse the vessels or by employing double vessels, a plan adopted with particular advantage in the preparation of medicinal substances. Where a higher temperature than 212° is required it is necessary to employ steam under adequate pressure.

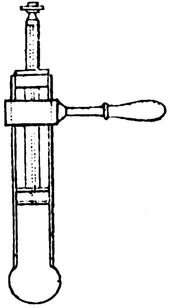
Taken advantage of in some arts.

Steam is transparent.

194. The perfect transparency of steam, and also two other important properties, on which depends its use as a moving power, viz. its elasticity and its condensibility by a reduced temperature, are beautifully shown by a little apparatus contrived by Wollaston.

It consists of a glass tube (Fig. 43) about 6 inches long and ¾ inch bore, as cylindrical as possible, and blown out a little at the lower end. It has a wooden handle, to which is attached a brass clip embracing the tube; and within is a piston, which, as well as its rod, is perforated, as shown by the dotted lines. This canal may be occasionally opened or closed by a screw at the top: and the piston rod is kept in the axis of the cylinder by being passed through a piece of cork fixed at the top of the tube. When the instrument is used, a little water is put into the bottom; the piston is then introduced with its aperture left open; and the water is heated over a spirit lamp. The common air is thus expelled from the tube, and when this may be supposed to be effected, the aperture in the rod is closed by the screw. On applying heat, steam is produced, which drives the piston upwards. On immersing the bulb in water, or allowing it to

Fig. 43.



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* Fig 42, *g* represents the apparatus for boiling water by the condensation of steam, without adding to its quantity; a circumstance occasionally of considerable importance. The steam is received between the vessel, which contains the water to be heated, and an exterior case; it imparts its caloric to the water, through the substance of the vessel; is thus condensed, and returns to the boiler by the perpendicular pipe. An alteration of the form of the vessel adapts it to evaporation (Fig. 42, *h*). This method of evaporation is admirably suited to the concentration of liquids, that are decomposed, or injured by a higher temperature than that of boiling water, such as medicinal extracts; to the drying of precipitates, &c. In the employment of either of these vessels, it is expedient to surround it with some slow conductor of heat. On a small scale a few folds of woollen cloth are sufficient; and when the vessel is constructed of a large size for practical use, this purpose is served by the brick work in which it is placed. H. 1. 135.

Ure's drying apparatus.

A very convenient apparatus for drying precipitates, &c. by steam is described by Ure. A square tin box, about 18 inches long, 12 broad, and 6 deep, has its bottom hollowed a little by the hammer towards its centre, in which a round hole is cut of 5 or 6 inches diameter. Into this a tin tube, 3 or 4 inches long, is soldered. This tube is made to fit tightly into the mouth of a common teakettle, which has a folding handle. The top of the box has a number of circular holes cut into it, of different diameters, in which evaporating capsules are placed. When the kettle, filled with water, and with its nozzle corked, is set on a stove, the vapour playing on the bottoms of the capsules, heats them, to any required temperature; and being itself continually condensed runs back into the kettle. The orifices not in use may be closed with tin lids. In drying precipitates, the tube of the glass funnel should be corked up, and the funnel be placed, with its filter, directly into the proper sized opening. For drying red cabbage, violet petals, &c. a tin tray is provided, which fits close on the top of the box, within the rim which goes about it. The round orifices are left open when this tray is applied. (*Dict. Chem.* 291.)

cool spontaneously, a vacuum is produced in the tube, and the piston is forced downwards by the weight of the atmosphere. These appearances may be alternately produced by repeatedly heating and cooling the water in the ball of the instrument.

In the original steam engine, the vapour was condensed in the cylinder, as it is in the glass tube; but in the engine as improved by Watt, the steam is pumped into a separate vessel, and there condensed; by which the loss of heat, occasioned by cooling the cylinder every time, is avoided.

Reduction of temperature by evaporation.

195. Liquids assume the aëriform state much more rapidly under a diminished pressure, especially if the vapour which is formed, be condensed as soon as it is produced, so as to maintain the vacuum; and the cold produced is very great.

Leslie's method of freezing water.

On this principle depends Leslie's ingenious mode of freezing water, in an atmosphere of any common temperature, by producing a rapid evaporation from the surface of the water itself. The water to be congealed is contained in a shallow porous vessel, which is supported above another vessel, containing strong sulphuric acid, or dry chloride of calcium; or even dried garden mould or parched oatmeal. Any substance, indeed, that powerfully attracts moisture, may be applied to this purpose. The whole is covered by the receiver of an air pump, which is rapidly exhausted; and as soon as this is effected, crystals of ice begin to shoot in the water, and a considerable quantity of air makes its escape, after which the whole of the water becomes solid. The rarefaction required is to about 100 times; but to support congelation, after it has taken place, 20 or even 10 times are sufficient. The sulphuric acid becomes very warm; and it is remarkable, that, if the vacuum be kept up, the ice itself evaporates. In five or six days, ice of an inch in thickness will entirely disappear. The acid continues to act, till it has absorbed an equal volume of water.*

In this interesting process, if it were not for the sulphuric acid, an atmosphere of aqueous vapour would fill the receiver; and, pressing on the surface of the water, would prevent the further production of vapour. But the steam, which rises, being condensed the moment it is formed, the evaporation goes on very rapidly, and has no limits but the quantity of the water, and the diminished concentration of the acid.

Wollaston's Cryophorus.

196. It is on the same principle, that the instrument invented by Wollaston, and termed by him the *Cryophorus*, or *Frostbearer*, is founded. (Fig. 45.) When an instrument of this kind is well prepared, if the empty ball be immersed in a mixture of snow and salt, the water in

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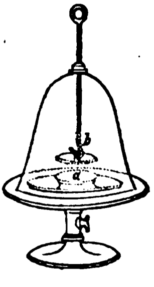
*This beautiful experiment is not successful with pumps on the usual construction. Pumps are now made by Chamberlain of Boston, which produce the effect with ease and rapidity. See Frontispiece.

An elegant manner of making the experiment is to cover the vessel of water (Fig. 44, *a*) with a plate of metal or glass, fixed to the end of a sliding wire *b*, which must pass through the neck of the receiver, and be at the same time air tight, and capable of being drawn upwards. When the receiver is exhausted, the water will continue fluid, till the cover is removed, when, in less than five minutes, needle-shaped crystals of ice will shoot through it, and the whole will soon become frozen.

Fig. 44.



the other ball, though at the distance of two or three feet, will be frozen solid in the course of a very few minutes.*

197. The disappearance of heat that accompanies vaporization was explained by Black, in the way already mentioned under the head of liquefaction, (177.)

The variation of volume and elasticity in vapours is attended, as in gases, with a change of specific heat and a consequent variation of temperature. Thus when steam, highly heated and compressed in a strong boiler, is permitted to escape by a large aperture, the sudden expansion is attended with a great loss of sensible heat: its temperature instantly sinks so much, that the hand may be held in the current of vapour without inconvenience. The same principle accounts for the fact, first ascertained by Watt, that distillation at a low temperature is not attended with any saving of fuel. For when water boils at a low temperature in a vacuum, the vapour is in a highly expanded state, and contains more insensible heat than steam of greater density.

198. In many natural operations the conversion of water into vapour, and the condensation of vapour in the form of dew and rain, is a process of the utmost importance, and tends considerably to the equalization of temperature over the globe.

Temperature of the globe how equalized.

Water, as has been seen (192) in passing into vapour from heat, absorbs caloric without increasing in temperature; this vapour ascends in the atmosphere; when the heat diminishes, or when wafted to colder regions, it is condensed, and gives out the caloric it had absorbed. In seasons or situations where the cold becomes still more intense, water is congealed; and in suffering this change it evolves caloric (180) to moderate the progressive reduction of temperature. When warmth is restored, it returns to the liquid state, absorbs caloric, and retards the approaching heat. The transition of seasons is thus moderated; sudden and extreme variations are guarded against, and the temperature of the globe everywhere preserved more uniform. M. I. 480.

199. As evaporation goes on to a certain extent even at low tem-

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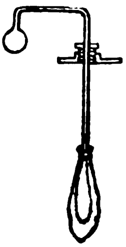
Fig. 45.

Fig. 46.



* It may be formed by taking a glass tube, having an internal diameter about ⅛th of an inch, the tube being bent to a right angle at the distance of half an inch from each ball (Fig. 45). One of these balls should be about ⅓d filled with water, and the other should be as perfect a vacuum as can readily be obtained, the mode of effecting which is well known to those accustomed to blow glass. One of the balls is made to terminate in a capillary tube; and when the water in the other ball has been boiled over a lamp a considerable time, till all the air is expelled, the capillary extremity, through which the steam is still issuing with violence, is held in the flame of the lamp, till the force of the vapour is so far reduced, that the heat of the flame has power to seal it hermetically.

The experiment may be rendered even more striking, if performed according to Marcet's modification of it: the empty ball covered with a little moist flannel, is to be suspended in the manner shown in Fig. 46, within a receiver, over a shallow vessel of strong sulphuric acid, and the receiver is then to be exhausted. In both cases the vapour in the empty ball is condensed by the common operation of cold; and the vacuum produced by this condensation gives opportunity for a fresh quantity to arise from the opposite ball, with a proportional reduction of the temperature of its contents.

peratures, it is probable that the atmosphere is never absolutely free from vapour.

The quantity of vapour present in the atmosphere is very variable, in consequence of the continual change of temperature to which the air is subject. But even when the temperature is the same, the quantity of vapour is still found to vary; for the air is not always in a state of saturation. This variable condition of the atmosphere as to saturation is ascertained by the hygrometer.

Hygrometers,

200. A great many hygrometers have been invented; but they may all be referred to three principles. The construction of the first kind of hygrometer is founded on the property possessed by some substances of expanding in a humid atmosphere, owing to a deposition of moisture within them; and of parting with it again to a dry air, and in consequence contracting. Of these, none is better than the human hair, which not only elongates freely from imbibing moisture, but, by reason of its elasticity, recovers its original length on drying. The hygrometer of Saussure is made with this material.

Saussure's,

The second kind of hygrometer points out the opposite states of dryness and moisture by the rapidity of evaporation. Water does not evaporate at all when the atmosphere is completely saturated with moisture; and the freedom with which it goes on at other times, is in proportion to the dryness of the air. The hygrometric condition of the air may be determined, therefore, by observing the rapidity of evaporation. The most convenient method of doing this is by covering the bulb of a thermometer with a piece of silk or linen, moistening it with water, and exposing it to the air. The descent of the mercury, or the cold produced, will correspond to the quantity of vapour formed in a given time. Leslie's hygrometer is of this kind.

Leslie's.

The third kind of hygrometer is on a principle entirely different from the foregoing. When the air is saturated with vapour, and any colder body is brought into contact with it, deposition of moisture immediately takes place on its surface. This is often seen when a glass of cold spring water is carried into a warm room in summer; and the phenomenon is witnessed in the formation of dew, the moisture appearing on those substances only which are colder than the air.

Dew and Hoar frost.

201. Until the experiments of Wells* the deposition of dew and hoar frost had been supposed to depend entirely upon the reduction of temperature in the air during the night, and the consequent precipitation of its moisture to the earth. Wells has shown that the deposition of dew and hoar frost, is the consequence of the radiation of caloric from the surface of the earth, and that, under favourable circumstances, the temperature of the ground, especially when its covering is formed of some substance that radiates freely, as grass, is several degrees below that of the atmospheric stratum, a few feet above it. It is this diminished temperature of the earth's surface, that occasions the depositions of dew and hoar frost, which are always observed to be most abundantly formed under a clear unclouded sky; a covering of clouds serves as a mantle to the earth, and prevents the free escape of radiant caloric, hence the advantage of snow and artificial coverings in protecting plants.

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* *Essay on Dew, &c.*

Dew point.

The temperature at which dew begins to be deposited is called the dew point, for determining which a very ingenious instrument has been contrived by Daniell.* (*Jour. Royal Institut.* Vol. 8.)

Conducting power of bodies for caloric,

202. When different bodies are exposed to the same source of heat, they suffer it to pass through them with very different degrees of velocity, or they have various *conducting powers* in regard to heat. Among solid bodies, metals are the best conductors; and silver, gold, tin and copper, are better conductors than platinum, iron, and lead. Next to the metals, we may, perhaps, place the diamond and topaz; then glass; then siliceous and hard stony bodies in general; then soft and porous earthy bodies, and wood; and lastly, down, feathers, wool, and other porous articles of clothing.

Apparatus for illustrating.

203. To exhibit the general fact, small cones of the different substances may be used about three inches high, and half an inch in diameter at their bases: these may be tipped at the apex with a small piece of wax, and being placed on a heated metallic plate, will indicate the conducting powers by the relative times required to fuse the wax, which will be inversely, as the power of conducting heat.†

The difference between the conducting power of the diamond and rock crystal or glass, is shown by applying the tongue to those substances, when the former feels colder than the latter.‡

Conducting power of clothing substances.

204. Rumford's experiments on the conducting power of several substances used as clothing, offer some interesting results.§ He found that a thermometer enclosed in a tube and bulb of the same shape, but large enough to allow of an inch vacant space between the two, being previously heated, required 576 seconds to cool 135°. When 16 grains of lint were diffused through the confined air, it took 1032 seconds to undergo the same change of temperature; and 1305 seconds, with the same weight of eider down. The compression of flocculent substances to a certain extent, renders them still inferior conductors; thus, when the space which in the above experiments contained 16 grains of eider down was filled with 32, and then with 64 grains, the times required for the escape of 60 degrees of heat were successively increased from 1305'' to 1475'' and 1615''.

Effect of texture.

On the other hand to show the effect of mere *texture*, similar comparative trials were made of the conducting powers of equal weights of raw silk, of ravellings of white taffeta, and of common sewing silk, of which the first has the finest fibre, the second less fine, and the third, from being twisted harder, is much coarser.

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* A less expensive instrument is made by Pollock, of Boston; it is a thermometer filled with ether, having two bulbs at the same extremity of the tube, the upper one being covered with muslin. When sulphuric ether is dropped upon the muslin, the temperature of the two bulbs falls, and a deposition of dew becomes visible on the lower and exposed bulb. The degree indicated by the thermometer at that instant is the dew point.*

† This experiment may be varied by attaching small pieces of phosphorus to the cones. See on this subject ingenious experiments and apparatus by Bache, in *Am. Jour.* xxviii. 320.

‡ From the experiments of Mayer, of Erlangen, (*Ann. de Chim.* tom. xxx,) it would appear that the conducting powers of different woods are in some measure inversely as their specific gravities, water being assumed as = 1.

§ *Phil. Trans.* 1792.

* See description of a Portable Hygrometer, Hayes, in *Am. Jour. Sci.* xvii. 351.

The difference between these three modifications of the same substance is very striking, the raw silk detaining the heat for 1824″, the taffeta ravellings 1469″, and the silk thread only 947″.*

Practical application.

205. The different conducting powers of bodies in respect to heat, are shown in the application of wooden handles to metallic vessels; or a stratum of ivory or wood is interposed between the hot vessel and the metal handle. The transfer of heat is thus prevented. Heat is confined by bad conductors; hence clothing for cold climates consists of woollen materials; hence, too, the walls of furnaces are composed of clay and sand. Confined air is a very bad conductor of heat; hence the the advantage of double doors to furnaces, to prevent the escape of heat; and of a double wall, with an interposed stratum of air, to an ice-house, which prevents the influx of heat from without.

Sensations of heat and cold

206. From the different conducting powers of bodies in respect to heat, arise the sensations of heat and cold experienced upon ther application to our organs, though their thermometric temperature is similar. Good conductors occasion, when touched, a greater sensation of heat and cold than bad ones. Metal feels cold because it readily carries off the heat of the body; and we cannot touch a piece of metal immersed in air of a temperature moderate to our sense.

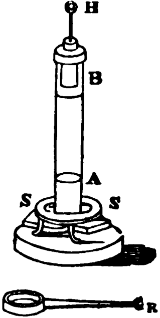
Liquids and gases imperfect conductors.

207. Liquids and gases are very imperfect conductors of heat, and heat is generally distributed through them by a change of specific gravity; by an actual change in the situation of their particles.

Exp.

Take a glass tube, ten or twenty inches long, and four or six in diameter. Pour into the bottom part, for about the depth of five inches, water tinged with litmus, or cabbage, and fill up the tube with common water, pouring on the latter extremely gently, so as to keep the two strata quite distinct. If the upper part of the tube be first heated, the coloured liquor will remain at bottom; but if the tube be afterwards heated at bottom, the infusion will ascend, and will tinge the whole mass of fluid.

Fig. 47.



Exp.

A convenient method of exhibiting this has been contrived by Hare. (Fig. 47.) A glass jar, about 30 inches in height, is supplied with as much colourless water as will rise in it within a few inches of the brim. By means of a tube descending to the bottom, a small quantity of blue colouring matter is introduced *below* the colourless water, so as to form a stratum, as represented at A in the annexed cut. A stratum differently coloured, is formed in the upper part of the vessel, as at B. A tin cap, supporting a hollow tin cylinder, closed at the bottom, and about an inch less in diameter than the jar, is next placed as it is seen in the figure, so that the cylinder may be concentric with the jar, and descend about 3 or 4 inches into the water. If an iron heater H while red hot, be placed within the tin cylinder, the coloured water about it will soon boil; but the heat penetrates only a very small distance below the tin cylinder, so that the colourless water, and the coloured stratum, at the bottom of the vessel, remain undisturbed, and do not mingle. But if an iron ring R be placed while red hot, upon the iron stand which surrounds the jar at S, S, the liquid soon rises, in beautiful clouds, until it encounters the warmer and lighter particles which had been in contact with the tin cylinder.†

Exp.

Fill a jar with hot water; and place a cake of ice on the surface of the water. The ice will soon be melted. This experiment is the more striking, if the water

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* Aiken's *Dict.* art. Caloric.

† From Hare's *Engravings and description of Chemical Apparatus*, &c. Part 1st, page 41.

used for forming the cake of ice, be previously coloured with litmus; for, the descending currents of cold water are thus made apparent.

Rumford's experiments. 41

Substituting water of the temperature of [illegible] for the boiling water used in this experiment, Rumford found, that, in a given time, a much greater quantity of ice was melted by the cooler water. This appears, on first view, rather paradoxical. The fact, however, is explained by the remarkable property of water, viz. that when cooled, below 40°, it ceases to contract, and experiences on the contrary, an enlargement of bulk. Water, therefore, at 40° (at the bottom of which is a mass of ice at 32°,) is cooled by contact with the ice, and is expanded at the same moment. It therefore ascends, and is replaced by a heavier and warmer portion from above.

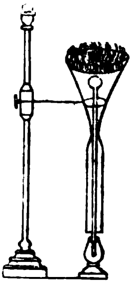
208. It is a consequence of the same property, that the surface of a deep lake is sometimes covered with ice, even when the water below is only cooled to 40°; for the superficial water is specifically lighter than the warmer water beneath it, and retains its place, till it is changed into ice. This property of water is one of the most remarkable exceptions to the law of expansion. (153.)

209. From the fact that heat applied to the upper surface of water, will with difficulty make its way downwards, (207), Rumford was induced to deny that water could conduct at all.

Exp.

Let an air thermometer be cemented into a glass funnel supported as represented in Fig. 48; cover the bulb of the instrument with water, and upon the surface of the water pour a small quantity of ether. The ether may be inflamed and the air thermometer will not be sensibly affected.

Fig. 48.



Fluids imperfect conductors.

210. The inference that water is a complete non-conductor of caloric has been contradicted by the subsequent inquiries of Hope, Thomson, and Murray. Though they all admit that water and liquids in general, mercury excepted, possess the power of conducting caloric in a very slight degree. The following experiment made by Murray has been deemed conclusive.

Exp.

If we carefully pour hot oil upon water in a tall glass jar, with delicate thermometers placed at different distances under the surface, it will be found that those near the heated surface indicate increase of temperature.

It might here be said that the heat was conducted by the sides of the jar, and so communicated to the water; to obviate such objection Murray made the experiment in a vessel of ice, which being converted into water at 32°, cannot convey any degree of heat above 32° downwards; yet the thermometers were affected, as in the former trial.*

Aëriform fluids.

211. It is extremely difficult to estimate the conducting power of aëriform fluids. Their particles move so freely on each other, that the moment a particle is dilated by heat, it is pressed upwards with great velocity by the descent of colder and heavier particles, so that an ascending and descending current is instantly established. Besides, these bodies allow a passage through them by radiation.

Radiation.

212. There is yet another mode by which heat passes from one body to another; and as it takes place in all gases, and even *in vacuo*, it is inferred that the presence of a medium is not necessary to its passage. This mode of distribution is called *Radiation* of Heat, and the heat so distributed is called *Radiant*, or *Radiated Heat.* A heated body suspended in the air cools, or is reduced to an equili-

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* See Matther's Experiments in *Amer. Jour. of Sci.* xii. 368.

brium with surrounding bodies, in three ways; first, by the conducting power of the air, the influence of which is very trifling; secondly, by the mobility of the air, in contact with it; and thirdly, by radiation.

Course of radiant caloric.

213. Radiant caloric passes from a hot body in all directions in right lines, like radii drawn from the centre to the circumference of a circle.

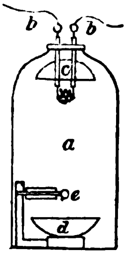
When these rays fall upon the surface of a solid or liquid substance, they may be disposed of in three different ways. By reflection, by absorption, and by transmission.

In the first and third cases the temperature of the body on which the rays fall is altogether unaffected, whereas in the second it is increased.

Radiation, in vacuo

214. Radiation in the air-pump vacuum, may be shown by igniting charcoal, by means of the Voltaic battery, placed in the focus of a small mirror confined in the exhausted receiver of the air-pump. Davy found that the receiver being exhausted to $\frac{1}{120}$, the effect upon the thermometer in the opposite focus was nearly three times as great as when the air was in its natural state of condensation, Fig. 49, *a* is the receiver, *b b* the insulated wires connected with the voltaic apparatus igniting the charcoal in the focus of the upper mirror *c*. In the focus of the lower mirror *d* is the thermometer *e*.

Fig. 49.



Influenced by surface.

215. The radiation of heat by hot bodies is singularly influenced by the nature and condition of their surfaces, a circumstance which was first examined by Leslie.*

Leslie's experiments.

He made use of a canister of planished block tin, forming a cube of six or eight inches, having an orifice at the middle of its upper side. This orifice received a cap having a small hole, through which a thermometer was inserted, so that its bulb reached the centre of the canister. One side of the canister he covered with black paint; destroyed the polish of another side, by scratching it with sand-paper; tarnished a third with quicksilver; and left the fourth bright. The vessel was filled with boiling water. The radiation of caloric from the blackened side was so much more abundant than from the others, as to be even sensible to the hand. He placed it before a reflector (Fig. 51) in lieu of the heated iron ball described (220.) The thermometer, in the focus of the second reflector, indicated the highest temperature, or most copious radiation of caloric, when the blackened side was presented to the reflector; less, when the tarnished or scratched side was turned towards it; and least of all from the polished side.†

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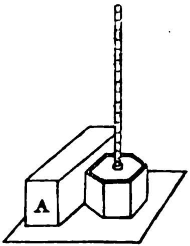
[*] *Essay on Heat*, 1804.

Bache's apparatus.

[†] The annexed figure represents an ingenious and much better apparatus for showing the different absorbing and radiating powers of different surfaces. A prism of any convenient number of sides, is made into an air thermometer, by placing a glass tube in it through a conical opening which can be made air tight; the sides are variously coated. This is made to fit loosely into a prism of the same form, but wanting one side. To show the different absorbing powers of the different substances, the vessels are placed as in the figure, before another, A, containing hot water, hot sand or any other convenient source of heat. If the side of the air thermometer which is the worst absorbent of heat is exposed to the source of heat, the air within is expanded, and the position of the liquid in the tube is marked by the index; a better absorbent is exposed, and the liquid rises higher; a worse and it falls below its original level. The outer sheath protects the sides which are not intended to be exposed, from the radiation of the vessel A and equalizes the radiation from the surfaces not exposed.

Fig. 50.



To show the radiating powers of the surfaces, the sheath is turned so that the open side is exposed to the air.—Bache in *Amer. Jour.* xxviii. 326.

Inferences.

216. It follows from these researches that velocity of radiation depends more on the *surface* than the *substance* of a radiating body: that the most imperfect radiators are to be sought among those bodies which are highly smooth and bright, such as polished gold, silver, tin, and brass; but that these same metals radiate freely when their smoothness and polish are destroyed, as by scratching their surfaces with a file, or covering them with whiting or lampblack. A metallic surface seems adverse to radiation independently of its smoothness, since a highly polished piece of glass radiates far better than an equally polished metallic surface. Scratching a surface probably favours radiation by multiplying the number of radiating points.

Stark's experiments.

217. Some interesting experiments by Stark of Edinburgh have appeared,* illustrative of the connexion between radiation and the colour of surfaces. The bulb of a delicate thermometer was successively surrounded by equal weights of differently coloured wool, was placed in a glass tube, heated by immersion in hot water to 180°, and then cooled to 50° in cold water. The times of cooling were 21 minutes with black wool, 26 with red wool, and 27 with white wool. Concurring results were obtained with flour of different colours. Likewise, black wool was found to collect more dew than an equal weight of white wool, other circumstances being alike. This is the first time that direct experiments, seemingly unexceptionable, have been made in proof of the influence of colour over radiation.

Reflection of caloric.

218. It has been known for ages that the heat contained in the solar rays admits of being *reflected* by mirrors, and a like property has long since been recognized in the rays emitted by red-hot bodies; but that heat emanates in invisible rays, which are subject to the same laws of reflection as those that are accompanied by light, is a modern discovery, noticed indeed by Lambert, but first decisively established by Saussure and Pictet of Geneva. (220)

This reflection of heat may be shown by standing at the side of a fire in such a position that the heat cannot reach the face directly, and then placing a plate of tinned iron opposite the grate, and at such an inclination as permits the observer to see in it the reflection of the fire: as soon as it is brought to this inclination, a distinct impression of heat will be perceived upon the face. If a line be drawn from a radiating substance to the point of a plane surface by which its rays are reflected, and a second line from that point to the spot where its heating power is exerted, the angles which these lines form with a line perpendicular to the reflecting plane are called the angles of *incidence* and *reflection*, and are invariably equal to each other. It follows from this law, that when a heated body is placed in the focus of a concave parabolic reflector, the diverging rays which strike upon it assume a parallel direction with respect to each other; and that when these parallel rays impinge upon a second concave reflector, standing opposite to the former, they are made to converge, so as to meet together in its focus. Their united influence is thus brought to bear upon a single point.

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* *Edin. Phil. Trans.* Part II. 1833.

Chap. I.

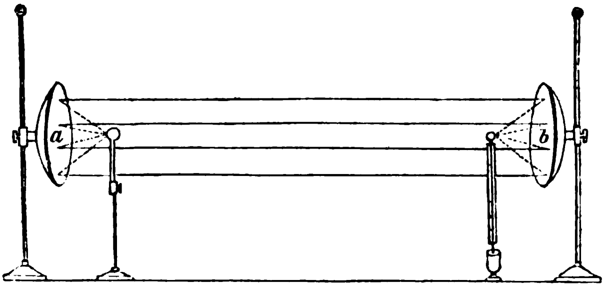
219. Those surfaces, that reflect light most perfectly are not equally adapted to the reflection of caloric. Thus, a glass mirror, which reflects light with great effect when held before a blazing fire, scarcely returns any heat, and the mirror itself becomes warm. On the contrary, a polished plate of tin, or a silver spoon, when similarly placed reflects, to the hand, a very sensible degree of warmth; and the metal itself remains cool. Metals, therefore, are much better reflectors of caloric than glass; and they possess this property, exactly according to their degree of polish.

Pictet's experiments.

220. Caloric is reflected according to the same law that regulates the reflection of light. This is proved by an interesting experiment of Pictet; the means of repeating which may be attained at a moderate expense.

Provide two reflectors of planished tin, (*a* and *b*, Fig. 51), which may be 12 inches diameter, and segments of a sphere of nine inches radius. Parabolic mirrors are still better adapted to the purpose, but their construction is less easy. Each of these must be furnished, on its convex side, with the means of supporting it in a perpendicular position on a proper stand. Place the mirrors opposite to each other on a table, at the distance of from 6 to 12 feet. Or they may be placed in a horizontal position, as represented in the fourth plate to Davy's *Chemical Philosophy*, an arrangement in some respects more convenient. In the focus of one, let the ball of an air thermometer, or (which is still better) one of the balls of a differential thermometer, be situated; and in that of the other, suspend a ball of iron, about four ounces in weight, and heated below ignition, or a small matrass of hot water; having previously interposed a screen before the thermometer. Immediately on withdrawing the screen, the depression of the column of liquid, in the air thermometer, evinces an increase of temperature in the instrument.

Fig. 51.



In this experiment, the caloric flows first from the heated ball to the nearest reflector; from this it is transmitted, in parallel rays, to the surface of the second reflector, by which it is collected into a focus on the instrument. This is precisely the course that is followed by radiant light; for if the flame of a taper be substituted for the iron ball, the image of the candle will appear precisely on that spot, (a sheet of paper being presented for its reception,) where the rays of caloric were before concentrated.

Apparent reflection of cold.

221. When a glass vessel, filled with ice or snow, is substituted for the heated ball, the course of the coloured liquid in the thermometer will be precisely in the opposite direction; for its ascent will show, that the air in the ball is cooled by this arrangement. This experiment, which appears, at first view, to indicate the reflec-

tion of cold, presents, in fact, only the reflection of heat in an opposite direction; the ball of the thermometer being, in this instance, the hotter body.

222. From what has been said concerning the communication and radiation of heat, and of the circumstances that influence the heating and cooling of bodies in these different ways, many useful practical observations may be drawn. Water continues much longer warm in a resplendent than in a blackened vessel. Hence metallic ones, with their surfaces polished, are employed for holding warm water, when we wish it to retain its heat for some time. It is a common remark, that tea is more easily infused in a silver than in an earthen tea-pot, which was at one time supposed to be owing to some property of the metal itself, but which is now accounted for by the laws of radiation, the bright metallic surface giving forth fewer rays than the other, and, of course, cooling the water less slowly. A metal is, however, a good conductor; it is of advantage therefore, to have not only a bad radiator, but also a bad conductor, that the heat given off from the surface by radiation, may be slowly supplied from the interior. Hence the frequent use of earthen ware covered with metallic matter, for holding warm fluids, as for jugs and tea-pots, the earthen ware being a bad conductor, and, by having its surface resplendent, becoming also a bad radiator, by which little heat is given off. **Practical uses.**

223. When, on the contrary, we wish to cool a fluid quickly, it must be put into a vessel which is a good conductor, as a metallic one, and with its surface blackened, to make it a good radiator. In conveying heated air, or steam, from one place to another, with the view of heating apartments, the tube ought to be made of bright metal, as tinned iron, that there may be little heat lost before the air reaches the place to be warmed. When, on the contrary, the steam is to be condensed, the tubes ought to be made of blackened metal, as sheet iron, so that a great deal of caloric may be given off, both by radiation and by communication.

224. When we have to guard a body from heat, we cannot employ a better protector than a plate of bright metal. Thus, in erecting a stove near woodwork, the latter ought to have a sheet of tinned iron placed near it, but not in contact with it, by which the greater part of the rays sent off from the stove are reflected. Should the metal itself become warm, the layer of air between it and the wood, being a very bad conductor, prevents in a great measure the transmission of the heat. Should stone be employed as the protector, it should be whitened, so that it may absorb as few of the rays as possible.

225. As the reflecting power is materially influenced by the nature of surfaces, the absorptive power must be so likewise. Those qualities of a surface which increase reflection are to the same extent adverse to absorption; and those which favour absorption are proportionally injurious to reflection.* Colour has considerable influence, as is shown by the following very simple experiment of Franklin. **Influence of colour.**

On a winter's day, when the ground is covered with snow, take four pieces of woollen cloth, of equal dimensions, but of different colours, viz. black, blue, **Exp.**

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* See Ritchie's experiments, *Jour. Roy. Inst.* v. 305.

brown, and white, and lay them on the surface of the snow, in the immediate neighbourhood of each other. In a few hours, the black cloth will have sunk considerably below the surface; the blue almost as much; the brown evidently less; and the white will remain precisely in its former situation.

Thus it appears that the sun's rays are absorbed by the dark coloured cloth, and excite such a durable heat, as to melt the snow underneath; but they have less power of penetrating the white. Hence the preference, generally given to dark coloured clothes during the winter season, and to light coloured ones in summer, appears to be founded on reason.

Researches of Stark, 226. The dependence of the absorptive power for simple heat on colour has not till lately been noticed. From researches by Stark, it seems that differently coloured wools wound upon the bulb of a thermometer, and exposed within a glass tube to hot water, rose from 50° to 170 in the following times,—black wool in 4′ 30″; dark green in 5′, scarlet in 5′ 30″, white in 8′.

Of Nobili and Melloni. 227. An interesting connexion has been traced by Nobili and Melloni between the absorbing and conducting power of surfaces,[*] and their researches, if free from fallacy, justify the inference that the radiating and absorbing powers of surfaces for simple heat are in the inverse order of their conducting powers. T. II.

Transmission of heat. 228. Radiant heat passes with perfect freedom through a vacuum. The air and gaseous substances present but a feeble barrier to its progress; so feeble, indeed, that the degree of impediment which they occasion has not yet been appreciated. Transparent media of a denser kind, on the contrary, such as the diamond, rock-crystal, glass, and water, even in thin strata, greatly interfere with its passage, and when in moderately thick masses intercept it altogether. This last remark, however is only applicable to simple heat, that is, to heat unassociated with light. The solar rays pass readily through the substance of glass, both heat and light being refracted in their passage, as is shown by the operation of a burning-glass or lens; and though much of the heat emitted by the flame of a lamp, or a red hot ball of iron, is arrested by glass, many calorific rays are directly transmitted along with the light. But the result is different when the heated body is not luminous. Leslie denied that any rays of simple heat can pass by direct transmission through glass, and Brewster has supported this opinion by an argument suggested by his optical researches.[†] Several ingenious experiments have been made on this subject by Ritchie; and it has lately been examined by Nobili and Melloni with the aid of their thermo-multiplier. All these experimenters concur in the belief of direct transmission. The total effect from this cause is, however, very small; and with screens of moderate thickness it is wholly imperceptible.

Heat polarized. 229. The recent experiments of Forbes[‡] have established the *polarization* of heat under all the circumstances in which light is polarized, namely, by reflection, transmission, and double refraction.[§]

Theories of radiation. 230. The tendency which all bodies evince to attain an equality of temperature by means of radiation, has given rise to two ingenious theories, suggested respectively by Pictet and Prevost.

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[*] *An. de Chim. et de Phys.* xlviii. 198.

[†] *Phil. Trans.* 1816, p. 106.

[‡] *Lond. and Edin. Phil. Mag.* vi. 134.

[§] *Edin. new Philos. Jour.*, No. 40.

According to the former, bodies of equal temperature do not radiate at all; and when the temperature is unequal, the hotter give calorific rays to the colder bodies till an equilibrium is established, at which moment the radiation ceases. Prevost, on the contrary, conceived radiation to go on at all times, and from all substances, whether their temperature were the same or different from that of surrounding objects.* Consistently with this view, the temperature of a body falls whenever it radiates more heat than it absorbs; its temperature is stationary when the quantities emitted and received are equal; and it grows warm when the absorption exceeds the radiation. A hot body surrounded by others colder than itself, affords an instance of the first case; the second happens when all the substances within the sphere of each other's radiation have the same temperature; and the third occurs when a body is introduced into a room which is warmer than itself. Of these theories the preference is very generally accorded to the latter. Most of the phenomena of radiation, indeed, admit of a satisfactory explanation by both; but, on the whole, the theory of Prevost is more generally applicable. T. 12.

Sources of heat.

231. The sources of heat may be reduced to six. 1. The sun. 2. Combustion. 3. Electricity. 4. The bodies of animals during life. 5. Chemical action. 6. Mechanical action. All these means of procuring a supply of heat, except the last, will be more conveniently considered in other parts of the work. The mechanical method of exciting heat is by friction and percussion.

Nature of heat.

232. Nothing is known of the nature or cause of heat. It has been by some considered as a peculiar fluid, to which the term *Caloric* has been applied; and many phenomena are in favour of the existence of such a fluid. By others, the phenomena above described have been referred to a *vibratory motion* of the particles of matter, varying in velocity with the perceived intensity of the heat. In fluids and gases the particles are conceived to have a motion round their own axes. *Temperature*, therefore, would increase with the velocity of the vibrations; and increase of *capacity* would be produced by the motion being performed in greater space. The loss of temperature, during the change of solids into liquids and gases, would depend upon loss of *vibratory* motion, in consequence of the acquired *rotatory* motion.

Upon the other hypothesis, *temperature*, is referred to the *quantity of caloric* present; and the loss of temperature, which happens when bodies change their state, depends upon the chemical combination of the caloric with the solid in the case of liquefaction, and with the liquid in the case of conversion into the aëriform state. B.

SECTION IV. *Of Light.*

233. The minute investigation of the laws of light belongs to Mechanical Philosophy; it is however requisite that some of them should partially be considered as bearing upon important questions of chemical inquiry.

Vision.

The phenomena of vision are produced either by bodies inherent-

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* *Recherches sur la Chaleur.*

ly luminous, such as the sun, the fixed stars, and incandescent substances; or they are referable to the *reflection* of light from the surfaces of bodies.

Light transmitted in right lines.

234. The manner in which the eye is affected by luminous bodies shows that light is transmitted in right lines, and every right line drawn from a luminous body to the eye is termed a *ray of light*, and as a congeries of rays possesses the same properties as the single ray, the same abstract term is frequently employed to designate the congeries.

Refraction.

235. Newton first discovered that certain bodies exercise on light a peculiar attractive force. When a ray passes obliquely from air into any transparent liquid or solid surface, it undergoes at entrance an angular flexure, which has been called *refraction*. The refraction is *towards* the perpendicular when the ray passes into a denser medium, and *from* the perpendicular when it passes into a rarer medium. The medium in which the rays of light are caused to approach nearest to the line perpendicular to its surface, is said to have the greatest refractive density.

Refractive power of inflammable bodies,

It was found by Newton, that unctuous, or inflammable bodies occasioned a greater deviation in the luminous rays than their attractive mass, or density gave reason to expect. Hence he conjectured, that both diamond and water contained combustible matter. Observation has since shown that oils and other highly inflammable bodies, such as hydrogen, diamond, phosphorus, sulphur, amber, olive oil and camphor, have a refractive power which is from two to seven times greater than that of incombustible substances of equal density.

May be used as a test of their purity,

236. The refractive power of the same inflammable substance bears a proportion to its perfection, insomuch that this property may be used as a test of its purity. Thus Wollaston found that genuine oil of cloves has a refractive power of 1,535, while that of an inferior quality did not exceed 1,498.

Depends on the chemical nature as well as density,

The density of bodies is not the only circumstance that affects their refractive power; it also depends on their chemical nature, and from the refractive power of bodies we may in many cases infer their chemical constitution.

Of compounds not the mean of that of their constituents.

237. The refractive power of compounds is not the mean deduced from that of their components; which, however, it generally is in mere mixtures.

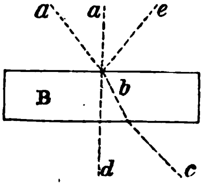
Reflected light.

238. When the rays of light arrive at the surfaces of bodies, a part of them, and sometimes nearly the whole, is thrown back, or *reflected*, and the more obliquely the light falls upon the surface, the greater in general is the reflected portion. In these cases the angle of reflection is always equal to the angle of incidence.

Let *a a* represent pencils of light falling upon the surface of a polished piece of glass B, the perpendicular pencil will pass on in a straight line to *d*.

Of the oblique pencil, one portion will enter the glass and suffer refraction towards the perpendicular as at *b*, and re-entering the atmosphere, it will bend from the perpendicular, and re-assume its former direction, as at *c*. Another portion of the oblique pencil will be reflected at an angle equal to that of its incidence, as at *e*.

Fig. 52.



239. When a ray of light passes through an oblique angular crystalline body, it exhibits peculiar phenomena; one portion is refracted in the ordinary way; another suffers extraordinary refraction, in a plane parallel to the diagonal joining the two obtuse angles of the crystal; so that objects seen through the crystal appear double. Transparent rhomboids of carbonate of lime, or Iceland crystal, exhibit this phenomenon of *double refraction* particularly distinct.

Double refraction.

If a ray of light, which has thus suffered double refraction, be received by another crystal, placed parallel to the first, there will be no new division of the rays; but if it be placed in a transverse direction, that part of the ray which before suffered ordinary refraction will now undergo extraordinary refraction, and reciprocally that which underwent extraordinary refraction now suffers ordinary refraction.

Ordinary and extraordinary refraction.

If the second crystal be turned gradually round in the same plane, when it has made a quarter of a revolution, there will be four divisions of the ray, and they will be reduced to two in the half of the revolution; so that the refracting power appears to depend upon some relation of the position of the crystalline particles.

Refracting power seems dependent upon some position of crystalline particles.

240. When light is reflected from bodies, it retains, under many circumstances, its former relations to the refractive power of transparent media; but, in certain cases, at angles differing for different substances, the reflected rays exhibit peculiar properties, analogous to those which have suffered extraordinary refraction. Thus, if the flame of a taper reflected at an angle of 52° 45′ from the surface of water, be viewed through a piece of double refracting spar, one of the images will vanish every time that the crystal makes a quarter of a revolution.

241. When a ray of light is made to fall upon a polished glass surface, at an angle of incidence of 35° 25′, the angle of reflection will be equal to that of incidence. Let us suppose another plate of glass so placed that the reflected ray will fall upon it at the same angle of 35° 25′; this second plate may be turned round its axis without varying the angle which it makes with the ray that falls upon it. A curious circumstance is observed as this second glass is turned round. Suppose the two planes of reflection to be parallel to each other, in that case the ray of light is reflected from the second glass in the same manner as from the first. Let the second glass be now turned round a quadrant of a circle, so as to make the reflecting planes perpendicular to each other: now, the whole of the ray will pass through the second glass, and none of it will be reflected. Turn the second glass round another quadrant of a circle, so as to make the reflecting planes again parallel, and the ray will again be reflected. When the second glass is turned round, three quadrants, the light will be again transmitted, and none of it reflected. Thus, when the reflecting planes are parallel, the light is reflected, but when they are perpendicular the light is transmitted. This experiment proves, that, under certain circumstances, light can penetrate through glass when in one position, but not in another. This curious fact was first observed by Malus, who accounted for it by supposing the particles of light to have assumed a particular position as a needle does when under the influence of a magnet, and

Angle of incidence equal to the angle of reflection.

Curious instance of the transmission and reflection of light.

Polarization.

hence he called this property of light, its *Polarization*.* It has since been studied with laborious diligence by Brewster, and by Arago and Biot.†

Analysis of light.

Prismatic colours.

242. That a sunbeam, in passing through a dense medium, and especially through a triangular prism of glass, gives rise to a series of brilliant tints similar to those of the rainbow, was known in the earliest ages, but it required the sagacity of Newton to develop the cause of the phenomenon. He inferred, that light consists of rays differing from each other in their relative refrangibilities; and, guided by their colour considered their number as seven: red, orange, yellow, green, blue, indigo, and violet.‡ If the prismatic colours, or *spectrum*, be divided into 360 equal parts, the red rays will occupy 45 of these parts, the orange 27, the yellow 48, the green 60, the blue 60, the indigo 40, and the violet 80. Of these rays the red being least refrangible, fall nearest that spot which they would have passed to, had they not been refracted; while the violet rays being most refrangible, are thrown to the greatest distance; the intermediate rays, possess mean degrees of refrangibility.

Newton's theory of colours.

243. These differently coloured rays, when collected into a focus reproduce white light. Upon these phenomena is founded the Newtonian *theory* of *colours*, which supposes them to depend upon the absorption of all rays, excepting those of the colour observed.

Seebeck's experiments.

Melloni's.

244. If a solar beam be refracted by a prism, and the coloured image received upon a sheet of paper it will be found, on moving the hand gently through it, that there is an evident difference in the heating power of the rays. Englefield, Davy and others, affirmed with Herschel, that the heat is greatest beyond the red ray; while others contend that it is in the red ray itself. The observations of Seebeck§ have explained these contradictory statements, by showing that the point of greatest heat varies with the kind of prism employed. These results have been confirmed by Melloni, who has succeeded with a prism of rock salt in separating the spot of maximum heat from the coloured part of the spectrum by a much greater interval than had been done previously. The facts that have been arrived at, go far to prove that most, if not all, of the heating power ascribed to light, is due, not to the absorption of luminous rays, but to that of the heat by which they are accompanied.

Influence over the chemical energies of bodies.

245. Light possesses considerable influence over the chemical energies of bodies. If a mixture of equal volumes of the gases called chlorine and hydrogen be exposed in a dark room, they slowly combine, and produce hydrochloric acid gas; but, if exposed to the direct rays of the sun, the combination is very rapid, and often accompanied by an explosion.

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* See Fischer's *Elements of Natural Philosophy*, page 336. Thomson's *System* 1. p. 16.

† *Phil. Trans.* 1813, 1814, 1815, 1816, 1817.—*Ann. de Chim.* tom. 94. *Traité de Phys.*

‡ Wollaston found, however, that when a beam of light only $\frac{1}{20}$th of an inch broad is received by the eye, at the distance of ten feet, through a clear prism of flint glass, only four colours are seen, viz. red, yellowish green, blue, and violet. Brewster has proved that the colours of the spectrum are occasioned by three simple primary rays viz. the red, yellow and blue.

§ *Edin. Jour. of Sci.* 1, 358.

Chlorine and carbonic oxide have scarcely any tendency to combine, even at high temperatures, when light is excluded, but exposed to the solar rays they enter into chemical union. Chlorine has little action upon water, unless exposed to light, and, in that case, the water, which consists of oxygen and hydrogen, is decomposed. The hydrogen unites with the chlorine to produce hydrochloric acid, and the oxygen is evolved in a gaseous form.

Produces chemical changes.

246. These, and numerous other similar cases, show that solar light influences the chemical energies of bodies, independent of its heating powers. Many important facts have been ascertained by Ritter, Wollaston, and Davy. Scheele* threw the prismatic spectrum upon a sheet of paper, moistened with a solution of nitrate of silver, a salt quickly decomposed by the agency of light. In the blue and violet rays the silver was soon reduced, producing a blackness upon the paper, but in the red ray scarcely any similar effect was observed. Wollaston and Ritter discovered that these chemical changes were most rapidly effected in the space which bounds the violet ray, and which is out of the visible spectrum.

Davy has observed, that certain metallic oxides, when exposed to the violet extremity of the prismatic spectrum, undergo a change similar to that which would have been produced by exposure to a current of hydrogen; and that when exposed to the red rays, they acquire a tendency to absorb oxygen.†

Magnetizing rays.

247. The more refrangible rays of light have been thought to possess the property of rendering steel or iron magnetic. This property was announced by Morrichini of Rome; but as the experiment did not succeed in other hands, the subject was involved in some degree of uncertainty. The fact, however, appeared to be established by Mrs Somerville of London, in 1826, who gave an account of her researches to the Royal Society. Since that period the subject has been re-examined by Riess and Moser. They object to Mrs Somerville's results, that her method of ascertaining the magnetic state of the needles used in the experiments, was not sufficiently precise: they deny the supposed magnetizing power of light.‡

Photometer.

248. The comparative intensities of light are measured by the instrument called a Photometer: that which is known as Leslie's is constructed on the principle that light, in proportion to its absorption, produces heat. It is merely a very delicate and small differential thermometer, enclosed in a thin and pellucid glass tube. One of the bulbs is of black glass, which, when the instrument is suddenly exposed to light, becoming warmer than the clear bulb, indicates the effect by the depression of the fluid.§ From the experiments of Turner and Christison this instrument does not appear applicable to lights which differ in colour, because the relation between the heating and illuminating power of such light is exceedingly variable. Thus, the light emitted by burning cinders or red-hot iron, even after passing through glass, contains a quantity of calorific rays, which is out of all proportion to the luminous ones; and, consequently, they may and do produce a greater effect on the photometer, than some

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* *Experiments on Air and Fire*, p. 78, &c.

† *Elements of Chem. Phil.*

‡ *Edin. Jour. of Sci.* 2, 225.

§ Leslie on *Heat*, p. 424.

Chap. I.

lights whose illuminating powers are far stronger. Leslie conceived that light when absorbed is converted into heat; but according to the experiments already referred to, the effect must be attributed, not so much to the light itself, as to the absorption of the calorific rays by which it is accompanied. A differential thermometer, containing the vapour of ether, may also, in certain experiments be advantageously used as a *Photometric Thermometer*.*

Perfect vegetation requires the influence of solar rays.

249. In nature the influence of the solar rays is very complex, and the growth, colour, flavour, and even the forms of many vegetables, are much dependent upon them. This is seen in many plants which are protected from the sun's rays: celery and endive are thus cultivated with the view of rendering them palatable;† and plants which are made to grow in a room imperfectly illuminated, always bend towards the apertures by which the sun's rays enter. The changes too which vegetables effect upon the circumambient atmosphere are influenced by the same cause.

250. In the animal creation, brilliancy of colour and gaudy plumage belong to the tropical climates; more sombrous tints distinguish the polar inhabitants; and dull colours characterize nocturnal animals, and those who chiefly abide below the surface.

Drummond's light.

251. When bodies are rendered luminous by elevation of temperature, the light which they emit often appears dependent upon the heat to which they are subjected, and the common terms *red-hot* and *white-hot* are used to designate those appearances. There are, however, certain bodies, which, at high temperatures, are remarkable for the quantity and extreme brilliancy of their light, independent of actual combustion; this is the case with several of the earths, but more especially with lime, a small ball of which, ¼ inch in diameter, being ignited in the flame of alcohol urged by oxygen gas, emits light, having about thirtyseven times the intensity of an Argand's lamp burner.‡

Phosphorescent bodies.

252. There are many substances which, when heated to a certain point, become luminous without undergoing combustion, and such bodies are said to be *phosphorescent*. The temperatures which they require for this purpose are various; it generally commences at about 400°, and may be said to terminate at the lowest visible redness. Some varieties of phosphate of lime, of fluor spar, of bituminous carbonate of lime, of marble, and sand, and certain salts, are the most remarkable bodies of this description.§ Their luminous property may be best exhibited by scattering them in coarse powder upon an iron plate heated nearly to redness. Oil, wax, spermaceti, and butter, when nearly boiling, are also luminous.

Solar phosphori.

253. Another class of phosphorescent bodies has been termed

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* Brande, *Phil. Trans.* 1820. A photometer has been described by Ritchie, in the *Quart. Jour.* vol. 19, p. 299. For a description of Rumford's Photometer, see *Phil. Trans.* vol. 84. It determines the comparative strength of lights by a comparison of their shadows.

† The process is termed *etiolation*, or blanching.

‡ Drummond, in *Phil. Trans.* 1826. See figure and description of his apparatus in Brewster's *Edin. Jour. of Sci.* v.

§ Wedgewood, *Phil. Trans.* vol. 82.

solar phosphori, from becoming luminous when removed into a dark room after having been exposed to the sunshine.[*] Of this description are Canton's, Baldwin's, and the Bolognian phosphorus.[†]

Spontaneous phosphorescence.

254. A third set of bodies, belonging to this class, are those which are *spontaneously phosphorescent*. Such are, especially, the flesh of salt-water fish just before it putrefies, and decayed wood. The *glow-worm* and the *lantern-fly* are also luminous when alive; and the *hundred legged worm*, and some others, shine brilliantly when irritated.[‡] (See *Bost. Jour.* 2, 101.)

Light from percussion or friction.

255. Percussion and friction are often attended by the evolution of light, as when flint pebbles, pieces of sugar, and other substances, are struck or rubbed together. The crystallization of some substances, as benzoic acid, and acetate of potassa has been found to be attended with similar phenomena.[§]

Air incapable of becoming luminous.

256. From experiments in which air has been intensely heated, it has been concluded that gaseous matter is incapable of becoming luminous; for, though the temperature of air be such as to render solid bodies white-hot, it does not itself become visible.[‖] Flame, however, may, in general, be regarded as luminous gaseous matter. Hydrogen gas, probably, furnishes the purest form of flame which can be exhibited; for the flames of bodies which emit much light, derive that power from solid matter which is intensely ignited and diffused through them, and which, in ordinary flames, as of gas, tallow, wax, oil, &c. consists of finely divided charcoal.

Light and temperature of flame.

257. The intensity of the heat of flames which are but little luminous, as of hydrogen gas, spirit of wine, &c. may be shown by introducing into them some fine platinum wire, which is instantly rendered white-hot in those parts where the combustion is most perfect. It is even intensely ignited in the current of air above the

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[*] For practical directions for observing the phosphorescence of bodies, see Faraday's *Chemical Manipulation*.

Canton's compound.

[†] Canton's phosphorus is prepared thus:—Calcine oyster-shells in the open fire for half an hour, then select the whitest and largest pieces and mix them with one third their weight of flowers of sulphur, pack the mixture closely into a covered crucible, and heat it to redness for an hour. When the whole has cooled, select the whitest pieces for use.[*]

Baldwin's and the Bolognian phosphorus.

Baldwin's phosphorus is prepared by heating nitrate of lime to a dull red heat, so as to form it into a compact mass; and the Bolognian phosphorus, discovered by Vincenzio Cascariolo, a shoemaker of Bologna, is made by reducing compact sulphate of baryta to a fine powder, which is formed into cakes with mucilage, and these are heated to redness.[†]

Wilson's experiments.

Wilson has also made a variety of curious experiments on solar phosphori; and he has discovered the simplest and most effectual of these bodies, which may be obtained by closely observing the following directions:—Take the most flaming coals off a brisk fire, and throw in some thick oyster shells; then replace the coals, and calcine them for an hour; remove them carefully, and, when cold, it will be found that after exposing them for a few minutes to the light, they will glow in the dark, with most of the prismatic colours.[‡]

[‡] It appears from the experiments of Canton and of Hulme,[§] that sea-fish become luminous in about twelve hours after death, that it increases till putrefaction is evident, and then it decreases. Immersion in sea-water does not affect this luminous matter; on the contrary, the brine is itself rendered luminous; but it is extinguished by pure water, and by a variety of substances which act chemically upon the animal matter.

[§] Brewster's *Journal*, 3, 368. [‖] Wedgewood, *Phil. Trans.* 1792.

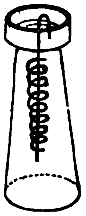
[*] *Phil. Trans.* Vol. 58. [†] Aikin's *Dict.* art. *Phosphori.* [‡] Wilson on *Phosphori*, p. 20.

[§] *Phil. Trans.* Vols. lix. xc. and xci.

flame, as may be shown by holding a piece of platinum wire over the chimney of an Argand lamp fed with spirit of wine; the high temperature of this current is also exhibited by the common expedient of lighting paper by holding it in the heated air which rushes out of a common lamp-glass.

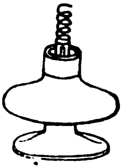
The high temperature of flame is further proved by certain cases of combustion without flame. Thus, if a heated wire of platinum be introduced into any inflammable or explosive mixture, it will become *ignited*, and continue so till the gas is consumed; but *inflammation* will, in most cases, only take place when the wire becomes white-hot.

Fig. 53.



Exp. This experiment is easily made by pouring a small quantity of ether into the bottom of a deep wine-glass, or, what is better, a glass vessel, like that represented in Fig. 53, and suspending in it a coil of heated platinum wire so as to be a little above the surface of the ether; the wire becomes red hot, but does not inflame the vapour of the ether till it acquires an intense white heat.

Fig. 54.



Exp. The same fact is exhibited by putting a small coil of fine platinum wire round the wick of a spirit lamp, (Fig. 54,) which, when heated, becomes red hot, and continues so, as long as the vapour of the spirit is supplied, the heat never becoming sufficiently intense to produce its inflammation.

258. Such being the nature of flame, it is obvious, that if we *cool* it by any means, we must at the same time *extinguish* it. This may be effected by causing it to pass through fine wire gauze, which is an excellent conductor and radiator of heat, and consequently possessed of great cooling power.

Exp. If a piece of fine brass or iron wire-gauze be brought down upon the flame of a candle, or what answers better, upon an inflamed jet of oil gas, it will, as it were, cut the flame in half. That the cool gaseous matter passes through, may be shown by again lighting it upon the upper surface.

Effect of wire gauze on flame.

The power, therefore, of a metallic tissue thus to extinguish flame, will depend upon the heat required to produce the combustion, as compared with that acquired by the tissue; and the flame of the most inflammable substances, and of those that produce most heat in combustion, will pass through a metallic tissue that will interrupt the flame of less inflammable substances, or those that produce little heat in combustion; so that different flames will pass through at different degrees of temperature.

Davy's safety lamp.

259. The discovery of these facts, respecting the nature and properties of flame, led Davy to apply them to the construction of the *Miners' safety lamp*, which will be explained under the article *Light Carburetted hydrogen gas.*

Theory of phosphorescence and incandescence.

260. The phenomena exhibited by phosphorescent and incandescent bodies, and in the process of combustion, have sometimes been explained upon the idea that the light and heat evolved were previously in combination with the substances, and that they are afterwards merely emitted, in consequence of decomposition; and that the solar phosphori absorb light and again give it out unchanged; but the fact, that the colour of the light emitted is more dependent on the nature of the phosphorescent body than on the colour of the light to which it was exposed, seems inconsistent with this explana-

tion. Chemical action is not connected with the phenomena; for the phosphori shine *in vacuo*, and in gases which do not act on them, and some even under water.*

SECTION V. *Electricity.*

Electrical excitement.

261. The term *electricity* is derived from the Greek word ηλεκτρον [illegible] *amber*, on account of the property which this substance was known to possess of attracting light substances when rubbed. If a piece of sealing-wax and of dry warm flannel be rubbed against each other, they both become capable of attracting and repelling light bodies. A dry and warm sheet of paper, rubbed with India rubber, or woollen, or a tube of glass rubbed upon silk, exhibit the same phenomena. In these cases the bodies are said to be *electrically excited;* and when in a dark room, they appear luminous.

Repulsion and attraction.

262. If two pith-balls be electrified by touching them with the sealing-wax or with the flannel, they *repel* each other; but if one pith-ball be electrified by the wax, and the other by the flannel, they *attract* each other. The same applies to the glass and silk.

If one ball be electrified by sealing-wax rubbed by flannel, and another by silk rubbed with glass, those balls will repel each other. But if one ball be electrified by the sealing-wax and the other by the glass, they then attract each other.†

Dufay's theory.

263. The terms *vitreous* and *resinous* electricity were applied to these two phenomena. According to Dufay the vitreous and resinous electricities are distinct; an unexcited body contains both in a state of combination or neutralization, and cannot, therefore, exhibit any electrical attractions or repulsions. But friction disturbs this combination, or electric equilibrium, causing the vitreous electricity to accumulate in one body and the resinous in the other. They are both consequently in an excited state, and continue to be so till each recovers that kind of electricity which it had lost.

Franklin's theory.

A different explanation was proposed by Franklin, which is founded on the supposition that there is only one kind of electricity. When bodies contain their natural quantity of electricity, they do not manifest any electrical phenomena; but they are excited either by an increase or diminution in that quantity. Thus on rubbing a piece of glass with a woollen cloth, the electrical condition of both substances is disturbed; the former acquires more, the other less than its natural quantity. These different states were expressed by the terms *plus* and *minus*, or *positive* and *negative*, the first corresponding to the vitreous, the second to the resinous electricity of Dufay.‡

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* See Davy's *Elements* 1, 213, &c.—Murray's *System* 1, 570—Ure's *Dict.* article *Caloric*—Hare in *Amer. Jour.* iv. 12, &c.—Turner's *Elements*, 69.

† These experiments are conveniently performed with a large downy feather suspended by a dry thread of white silk.

‡ As writers on chemistry continue to use the terms *positive* and *negative*, they are here retained.

Fig. 55.

Electrometer.

264. Very delicate pith-balls, or strips of gold leaf, are usually employed in ascertaining the presence of electricity; and, by the way in which their divergence is affected by glass or sealing-wax, the kind or state of electricity is judged of. When properly suspended or mounted for delicate experiments, they form an *electrometer* or *electroscope*. (Fig. 55.) For this purpose the slips of gold leaf are suspended by a brass cap and wire in a glass cylinder; they hang in contact when un-electrified; but when electrified they diverge.*

Method of determining the kind of electricity.

265. The kind of electricity by which the gold leaves are diverged may be judged of by approaching the cap of the instrument with a stick of excited sealing-wax; if it be *negative* the divergence will increase; if *positive*, the leaves will collapse, upon the principle of the mutual annihilation of the opposite electricities, or that bodies similarly electrified repel each other, but that when dissimilarly electrified they become mutually attractive.

Conductors and non-conductors.

266. Some bodies suffer electricity to pass readily along their surfaces, and are called *conductors*. Others only receive it upon the spot touched, and are called imperfect or *non-conductors*. They are also called *insulators*.† The metals are all conductors;‡ dry air, glass, sulphur, and resins, are non conductors. Water, damp wood, spirit of wine, damp air, and some oils are imperfect conductors.

Electricity passes through rarefied air or a vacuum.

Rarefied air admits of the passage of electricity; so does the Torricellian vacuum.

No constant relation between the state of bodies and their conducting powers.

267. There appears to be no constant relation between the state of bodies and their conducting powers; among solids, metals are conductors, but gums and resins are non-conductors; among liquids, strong alkaline, acid, and saline solutions, are good conductors; pure water is an imperfect conductor, and oils are non-conductors; wax and many other solids are imperfect conductors, but when fused are good ones. Conducting powers belong to bodies in the most opposite states; thus the flame of alcohol, and ice, are equally good conductors.§ Glass is a non-conductor when cold, but conducts when red-hot; the diamond is a non-conductor, but pure and well burned charcoal is among the best conductors.

Some substances become electric by heat.

268. There are many mineral substances which show signs of electricity when heated, as the tourmalin, topaz, diamond, boracite, &c.; and in these bodies the different surfaces exhibit different electrical states.‖

Phenomena observed in using electrical machines.

269. When an electrical machine is in good order, and the atmosphere dry, it produces a crackling noise when the plate or cylinder is turned, and flashes or sparks of light are seen upon various

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* For other forms see Turner's *Chem.* 81.

† The *insulation* of substances is frequently required in electro-chemical experiments; a plate of mica is the best substance for the purpose, then a plate of resin or wax, or in their absence, a plate of warm glass. *Faraday*.

‡ Of the metals, Harris found silver and copper to be the best conductors, and after these gold, zinc, platinum, iron, tin, lead, antimony, and bismuth.—*Phil. Trans.* 1827. Part 1, 21.

§ Biot, *Traité de Physique*, tom. ii. p. 213.

‖ For a description of Electrical machines and a more full account of Electricity, see *Cambridge Nat. Phil.* vol. 2, Fischer's *Elements of Nat. Phil.* p. 164. Brande's *Chem.* 69.

parts of the glass passing from the cushion to the conductor; if the knuckle be held near the conductor, sparks pass to it through some inches of air, with a peculiar noise, and excite slightly painful sensation in the part upon which they are received. It is conjectured that the cause of the light thus perceived, is the sudden compression of the air or medium through which the electricity passes, and it is always probably attended by a proportionate elevation of temperature, as is shown by the power of the spark to inflame spirit of wine, fulminating silver, and other easily inflammable compounds.

Light and heat.

Electricity by induction.

270. Another cause of excitement is proximity to an electrified body, which has a tendency to *induce* an electrical state opposite to its own. Thus an excited stick of sealing-wax attracts light bodies in its vicinity, and occasions them to be positively electrified. If an insulated conductor be electrified, and an uninsulated conductor be opposed to it, there being between the two a thin stratum of air, glass, or other non-conductor, the uninsulated conductor, under such circumstances, acquires an opposite electrical state to that of the originally electrified insulated conductor. In this case, the uninsulated body is electrified by *induction*, and the induced electricity remains evident, until an explosion, spark, or discharge happens, when the opposite electricities annihilate each other. Induced electricity may thus be exhibited through a long series of insulated conductors, provided the last of the series be in communication with the earth.

Fig. 56.

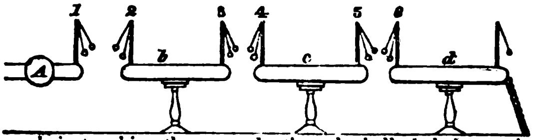

Illustration.

Thus, in Fig. 56, A, may represent the positive conductor of the electrical machine; *b*, *c*, and *d*, three insulated conductors, placed at a little distance from each other, *d*, having a chain touching the ground; then the balls 1, being positive, will attract the balls 2, which are rendered negative by induction. Under these circumstances, each of the conductors becomes polar, and the balls 3 are positive, while 4 are negative, 5 positive, 6 negative, &c.; the central points of the conductors, *b c d*, are neutral. When these opposite electrical states have arrived at a certain intensity*, sparks pass between the different conductors, and the electrical phenomena cease. B. 73.

Faraday's views.

271. The recent investigations of Faraday,† have led him to the inference that induction is essentially an action of contiguous particles, through the intermediation of which the electric force, originating or appearing at a certain place, is propagated to or sustained at a distance, appearing there as a force of the same kind exactly equal in amount, but opposite in its directions and tendencies. Induction is considered as the essential function, both in the first development and the consequent phenomena of electricity. He conceives that induction consists in a certain polarized state of the particles, into which they are thrown by the electrified body sustaining the action, the particles assuming positive and negative points or

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* Electricians generally employ the term *quantity* to indicate the absolute quantity of electric power in any body, and the term *intensity* to signify its power of passing through a certain stratum of air or other ill-conducting medium.

† *Philos. Trans.* 1838. p. 1.

parts, which are symmetrically arranged with respect to each other and the inducting surface or particles.*

Specific inductive capacity. Faraday's differential inductometer.

272. For examining the specific inductive capacity of bodies, Faraday has contrived an apparatus, which he calls a *Differential Inductometer*. It consists of three insulated metallic plates, placed facing each other; the centre one being fixed, and the other two moveable upon slides, by which they may be approximated to or withdrawn from the centre. When a charge is communicated to the centre plate under ordinary circumstances, the induction is equal on both sides and the gold leaves are not disturbed. But if after uninsulating them, and again insulating them, a thick plate of shellac or sulphur, be interposed between two of the plates, unequal induction will take place on the two sides, and the gold leaves will attract each other. By these means, Faraday has ascertained that, taking the specific inductive capacity of air to be 1.

That of Glass is - - -	1.76
Shellac - - -	2.
Sulphur - - -	2.24

The results obtained with spermaceti, oil of turpentine, and naptha, were higher than that of air, but their conducting powers interfered with the accuracy of the experiments.

By another form of apparatus, he ascertained that all aëriform matter has the same power of sustaining induction; and that no variations in the density or elasticity of gases produced any variation in their electric tension, until rarefaction is pushed so far as that discharge may take place across them.

No difference was found with hot, cold, dry or damp air. These experiments have established the important discovery of the principle of specific inductive capacity.†

273. It is essential that the student should reflect carefully on the plain consequences of the theory of electricity, since the applications of this knowledge are numerous. A few of these may now be enumerated:—

Consequences of the theory.

1. An electrified body attracts light objects near it, because it induces in them a state opposite to itself. The attraction is most lively when the light object is a conductor, and in contact with the ground, since it then more completely assumes an electric state opposed to that of the inducing body. A non-conductor is very imperfectly electrified by induction, because the electric fluids cannot quit each other from inability to move through the non-conductor.

2. If a stick of sealing-wax, strongly negative, be presented to a thread or pith-ball which is also negatively, but feebly, excited, repulsion will ensue at a considerable distance, followed by attraction when the distance is small. This attraction is due to the strongly excited wax acting by induction on the feeble negative thread, thereby causing it to have an excess of positive electricity.

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* According to Faraday, bodies cannot be charged absolutely, but only relatively, and by a principle which is the same with that of induction: all charge is sustained by induction; all phenomena of intensity include the principle of induction; all excitation is dependent on or directly related to induction; and all currents involve previous intensity and therefore previous induction.

† See *Lond. and Edin. Philos. Mag.* Jan. and Feb. 1839.

3. The positive electricity collected on the prime conductor of an electrical machine is by some ascribed, not to a transfer of that fluid from the glass to the prime conductor, but to a part of the combined electricities of the prime conductor being separated by induction, and the negative fluid being imparted to the positive glass. The same view is applicable to any system of conductors in contact with the prime conductor, as also to conductors connected with the rubber. It is difficult to say which explanation is the more correct, or whether both may not be true.

4. On moving the hand towards the prime conductor of an excited electrical machine, the hand becomes negative by induction, and the spark ultimately obtained restores the equilibrium. In like manner a negatively electrified cloud renders positive a contiguous tree or tower, and then a stroke of lightning follows as a consequence of attraction between the two accumulated fluids.

Action of the Leyden jar.

5. The action of the *Leyden Jar* depends on the principle of induced electricity. A glass jar or bottle with a wide mouth is coated externally and internally with tinfoil, except to within three or four inches of its summit; and its aperture is closed by dry wood or some imperfect conductor, through the centre of which passes a metallic rod communicating with the tinfoil on the inside of the jar. On placing the metallic rod in contact with the prime conductor of an excited electrical machine, while the outer coating communicates with the ground, the interior of the jar acquires a charge of positive electricity, and the exterior becomes as strongly negative. If, the jar being insulated, the metallic rod be placed close to the prime conductor, avoiding actual contact, while an uninsulated conductor be held at an equal distance from the outer coating, electric sparks in equal number and of equal size will pass between both intervals, and both sides of the jar are found to be in the same condition as before; but no charge will be received when the inner coating communicates with the prime conductor, and the outer coating is strictly insulated. From these facts it is inferred that the interior of the jar becomes positive, either by receiving positive electricity directly from the prime conductor, or, as is more probable, by communicating to it negative electricity; and that the exterior then becomes negative by the loss of a quantity of positive electricity equal to that on the interior. Unless means be afforded for the escape of the positive electricity from the exterior, no charge ought to be received; and this conclusion is quite conformable to the fact above stated.

Leyden jar.

274. The opposite electric fluids accumulated on the opposite sides of a charged Leyden jar exert a strong mutual attraction through the substance of the glass, and the presence of each secures the continuance of the other. The exterior of the jar may be freely handled, and its coating removed, without destroying the charge, provided no communication be made at the same time with the interior; and if the exterior be insulated, the charge will be preserved, though the tinfoil of the interior be removed. But when a conductor communicates with both surfaces at the same instant, the two fluids rush together with violence, and the equilibrium is restored. Whether in this and similar cases the two fluids coalesce entirely on the intermediate conductor, or whether each from its velocity may not in part

pass the other, and be projected to the opposite surface, is a question on which electricians are not agreed.

Battery.

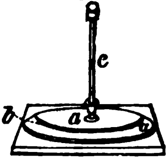
275. The Leyden jar affords the means of passing through bodies a large quantity of electricity. For not only may jars of any required size be employed, but it is easy so to arrange any number of such jars, that they shall all be charged and discharged at the same time, constituting what is termed an *Electrical Battery*. The arrangement is made, by placing a number of Leyden jars in a box lined with tinfoil, by which means their outer surfaces have free metallic communication with each other, and connecting their inner surfaces by wires. T. 78.

276. The operation of the instrument called the *Electrophorus* (or bearer of electricity) is referable to the phenomena of induction.

Electrophorus.

The *electrophorus* (Fig. 57), consists of two metallic plates, *a a*, with an intervening plate of resinous matter, *b*, for which equal parts of shellac, resin, and Venice turpentine, are generally used, the mixture being carefully melted in a pipkin, and poured, whilst liquid, into a wooden or metal hoop, of a proper size, placed upon a polished surface of glass or marble, from which it easily separates when cold; it should be about half an inch thick, and the smooth surface being uppermost the lower side should be covered with tinfoil, or attached to any other metallic plate; a polished brass plate, with a glass handle *c* attached to it, is then placed upon the upper surface of the resinous plate, and of rather smaller diameter.

Fig. 57.



The resin is excited with a piece of dry fur, and the instrument will be found to exhibit the following phenomena:—Upon raising the brass plate by its insulating handle, it will be found very feebly electrical; replace it, touch it with the finger and again lift it off by its handle, and it will give a spark of positive electricity. This process may very often be repeated without fresh excitation.* The electrophorus may often be used for the same purpose as the electrical machine, and in the laboratory it furnishes a very convenient substitute for that more expensive piece of apparatus.†

Mode of using it.

The electrophorus used as an electric machine.

Electricity from change of temperature.

277. Electricity is excited also by change of temperature. The electric equilibrium is disturbed in metallic rods or wires when one extremity has a different temperature from that of the other, whether the difference be effected by the application of heat or cold. The experiment is usually made by heating or cooling the point of junction of two metallic wires, which are soldered together; but Becquerel has proved that the contact of different metals is not essential.‡

Other sources of electricity.

278. There are many other sources of electricity. When glass is rubbed by mercury, it becomes electrified, and this is the cause of the luminous appearance observed when a barometer is agitated in a dark room, in which case flashes of light are seen to traverse the empty part of the tube. Even the friction of air upon glass is attended by electrical excitation. Whenever bodies change their forms, their electrical states are also altered. Thus during the congelation of melted resins and sulphur, electricity is rendered sensible. It is also developed during various natural processes; as evaporation

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* Ample directions for constructing this useful instrument, and for applying electricity in the laboratory, will be found in Faraday's *Chem. Manipulation*, p. 436.

† For a more full account, see Turner's *Elements*, Sect. 111.

‡ *An. de Chem. et de Phys.* xli. 353, *An. Philos.*, N. S., v. 427, and *Phil. Mag.* iii.

and the condensation of vapour, which may aid in accounting for certain electrical phenomena of the atmosphere.

Exp. Place a small iron cup, heated nearly to redness, over an electrometer; on dropping into it a small portion of water, vapour will be produced, and the leaves of the electrometer will diverge.

Electricity from the contact of metals. 279. Another reputed source of electricity is *contact* of different substances, especially of metals; a source originally suggested by Volta, who founded on it his theory of galvanism. When a plate of zinc furnished with a glass handle is brought into contact with one of copper or silver, it is found, after removal, to be positively electrical, and the silver or copper is left in the opposite state.

Galvanism. The electricity thus developed was distinguished as Galvanism, from the circumstance that Galvani, an Italian physiologist, about the year 1789, observed the first striking phenomenon which led to the discovery. He observed it only in its power of affecting the animal system. It was found that if the nerve of a recently killed frog was attached to a silver probe, and a piece of zinc was brought into contact with the muscles of the animal, violent contractions would be produced at every contact of the metals. Exactly the same effect is produced by an electric spark, or the discharge of a small Leyden phial. The following experiment produces a similar effect.

Exp. Place a piece of zinc upon the tongue, and a piece of silver under it; whenever the projecting edges of these different metals are made to touch, a peculiar taste or sensation will be perceived, and if the pieces are large the contact will sometimes be accompanied by a flash of light.

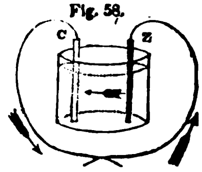
Galvani's hypothesis, Volta's 280. From these and similar experiments Galvani concluded that the phenomena were owing to the communication of electricity generated by the animal system. Volta supposed that the electricity was derived from the action exerted between the metal and the moist animal fibre, and soon discovered that it is evolved by arrangements wholly unconnected with any process of vitality. His discovery of a method of augmenting the galvanic energy, and of thus enabling us to investigate its effects with more precision, has acquired for this form of electricity the epithet *Voltaic.*

281. The identity of the agent concerned in the phenomena of galvanism and of the common electrical machine, is now a matter of demonstration. The effects of common electricity are caused by a comparatively small quantity of electricity brought into a state of insulation, in which state it exerts a high intensity, as evinced by its remarkable attractive and repulsive energies, and by its power to force a passage through obstructing media. In galvanism the electric agent is more intimately associated with other substances, is developed in large quantity, but never attains a high tension, and produces its peculiar effects while flowing along conductors in a continuous current.

Simple Voltaic circles. 282. When a plate of zinc and a plate of copper are placed in a vessel of water, and the two metals are made to touch each other, either directly or by the intervention of a metallic wire, galvanism is excited. The action is, indeed, very feeble, and not to be detected by ordinary methods; but if a little sulphuric acid be added to the water, numerous globules of hydrogen gas will be evolved at the surface of the copper. This continues while metallic contact between the plates continues, in which state the circuit is said to be *closed;*

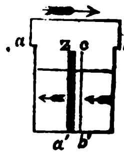
but it ceases when the circuit is broken, that is, when metallic contact is interrupted. The hydrogen gas which arises from the copper plate results from water decomposed by the electric current, and its ceasing to appear indicates the moment when the current ceases. In this case the voltaic circle consists of zinc, copper, and interposed dilute acid; and the circle gives rise to a current only when the two metals are in contact. This arrangement is shown in Fig. 58, where metallic contact is readily made or broken by means of copper wires soldered to the plates. It is found that a current of positive electricity continually circulates in the closed circuit from the zinc through the liquid to the copper, and from the copper along the conducting wires to the zinc, as indicated by the arrows in the figure. A current of negative electricity, agreeably to the theory of two electric fluids, ought to traverse the apparatus in a direction precisely reversed; but for the sake of simplicity the course of the positive current only will hereafter be indicated.

Fig. 58.



283. It matters not, so far as voltaic action is concerned, at what part the plates touch each other. Immersion of one plate only in the acid solution, however contact between the plates may be made, does not excite voltaic action; nor does it suffice to have one plate in one vessel, and the other plate in another vessel. A plate of zinc soldered to one of copper, and plunged into dilute acid, gives a current passing from the zinc through the fluid round to the copper: but if the soldered plates are cemented into a box with a wooden bottom and metallic sides, so as to form two *separate* cells, as shown in a vertical section by Fig. 59, then the introduction of dilute acid to the cells will not excite a current unless the fluid of the cells be made to communicate by means of moistened fibres of twine, cotton, or some porous matter, or, as in the figure, by wires *a b*, soldered to the metallic sides which contain the dilute acid, or dipping into the acid itself. Then the positive current circulates in the direction shown by the arrows.

Fig. 59.



Instead of a pair of plates being soldered together, they may be connected by a wire, and plunged into separate cells.

Circle of metal and liquid. 284. A simple voltaic circle may be formed of one metal and two liquids, provided the liquids are such that a stronger chemical action is induced on one side than on the other. Nay, the same acid solution may occupy both cells, provided some condition be introduced which shall cause one side of the zinc to be more rapidly dissolved than the other; as by the plate being rough on one side and polished on the other, or by the acid being hot in one cell and cold in the other. In this case, however, the result is the same as though two different liquids were used.

Zinc circle. 285. An interesting kind of simple voltaic circle is afforded by commercial zinc. This metal, as sold in the shops, contains traces of tin and lead, with rather more than one per cent. of iron, which is mechanically diffused through its substance: on immersion in dilute sulphuric acid, these small particles of iron and the adjacent zinc form numerous voltaic circles, transmitting their currents through the acid which moistens them, and disengaging a large quantity of hydrogen gas.*

Davy's protector.

286. While the current formed by the contact of two metals gives increased effect to the affinity of one of them for some element of the solution, the ability of the other metal to undergo the same change is proportionally diminished. Thus, when plates of zinc and copper touch each other in dilute acid, the zinc oxidizes more, and the copper less, rapidly than without contact. This principle was beautifully exemplified by the attempt of Davy to preserve the copper sheathing of ships. Davy found that the quantity of zinc required to form an efficient voltaic circle with copper was very small.† Unhappily, in practice, it is found that unless a certain degree of corrosion takes place in the copper, its surface becomes foul from the adhesion of sea-weeds and shell-fish.

Other circles.

287. Simple voltaic circles may be formed of various materials; but the combinations usually employed consist either of two perfect and one imperfect conductor of electricity, or of one perfect and two imperfect conductors. The substances included under the title of perfect conductors are metals and charcoal, and the imperfect conductors are water and aqueous solutions. It is essential to the operation of the first kind of circle, that the imperfect conductor act chemically on one of the metals: and in case of its attacking both, the action must be greater on one metal than on the other. It is also found generally, if not universally, that the metal most attacked is positive with respect to the other, or bears to it the same relation as zinc to copper.‡

Water not essential.

288. The presence of water has been shown by Faraday not to be essential. A battery may be composed of other liquid compounds, such as a fused metallic chloride, iodide, or fluoride, provided it is decomposable by galvanism, and acts chemically on one metal of the circle more powerfully than on the other.

The following table of voltaic circles of the second kind is from Davy's *Elements of Chemical Philosophy*:—

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* Mr Sturgeon has remarked that commercial zinc, with its surface amalgamated, which may be done by dipping a zinc plate into nitric acid diluted with two or three parts of water, and then rubbing it with mercury, resists the action of dilute acid fully as well as the purest zinc. This fact, of which Faraday in his late researches has made excellent use, appears due to the mercury bringing the surface of the zinc to a state of perfect uniformity, preventing those differences between one spot and another, which are essential to the production of minute currents; one part has the same tendency to combine with electricity as another, and cannot act as a discharger to it (Faraday).

† *Phil. Trans.* 1824.

‡ Davy, in his Bakerian lecture for 1826 (*Phil. Trans.*), gave the following list of the first kind of arrangements, the imperfect conductor being either the common acids, alkaline solutions, or solutions of metallic sulphurets, such as sulphuret of potassium. The metal first mentioned is positive to those standing after it in the series.

With common acids.—Potassium and its amalgams, barium and its amalgams, amalgam of zinc, cadmium, tin, iron, bismuth, antimony, lead, copper, silver, palladium, tellurium, gold, charcoal, platinum, iridium, rhodium.

With alkaline solutions.—The alkaligenous metals and their amalgams, zinc, tin, lead, copper, iron, silver, palladium, gold, and platinum.

With solutions of metallic sulphurets.—Zinc, tin, copper, iron, bismuth, silver, platinum, palladium, gold, charcoal.

Solution of sulphuret of potassium ———— potassa ———— soda	Copper Silver Lead Tin Zinc Other metals Charcoal	Nitric acid Sulphuric acid Hydrochloric acid Any solutions containing acid.

The most energetic of these combinations is that in which the metal is chemically attacked on one side by sulphuret of potassium, and on the other by an acid. The experiment may be made by pouring dilute nitric acid into a cup of copper or silver, which stands in another vessel containing sulphuret of potassium. The following arrangements may also be employed:—

Exp. Let two pieces of thick flannel be moistened, one with dilute acid and the other with the sulphuret, and then placed on opposite sides of a plate of copper, completing the circuit by touching each piece of flannel with a conducting wire: or, take two discs of copper, each with its appropriate wire, immerse one disk into a glass filled with dilute acid, and the other into a separate glass with alkaline solution, and connect the two vessels by a few threads of amianthus or cotton moistened with a solution of salt. A similar combination may be disposed in this order: let one disc of copper be placed on a piece of glass or dry wood; on its upper surface lay in succession three pieces of flannel, the first moistened with dilute acid, the second with solution of salt, and the third with sulphuret of potassium, and then cover the last with the other disc of copper.

Metals not essential. 289. Metallic bodies are not essential to the production of galvanic phenomena. Combinations have been made with layers of charcoal and plumbago, of slices of muscle and brain, and beet-root and wood; but the force of these circles though accumulated by the union of numerous pairs, is extremely feeble, and they are very rarely employed in practice.

Circles most used. 290. Of the simple voltaic circles above described, the one used for ordinary purposes is that composed of a pair of zinc and copper plates excited by an acid solution arranged as in Fig. 58. The form and size of the apparatus are exceedingly various. Instead of actually immersing the plates in the solution, a piece of moistened cloth may be placed between them. Sometimes the copper plate is made into a cup for containing the liquid, and the zinc is fixed between its two sides, as shown by the accompanying transverse vertical section, Fig. 60; care being taken to avoid actual contact between the plates, by interposing pieces of wood, cork, or other imperfect conductor of electricity. T. 91. Another contrivance, which is much more convenient, because the zinc may be removed at will and have its surface cleaned, is that represented by Fig. 61. An earthen pot A A is lined with a cylinder of thin copper, within which are one or more smaller cylinders of the same, connected at bottom by narrow pieces of copper. One, or more cylinders of zinc are placed in the space between the coppers, being somewhat shorter than the copper cylinders, and are supported on the edge of the pot by projecting pieces soldered to the upper edges. (Fig. 62.) Small cups

Fig. 60.

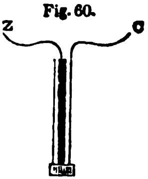


Fig. 61.

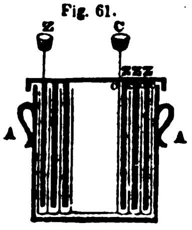
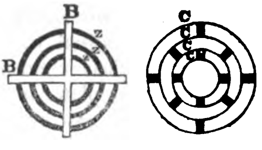


Fig. 62.



Circular arrangement.

are attached to the two metals for receiving a few drops of mercury, into which the ends of wires may be dipped and the circuit be closed or broken at pleasure. This apparatus is very serviceable in experiments on electro-magnetism. The liquid employed is a solution of sulphate of copper (blue vitriol) in water, and may be allowed to remain in the pot when the apparatus is not in use, all that is necessary is to remove the zinc cylinder.

Another kind of circle may be formed by coiling a sheet of zinc and copper round each other, so that each surface of the zinc may be opposed to one of copper, and separated from it by a small interval. The contrivance of opposing one large connected surface of zinc to a similar surface of copper, originated with Hare of Philadelphia, who, from its surprising power of igniting metals, gave it the name of *Calorimotor*.*

Compound circles.

291. Compound voltaic circles consist of a series of simple circles. The first combinations of the kind were described by Volta, and are

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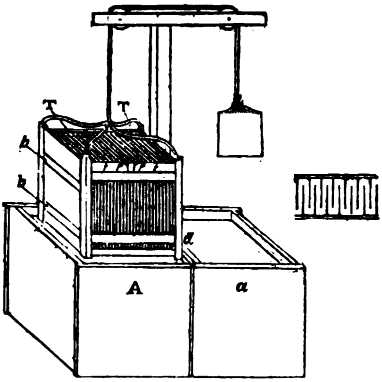
Hare's improvement.

Fig. 63.



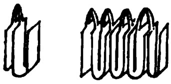
Calorimotor.

* A *a*, represent two cubical vessels, twenty inches square, inside. *b b*, a frame of wood containing 20 sheets of copper, and 20 sheets of zinc, alternating with each other, and about half an inch apart. T T *t t*, masses of tin cast over the protruding edges of the sheets which are to communicate with each other. The small fig. on the right, represents the mode in which the junction between the various sheets and tin masses is effected, The zinc only is in contact with the tin on one side; the copper alone touches on the other. At the back of the frame, ten sheets of copper and ten sheets of zinc are made to communicate, by a common mass of tin extending the whole length of the frame, between T T; but in front, as in Fig. 63, there is an interstice between the mass of tin connecting the ten copper sheets, and that connecting the ten zinc sheets. The screw forceps, appertaining to each of the tin masses, may be seen on either side of the interstice; and likewise a wire for ignition held between them. The application of the rope, pulley, and weights is obvious. The frame can be swung round and lowered into the water in the vessel *a*, to wash off the acid, which, after immersion in the other vessel, might continue to act on the sheets, incrusting them with oxide.

When the copper and zinc surfaces are united by an intervening wire, and the instrument is immersed in the acid liquor in the vessel beneath, the wire becomes intensely ignited, and when hydrogen is liberated in sufficient quantity it usually takes fire producing a very beautiful corruscating flame upon the surface of the liquid.* Or the following method may be employed: cut the plates into the form represented in Fig. 64, solder the zinc and copper together, bend them into the form of Fig.65 and arrange them in the trough as in Fig. 72. The zinc plates are kept from touching the copper plates by pieces of cork, and pieces of thick paper are interposed between the contiguous surfaces of copper. Faraday, in *Phil. Trans.* 1835.

Fig. 64.

Fig. 65.



* See *Amer. Jour. of Science*, vol. i. 413.

Chap. I.

now well known under the names of *voltaic pile* and *crown of cups.* (Fig. 66). In this apparatus the exciting solution is contained in separate glasses or cups; each glass contains a pair of plates, and each zinc plate is attached to the copper of the next pair by a metallic wire. The voltaic pile is made by placing pairs of zinc and copper, or zinc and silver plates one above the other, as shown in Fig. 67, each pair separated from those adjoining by pieces of cloth rather smaller than the plates, and moistened with a saturated solution of salt.

Fig. 66.

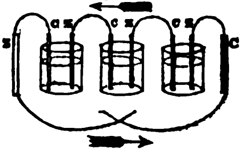
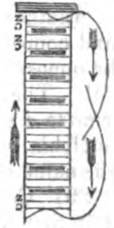


Fig. 67.



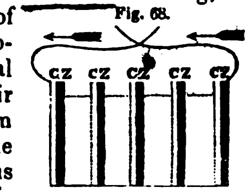
Position of the metals.

The relative position of the metals in each pair must be the same in the whole series; that is, if the zinc be placed below the copper in the first pair, the same order should be observed in all the others. Without such precaution the apparatus would give rise to opposite currents, which would neutralize each other more or less according to their relative forces. The pile, which may consist of any convenient number of combinations, should be contained in a frame formed of glass pillars fixed into a piece of thick dry wood, by which it is both supported and insulated. Any number of these piles may be made to act in concert by establishing metallic communication between the positive extremity of each pile and the negative extremity of the pile immediately following.

Trough.

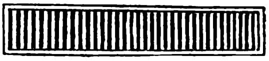
292. The voltaic pile is now rarely employed, because we possess other modes of forming galvanic combinations which are far more powerful and convenient. The galvanic battery proposed by Cruikshank, consists of a trough of baked wood, about 30 inches long, in which are placed at equal distances 50 pairs of zinc and copper plates previously soldered together, and so arranged that the same metal shall always be on the same side. Each pair is fixed in a groove cut in the sides and bottom of the box, the points of junction being made water-tight by cement. The apparatus thus constructed is always ready for use, and is brought into action by filling the cells left between the pairs of plates with some convenient solution, which serves the same purpose as the moistened cloth in the pile of Volta. By means of Figs. 68 and 69 the mode in which the plates are arranged will easily be understood.

Fig. 68.



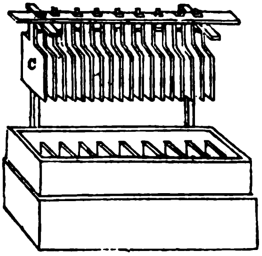
293. Other modes of combination are now in use, which facilitate the employment of the voltaic apparatus and increase its energy. Most of these may be regarded as modifications of the crown of cups. Instead of glasses it is more convenient to employ a trough of baked wood, (Fig. 69), or glazed earthenware, divided into separate cells by partitions of the same material; and in order that the plates may be immersed into and taken out of the liquid conveniently and at the same moment, they are all attached to a bar of dry wood, the necessary connexion between

Fig. 69.



the zinc of one cell and the copper of the adjoining one being accomplished, as shown in figure 70, by a slip or wire of copper.*

Fig. 70.



294. The size and number of the plates may be varied at pleasure. The common and most convenient size for the plates, is four or six inches square; and when great power is required, a number of different batteries are united by establishing metallic communication between the positive extremity of one battery and the negative extremity of the adjoining one. The great battery of the Royal Institution, with which Davy made his celebrated discovery of the compound nature of the alkalies, was composed of 2000 pairs of plates, each plate having 32 square inches of surface. It is now recognized, however, that such large compound batteries are by no means necessary. Increasing the number of plates beyond a very moderate limit gives, for most purposes, no proportionate increase of power; so that a battery of 50 or 100 pairs of plates, thrown into vigorous action, will be just as effective as one of far greater extent.

Condition of compound circles.

295. The electrical condition of compound voltaic arrangements is similar to that of the simple circle. In the broken circuit no electric current can be traced; but in the closed circuit, that is, when the wires from the opposite ends of the battery are in contact, the galvanometer indicates a positive electric current through the battery itself

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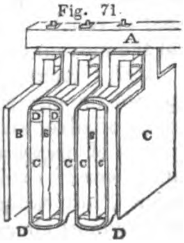
Wollaston's trough.

Fig. 71



* A material improvement in the apparatus was made by Wollaston, which consisted in extending the copper plate, so as to oppose it to every surface of the zinc, as seen in Fig. 71. A is the rod of wood to which the plates are screwed; B B the zinc plates connected as usual with the copper plates C C, which are doubled over the zinc plates, and opposed to them upon all sides, contact of the surfaces being prevented by pieces of wood or cork placed at D D. Hare adopted this with great advantage in his Deflagrator. (Fig. 72.) It consists of four troughs *a a*, *b b*, each 10 feet long. Each two of the troughs are joined lengthwise, edge to edge, so that when the sides of the two *b b* are vertical, those of the others *a a* are horizontal. The troughs are supported by a frame C C, and turn upon pivots *d d*. The pivots are made of iron coated with brass or copper, and a communication is made between these and the galvanic series within by strips of copper *e*.

Hare's Deflagrator.

Fig. 72.

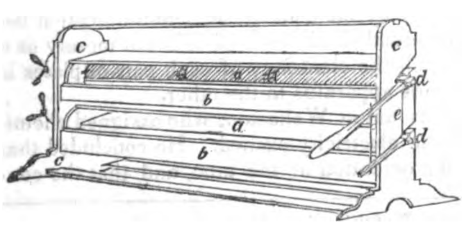


Fig. 73.

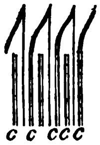
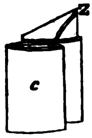


Fig. 74.



The galvanic series of 300 pairs of copper and zinc plates (connected as in Figs. 73 and 74, each zinc plate z being between two copper plates c c) are placed in the troughs *a a*.* The acid liquor is contained in the troughs *b b*, and by a partial revolution of the apparatus is made to flow into the troughs containing the plates.

* See *Amer. Jour.* iii. 347.

Chap. I.

and along the wires, as shown by the arrows in Figs. 66 and 68. The direction of the current appears at first view to be different from that of the simple circle; since in the latter the positive electric current flows from the zinc through the liquid to the copper, while in the compound circle its direction is from the extreme copper through the battery to the extreme zinc plate. This apparent difference arises from the compound circle being usually terminated by two superfluous plates. The extreme copper and extreme zinc plate of Fig. 68 are not in contact with the exciting fluid, and therefore contribute nothing to the galvanic action: removing these superfluous plates, which are solely conductors, there will remain four simple circles, namely, the three pair of soldered plates marked 2, 3, 4, which act as in Fig. 59, and the then extreme plates, 1, 1, which are related to each other as the plates in Fig. 58. When thus arranged, the direction of the current will be seen to correspond with that of the simple circle.

Evolution of hydrogen.

296. During the action of a simple circle, as of zinc and copper, excited by dilute sulphuric acid, all of the hydrogen developed in the voltaic process is evolved at the surface of the copper. This fact is not apparent when common zinc plates are used, owing to the numerous currents which form on the surface of the zinc (285); but when a plate of amalgamated zinc and another of platinum are introduced into dilute sulphuric acid of specific gravity 1.068 or a little higher, no gas whatever appears until contact between the plates is made, and then hydrogen gas rises solely from the platinum, while zinc is tranquilly dissolved. The separation of one ingredient of the exciting solution at one plate, while the element previously combined with it unites with the other plate, seems essential to voltaic action. It is in some way connected with the passage of the current across the exciting liquid.

297. Among the different kinds of voltaic apparatus is usually placed the electric column of De Luc, which is formed of successive pairs of silver and zinc, or silver and Dutch-metal leaf, separated by pieces of paper arranged as in a voltaic pile. It is remarkable for its power of exhibiting attractions and repulsions like common electricity, but cannot produce chemical decomposition or any of the effects most characteristic of a voltaic current, and is rather an electrical than a voltaic instrument.* T. 94.

Theories of Galvanism. Volta's,

298. Several theories have been proposed for the explanation of galvanism and its effects. Volta conceived that electricity was set in motion and kept up, solely by the contact or communication between the metals. He regarded the interposed solution merely as a conductor, by means of which the electricity of each pair of plates is conveyed from one part of the apparatus to the other.

Wollaston's,

299. The second theory is that of Wollaston, who assigned chemical action as the cause of the electricity excited. He concluded that the process begins with the oxidation of the zinc, and that the con-

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De Luc's columns.

*Fig. 2, Frontispiece, represents De Luc's columns, with a metallic ball suspended between them. The glass tubes are packed with 1000 or 1500 pairs of zinc and silver disks, the series commencing with zinc in one, and with silver in the other; the columns terminate at bottom in small bells, between which the ball is attracted and repelled for a considerable length of time, producing an irregular chime. See Singer's *Electricity*, 452.

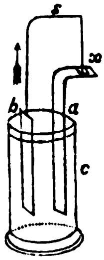
Davy's,

tact of the plates served only to conduct electricity. The third theory was that proposed by Davy, who maintained that, though not the primary movers of the electric current, the chemical changes are essential to the continued action of every voltaic circle. The electric excitement was begun, he thought, by metallic contact, and maintained by chemical action.

300. Conclusive evidence against the theory of Volta has very recently been obtained by Faraday.* He proved metallic contact not to be essential to voltaic action, by procuring that action quite characteristically without contact.

Faraday's Exp'ts.

Fig. 75.



A plate of zinc, *a*, Fig. 75, about 8 inches long by ½ an inch wide, was cleaned and bent at a right angle: and a plate of platinum, of the same width and three inches long, was soldered to a platinum wire, *b s x*, the point of which, *x*, rested on a piece of bibulous paper lying upon the zinc, and moistened with a solution of iodide of potassium. On introducing the plates into a vessel, *c*, filled with dilute sulphuric and nitric acid, a positive electric current instantly ensued in the direction of the arrow, as testified by the hydrogen evolved at the plate *a*, by the decomposed iodide of potassium, and by a galvanometer. We have thus a simple circle of the same construction and action as in Figure 58, except in the absence of metallic contact.

Another proof, aptly cited by Faraday, of electric excitement being independent of contact, is afforded by the spark which appears, when the wires of a pair of plates in vigorous action are brought into contact. The spark is occasioned by the passage of electricity across a thin stratum of air, and, therefore, its production proves that electro-motion really occurred while the wires were yet separated by a thin stratum of air, which permitted the electric current to pass, and anterior to their actual contact. This current, in Faraday's experiment, was so feeble compared with the one excited by the acid solution, that its influence was scarcely appreciable; but if the opposed currents had been of the same force, no action would have ensued. To illustrate this still further, Faraday fixed a plate of platinum, P, (Fig. 76) parallel and near to a plate of amalgamated zinc, Z. On placing a drop of dilute sulphuric acid at *y*, and making metallic contact between the plate at Z P, a positive electric current flowed in the direction of the arrows. If, in the same plates (Fig. 77), the acid be introduced at *x*, and metallic contact be made at P Z, the current, passing as before from zinc through the liquid to the platinum, has a direction opposed to that of Fig. 59, owing to the reversed position of the acid. If, then, in the same plate, (Fig. 78), a drop of acid be introduced at *y* and *x*, the conditions are obviously fulfilled for producing two opposite currents of positive electricity, each fluid acting as a substitute for metallic contact in conducting the current which the other tends to generate. If these opposing currents happen to be equal, they will annihilate the effects each separately would produce;

Fig. 76.

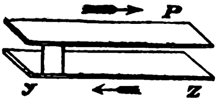
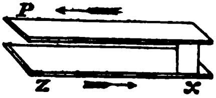


Fig. 77.



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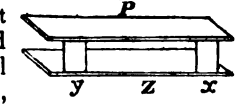
* The *Philosophical Transactions* contain a succession of essays on voltaic electricity from the pen of Faraday, in which numerous errors have been exposed and new views of deep interest established.

and if unequal, the stronger current, as in Fig. 75, will annihilate the weaker, and, though with diminished power, impress its character on the circuit.

Theory of compound circles.

301. These considerations, made in reference to a simple circle, lead at once to the theory of the compound circle. For if, in Fig. 78, a drop of dilute acid, which acts solely on the zinc, be introduced at *y*, and a different liquid at *x*, capable of corroding platinum and not zinc, then the chemical action at *y* will cause a positive current from zinc to platinum, and that at *x* a similar current from platinum to zinc. The two currents tend to circulate in the same direction, and each promotes the progress of the other. The same state of things exists in the batteries represented by Figs. 66 and 68. Chemical action taking place on the zinc of each pair of plates, there is a tendency to establish an equal number of positive currents all in the same direction; and the simultaneous effort of all urges on the current with a force which it could not derive from a single pair of plates. It is now, also, apparent that all the zinc plates should have their surfaces towards one side, and those of copper towards the other: one reversed pair tends to establish a counter-current, which enfeebles the influence of the rest. On the same principle, the exciting liquid of a voltaic circle should act exclusively on one of the plates: if the copper is oxidized as fast as the zinc, opposite currents will be excited, which more or less completely counteract each other. For this reason, platinum and zinc act better than copper and zinc, especially when nitric acid is employed.

Fig. 78.



Quantity and intensity.

302. Electricians distinguish between *quantity* and *intensity* in galvanism as in ordinary electricity. *Quantity*, in reference to a voltaic circle, signifies the quantity of electric fluid set in motion; and by *tension* or *intensity* is meant the energy or effort with which a current is impelled. The current of a single pair of plates, though variable in intensity according as the nature and strength of the exciting liquid varies, never attains a high tension. A compound circle does not act by directly increasing the quantity of electricity, but by giving impetus or tension to that which is excited.

Energy estimated.

303. The energy of a voltaic circle is usually estimated either by the deflection which it causes on a magnetic needle, or by its power of chemical decomposition.

Chemical decomposition depends on quantity and intensity together, and affords a criterion of the increased tension of a compound circle due to an increase in the number of its plates.

Nature of electricity.

304. Some conceive that what is called an electric current is not an actual transfer of anything, but a process of induction among the molecules of a conductor passing progressively along it. Others, denying independent materiality to electricity, may ascribe it to a wave of vibrating matter, just as the phenomena of optics are explained by the undulatory theory. But whatever theory of the nature of electricity may be adopted, it seems necessary, after the experiments of Faraday on the identity of voltaic and common electricity, that the nature of an electric and voltaic current is essentially the same.

Effect of galvanism, on electro-meter. similar

305. When a zinc and copper plate are immersed in dilute acid, and the wire attached to the former is connected with a gold-leaf electrometer of sufficient delicacy, the leaves diverge with negative electricity; and on testing the wire of the copper plate in a [redacted] manner, divergence from positive electricity is obtained. The effect is so feeble with a single pair of plates, as to be scarcely appreciable; but with a battery of many pairs it is very distinct, though never powerful. The condition of a battery which gives the greatest divergency to an electrometer is that of numerous plates; small plates an inch square being just as effectual as large ones.

Leyden jar charged;

Shock.

Effect on metals,

306. A Leyden jar may be charged from either wire of an unbroken circuit, provided the battery be in a state to supply a large quantity of electricity of high tension, as when formed of numerous four-inch plates excited by dilute acid. When the wires from such a battery are brought near each other, a spark is seen to pass between them; and on establishing the communication by means of the hands, previously moistened, a distinct shock is perceived. On sending the current through fine metallic wires or slender pieces of plumbago or compact charcoal, these conductors become intensely heated, the wires even of the most refractory metals are fused, and a vivid white light appears at the points of the charcoal. If the communication be established by metallic leaves, the metals burn with vivid scintillations. Gold-leaf burns with a white light, tinged with blue, and yields a dark brown oxide; and the light emitted by silver is exceedingly brilliant, and of an emerald-green colour. Copper emits a bluish-white light attended with red sparks, lead a beautiful purple light, and zinc a brilliant white light inclining to blue, and fringed with red. (Singer.)

Explained.

307. The phenomena seem to arise from the current passing along these substances with difficulty; a circumstance which, as they are perfect conductors, can only happen when the quantity to be transmitted is out of proportion to the extent of surface over which it has to pass. It is, therefore, an object to excite as large a quantity of electricity in a given time as possible, and for this purpose a few large plates answer better than a great many small ones. A strong acid solution should also be used; since energetic action, though of short continuance, is more important than a moderate one of greater permanence. A mixture of ten or twelve parts of water to one of nitric acid is applicable; or, for the sake of economy, a mixture of one part of nitric to two parts of sulphuric acid may be substituted for pure nitric acid.

Identity of galvanism and electricity.

308. Most of the effects of galvanism are so similar to those of the electrical machine, that it is impossible to witness and compare both series of phenomena without ascribing them to the same agent. The question of identity early occupied the attention of Wollaston, who made some very beautiful and conclusive experiments to prove that the chemical effects of galvanism may be characteristically produced by a current from the electrical machine.* The subject has been examined anew by Faraday, who has subjected the effects of electricity and galvanism to a minute and critical comparison: he has obtained ample proof of the decomposing power of an electric

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* *Phil. Trans.* 1801.

current from an electrical machine, both by repeating the experiments of Wollaston and devising new ones of his own. These researches have led to a remarkable contrast between the quantity of electricity concerned in the production of voltaic and ordinary electrical phenomena. Faraday states, that the quantity of electric fluid employed in decomposing a single grain of water is equal to that of a very powerful flash of lightning.

Chemical action of galvanism. **Water decomposed.**

309. The chemical agency of the voltaic apparatus, to which chemists are indebted for their most powerful instrument of analysis, was discovered by Carlisle and Nicholson. The substance first decomposed by it was water. When two gold or platinum wires are connected with the opposite ends of a battery, and their free extremities are plunged into the same portion of water, (Fig. 79,*) but without touching each other, hydrogen gas is disengaged at the negative and oxygen at the positive wire. By collecting the gases in separate tubes as they escape, (Fig. 81†) they are found to be quite pure, and in the exact ratio of two measures of hydrogen to one of oxygen. When wires of a more oxidable metal are employed, the result is somewhat different. The hydrogen gas appears as usual at the negative wire; but the oxygen, instead of escaping, combines with the metal, and converts it into an oxide.

Other compounds.

310. This important discovery led many able experimenters to make similar trials. Other compound bodies, such as acids and salts, were exposed to the action of galvanism, and all of them were decomposed without exception, one of their elements appearing at one side of the battery, and the other at its opposite extremity. An exact uniformity in the circumstances attending the decomposition was also remarked. Thus, in decomposing water or other compounds, the same kind of body was always disengaged at the same side of the battery. The metals, inflammable substances in general, the alkalies, earths, and the oxides of the common metals, were found at the negative wire; while oxygen, chlorine, and the acids, went over to the positive surface.

Davy's experiments.

311. Davy observed that if the conducting wires were plunged into separate vessels of water, made to communicate by some moist fibres of cotton or amianthus, the two gases were still disengaged in

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* Fig. 79. Shows the method of decomposing water in a glass tube. † Fig 81. Apparatus for collecting the gases in separate tubes; the tubes *h o*, are filled with water, and inverted in the globular vessel *d*, also containing water; the tubes pass through holes in a wooden cover; *n p*, are platinum wires passing through the globe to connect with the voltaic apparatus. Fig. 80. Similar arrangement for collecting the mixed gases.

Fig. 79.

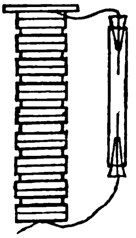


Fig. 80.

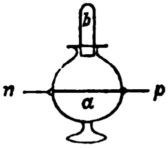
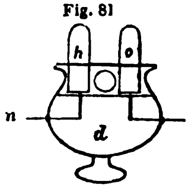
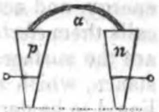


Fig. 81



their usual order, the hydrogen in one vessel, and the oxygen in the other, just as if the wires had been immersed into the same portion of that liquid. This singular fact, and another of the like kind observed by Hisinger and Berzelius, induced him to operate in the same way with other compounds, and thus gave rise to his celebrated researches on the transfer of chemical substances from one vessel to another.*

Fig. 82.



Exp.

In these experiments two agate cups, *n* and *p*, were employed, the first communicating with the negative, the second with the positive wire of the battery, and connected together by moistened amianthus. On putting a solution of sulphate of potassa or soda into *n*, and distilled water into *p*, the acid very soon passed over to the latter, while the liquid in the former, which was at first neutral, became distinctly alkaline. The process was reversed by placing the saline solution in *p*, and the distilled water in *n*, when the alkali went over to the negative cup, leaving free acid in the other.

That the acid in the first experiment, and the alkaline base in the second, actually passed along the amianthus, was obvious; for on one occasion, when nitrate of oxide of silver was substituted for the sulphate of potassa, the amianthus leading to *n* was coated with a film of metal. A similar transfer was effected by putting distilled water into *n* and *p*, and a saline solution in a third cup placed between the two others, and connected with each by moistened amianthus. In a short time the acid of the salt appeared in *p*, and the alkali in *n*. It was in pursuing these researches that Davy made his great discovery of the decomposition of the alkalies and earths, which till then had been regarded as elementary.† ‡

312. Such is a statement of the principal phenomena of electro-chemical decomposition according to the earlier experiments. The facts then observed were received as established truths of science. But Faraday, in his revision of this part of the science, has not only added much new matter, but proved that several points, which were considered as fundamental maxims, are erroneous. Before describing his results, however, it is necessary to define the new terms which he has had occasion to introduce. In order to decompose a compound, it is necessary that it should be liquid, and that an electric current should pass through it, an object easily effected by dip-

Faraday's researches.

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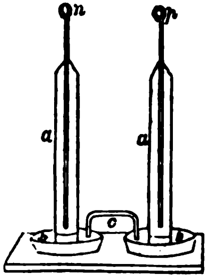
* *Phil. Trans.* 1807. † Ibib. 1808.

‡ The transfer of acid and alkali may be shown by the following arrangement: Fill the glass tubes *a a*, Fig. 83, which are closed at top and open at bottom, with infusion of violets, or purple cabbage, and invert them in the basins *b b*, containing a solution of Glauber's salt, and connected by the glass tube *c*, also containing the solution; *p* and *n* are platinum wires, which pass into the tubes nearly to the bottom, and which are to be connected with the positive and negative extremities of the Voltaic apparatus. It will be found that oxygen is evolved at the wire *p*, and hydrogen at *n*, derived from the decomposition of the water. The Glauber's salt, which consists of sulphuric acid and soda, will also be decomposed: and the blue liquor will be rendered red in the positive vessel, by the accumulation of sulphuric acid, and green in the negative, by the soda, while the acid and alkali will each traverse the tube *c* without uniting, in consequence of being under the influence of electrical attraction.

Fig. 83.



Transfer of acid and alkali.

New terms. Anode and Cathode. Electrolyze. Anions. Cations.

ping into the liquid the ends of the metallic wires which communicate with the voltaic circle. These extremities of the wires are commonly termed *poles*, from a notion of their exerting attractive and repulsive energies towards the elements of the decomposing liquid, just as the poles of a magnet act towards iron; and each is further distinguished by the term *positive* or *negative*, according as it affects an electrometer with positive or negative electricity. Faraday contends that these poles have not any attractive or repulsive energy, and act simply as a path or door to the current: he hence calls them *electrodes*, from ηλεκτρον, and ὁδος, a way. The electrodes are the surfaces, whether of air, water, metal, or any other substance, which serve to convey an electric current into and from the liquid to be decomposed. The surfaces of this liquid which are in immediate contact with the electrodes, and where the elements make their appearance, are termed *anode* and *cathode* from ἀνα, *upwards*, and ὁδος, the way in which the sun rises, and κατα, *downwards*, the way in which the sun sets. The anode is where the positive current is supposed to enter, and the cathode where it quits, the decomposing liquid, its direction, when the electrodes are placed east and west, corresponding with that of the positive current which is thought to circulate on the surface of the earth. To *electrolyze* a compound, is to decompose it by the direct action of galvanism, its name being formed from ηλεκτρον and λυω, *to unloose, or set free;* and an electrolyte is a compound which may be electrolyzed. The elements of an electrolyte are called ions, from ιον, going, neuter participle of the verb to go. *Anions* are the ions which appear at the anode, and are usually termed the electro-negative ingredients of a compound, such as oxygen, chlorine, and acids; and the electro-positive substances, hydrogen, metals, alkalies, which appear at the cathode, are *cations*. Whatever may be thought of the necessity for some of these terms, the words electrode, electrolyze, and electrolyte, are peculiarly appropriate.

Faraday's results.

313. The principal facts determined by Faraday, may be arranged under the following propositions:—

All compounds not electrolytes. Secondary action.

1. All compounds, contrary to what has been hitherto supposed, are not electrolytes, that is, are not directly decomposable by an electric current. But in making this assertion it is necessary to distinguish between primary and secondary decomposition. Thus water is an electrolyte, its hydrogen being delivered up at the negative and its oxygen at the positive electrode. Nitric acid is not an electrolyte, on subjecting it to voltaic action, the water of the solution is electrolyzed, and its hydrogen arriving at the negative electrode decomposes the nitric acid, water being there reproduced and nitrous acid formed. Very numerous secondary actions are occasioned in this way, because the disunited elements are presented in a nascent form, which is peculiarly favourable to chemical action. By slow secondary actions, effected by very feeble currents, Becquerel, Crosse, and others, have procured several crystalline compounds analogous to minerals.*

2. Most of the salts which have been examined are resolvable into

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* See notice of Crosse's experiments in *Sixth Report of British Association*, p. 47.

acid and oxide, apparently without reference to their proportions. But in compounds of two elements, the ratio of combination has an influence which has hitherto been wholly overlooked. No two elements appear capable of forming more than one electrolyte. Substances which consist of a single equivalent of one element and two or more equivalents of some other element, are not electrolytes: this is the reason why sulphuric and nitric acid and ammonia do not yield primarily to voltaic action. This principle bids fair to become very important in determining which of several compounds of two elements contain single equivalents, (116 note.) Water, which is remarkable for its easy decomposition, may hence be inferred to be a true binary compound.

Most elements are ions.

3. It has been ascertained that most of the elements are *ions*, and it is probable that all of them are so; but there are several which have not yet been proved to be so.

Character of electrolytic action.

4. A single *ion*, that is, one ion not in combination with another, has no tendency to pass to either of the electrodes, and is quite indifferent to the passing current, unless it be itself a *compound ion*, and therefore electrolyzable. The character of true electrolytic action consists in the separation of *ions*, one passing to one electrode and another to the opposite electrode, and appearing there at the same instant, unless the appearance of one or both be prevented by some secondary action.

No transfer of ions.

5. There is no such thing as a transfer of *ions* in the sense usually understood. In order that the elements of decomposed water should appear at the opposite electrodes, there must be water between the electrodes; and for the similar separation of sulphuric acid and soda, there must be a line of particles of sulphate of soda extending from one electrode to the other.

Air may be an electrode.

6. Faraday has proved that even air may serve as an electrode. A current from the prime conductor of an electrical machine was made to pass from a needle's point through air to a pointed piece of litmus paper moistened with sulphate of soda, and then to issue from a similarly moistened point of turmeric paper. True electrolytic action took place, the litmus becoming red and the turmeric paper brown, though both extremities of the decomposing solution communicated solely with a stratum of air.

Electrolytes conductors.

7. Electro-chemical decomposition cannot occur unless an electric current is actually transmitted through it; or, in other terms, an electrolyte is always a conductor of electricity. Water, which conducts an electric current, ceases to do so when it passes into ice, and then also resists decomposition—an observation equally true of all electrolytes in becoming solid.

Force required to decompose.

8. Chemical compounds differ in the electrical force required for decomposition.

Electrolytes only, excite.

9. The conduction of the electric currents within the cells of a voltaic circle depends on chemical decomposition equally with that between platinum electrodes. No substance not an electrolyte can serve to excite a voltaic apparatus, and for the passage of electricity from plate to plate through the intervening solution, the separation of substances previously combined in the required ratio is essential.

Circumstances to be regarded

314. In experiments on decomposition the course of the electricity should be facilitated by employing large electrodes and wires, and

in experiments on decomposition.

placing them at a short distance from each other in a good conducting solution. It is important, also, that all the cells of a circle be excited with a liquid of the same strength.*

Electro-chemical equivalents.

315. In a voltaic circle in which no zinc is oxidized but what contributes to excite an electric current, the quantity of zinc dissolved in a given time from each plate is in a constant ratio, not only to the hydrogen gas evolved from the corresponding copper plate, but to the hydrogen set free at the negative electrode. The ratio is such, that 32.3 parts of zinc are dissolved during the evolution of 1 part of hydrogen gas; and the conclusion which Faraday has drawn from this and numerous similar experiments is, that the quantity of electricity set in motion by the oxidation of 32.3 grains of zinc exactly suffices for resolving 9 grains of water into its elements. If the same current, by means of 4 pairs of electrodes, be made to decompose water, chloride of silver, chloride of lead, and chloride of tin, all in the liquid state, the quantities of hydrogen, silver, lead, and tin eliminated at the 4 negative electrodes will be in the ratio of 1, 108, 103.6, and 57.9; while, at one positive electrode, oxygen, and at the three others chlorine, in the ratio of 8 to 35.4, are separated. It thus distinctly appears—and it is a new and important discovery—that electro-chemical decomposition is perfectly definite, a given quantity of electricity evolving the ingredients of compound bodies in well defined and invariable proportions, to which Faraday has given the name of *electro-chemical equivalents*. The reader will at once see that these numbers are identical with the chemical equivalents (see table). Another connexion, then, closer than any before traced, is established between electricity and chemical attraction, showing a mutual dependence and similarity of effect between two agencies, such as almost forces a belief in their identity. T. 106.

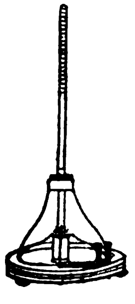
Quantity of electricity estimated.

316. The definite nature of electro-chemical action, suggested to Faraday a ready mode of estimating the quantity of electricity circulating in a voltaic apparatus. The instrument is contrived to collect the gases evolved from acidulated water during a given interval, in a tube divided into equal measures, which then expresses degrees of electricity, just as the expansion of a liquid in a thermometer indicates degrees of temperature. The instrument, as constructed for this object, is called by Faraday a *volta-electrometer*. Various forms of it have been described by him, according as it is wished to collect oxygen or hydrogen separately or both together.†

Exciting liquid.

* A mixture of a proper strength for galvanic troughs, is obtained by adding two parts in bulk of oil of vitriol and one part of common nitric acid to 100 parts of water, the whole being well stirred together until well mixed. Its power should be tested before it is poured into the troughs, by dipping a clean piece of zinc into a little of it in a glass, and observing the degree of action. A stream of bubbles should be disengaged, so small that their size can hardly be determined by the naked eye. If the action be strong, and bubbles of a considerable size are evolved, more water should be added. For full directions for operating with voltaic apparatus, see Faraday's *Chem. Manip.* 445.

Fig. 84.



Voltameter.†

† See Faraday's papers in *Philos. Trans.* (seventh series), 1834, p. 86. One of the most convenient forms is represented by Fig. 84. It is composed of three pieces, a wooden support, a glass tube, and chamber. The two latter are fitted with brass collars screwing into each other. The tube is 13½ inches long, and 5-8ths of an inch in diameter, open at bottom, closed at top, and divided into cubic inches and parts. The chamber is 4½ inches in diameter at the

Theories of electro-chemical decomposition,

317. The most celebrated attempt to explain the phenomena of galvanism, was made by Davy in his essay on *Some Chemical Agencies of Electricity* (*Phil. Trans.* 1807), by means of an hypothesis which has received the appellation of the *electro-chemical theory*. He considered that a certain electric condition, either positive or negative, is natural to the atoms or combining molecules of bodies; that chemical union is the result of electrical attraction taking place between oppositely excited atoms, and that ordinary chemical decomposition arises from two combined atoms being drawn asunder by the electric energies of other atoms more potent than those by which they were united. Davy regarded the metallic terminations or *poles* of a voltaic circle as two centres of electrical power, each acting repulsively to particles in the same electric state as itself, and by attraction on those which were oppositely excited. The necessary result was, that if the electric energy of the battery exceeded that by which the elements of any compound subject to its action were held together, decomposition followed, and each element was transferred bodily to the pole by which it was attracted. Substances which appeared at the positive pole, such as oxygen, chlorine, and acids, were termed *electro-negative* substances; and those *electro-positive* bodies, which were separated at the negative pole.

Davy's,

318. Faraday contends that, between the electrodes and acting in right lines, there is an axis of power which urges the electro-negative element of an electrolyte in the direction the positive current moves, and gives an opposite impulse to the electro-positive element. He adopts the opinion of Grotthuss, that the decomposing influence is not exerted on any single particle of the electrolyte, but that rows of particles lying between the electrodes are equally subject to its action. When a particle of oxygen is evolved at the positive electrode, the hydrogen with which it had been combined unites with the oxygen of a contiguous particle of water, on the side towards which the positive current is moving; the second particle of hydrogen decomposes a portion of water still nearer to the negative electrode; and the same process of decomposition and reproduction of water continues until it reaches the water in immediate contact with the negative electrode, the hydrogen of which is disengaged. This operation, described as commencing at one electrode, takes place simultaneously at both: a row of particles of oxygen suddenly lose their affinity for the hydrogen situated on the side next the negative electrode, in favour of those respectively adjacent to each on the other side; while the affinity of a similar row of particles of hydrogen is diminished for the oxygen on the side of the positive electrode, and is

Faraday's.

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base and 4½ in height. Through a short cylinder of wood, cemented into the bottom of the chamber, pass two platinum wires, prolonged by larger wires that dip into a small quantity of quicksilver in a cavity in the centre of the wooden support; the cavity is divided by a partition, and each wire communicates with a separate portion of the quicksilver: wires pass to small brass cups, on the support, to contain quicksilver; thus the connexion with any apparatus is readily made. When prepared for use, the chamber is to be filled to about three fourths with dilute sulphuric acid of specific gravity 1.336, or from that to specific gravity 1.25. The tube is then filled with the same liquid, and a piece of clean paper of a size to cover the open end, is pressed upon it. The tube can now be inverted and introduced, the paper withdrawn by a glass rod, and the tube screwed on. The connexion is now made, the evolved gases rise to the upper part of the tube, and their volumes are ascertained by inspection. This form of the apparatus is an improvement on that of Fig. 9, in the paper above referred to.

Chap II. increased for those on their opposite side. Hence, for the elimination of the elements of an electrolyte at the electrode, it is essential that the electrolyte itself should occupy the space between the electrodes, and be in contact with them. The theory, however, is at present incomplete.

Magnetic effects of galvanism. 319. The power of lightning in destroying and reversing the poles of a magnet, and in communicating magnetic properties to pieces of iron which did not previously possess them, was noticed at an early period of the science of electricity, and led to the supposition that similar effects may be produced by the common electrical and voltaic apparatus. Attempts were made to communicate the magnetic virtue by means of electricity and galvanism; but no results of importance were obtained till the winter of 1819, when Oersted of Copenhagen made his famous discovery, which forms the basis of a new branch of science.*

The fact observed by Oersted was, that the metallic wire of a closed voltaic circle, and the same is true of charcoal, saline fluids, and any conducting medium which forms part of a closed circle, causes a magnetic needle placed near it to deviate from its natural position, and assume a new one, the direction of which depends upon the relative position of the needle and the wire.†

320. In 1832 Forbes succeeded in obtaining a spark from a magnet without the aid of galvanism, and various methods have since been contrived. By causing the armature of soft iron to revolve with rapidity in front of the poles of a powerful magnet, very remarkable results have been obtained. The voltaic currents are induced in one direction as the armature approaches the magnetic poles, and are reversed as it quits them; so that the currents change their direction twice in each revolution. On all these occasions the source of the electricity is the same, being always induced in the silked wire or helix with which the armature is covered; it has all the characters of a voltaic current. It produces brilliant sparks, renders platinum wire red hot, and gives a strong shock. It readily explodes gunpowder, and a mixture of oxygen and hydrogen gases. It decomposes water rapidly; and though from the rapid reversal in the direction of the currents, both gases are given off at the same wire, Pixii succeeded in collecting them separately.‡ (*An. de Ch. et de Ph.* li. 72.)

CHAPTER II.

Section I. *Nomenclature.*

Old names. 321. The names formerly applied to chemical substances, were often fanciful and even absurd, but in 1787 a new nomenclature was framed by the celebrated French chemists Lavoisier, Berthollet,

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* *Ann. of Philos.* xvi. 273.

† On this subject, which belongs more to physics than chemistry, see the able outline in Turner's *Elements*, p. 109.

‡ For figures and description of magnetic electrical apparatus, see *Amer. Jour.* xxxiii. p. 213, and xxxiv. p. 368.

Morveau, and Fourcroy.[‡] Such names as had been already given to the known elementary substances, and the more familiar compounds were retained. To the newly discovered elements, names were given expressive of some striking property. To the beautiful element, to which the property of imparting acidity was believed exclusively to belong, the name *oxygen* was given, from the Greek οξὺς acid, and γεννειν to generate: to inflammable air, which, with oxygen composes water, the name *hydrogen* was given, from ὑδωρ water, and γεννειν. New elementary substances have since been named on the same principle, as the green gas chlorine from χλωρος green; iodine from its violet colour, 'Ιώδης violet, &c.

Principles of new nomenclature.

Oxidation.

Acids and oxides.

322. The act of combining with oxygen was called *oxidation*, and bodies which had united with it were said to be *oxidized*. Compounds, of which oxygen forms a part, were called *acids* or *oxides*, according as they do or do not possess acidity. An oxide of copper or iron signified a combination of those metals with oxygen, which had no acid properties. The termination *ide* was also applied to similar combinations of chlorine, iodine, &c., thus we have *chlorides*, *iodides*, *&c.*

Urets.

Oxides how distinguished.

Sesquioxides.

323. The combinations of the simple non-metallic substances, either with one another, with a metal, or with a metallic oxide, were denoted by the termination *uret*. Thus *sulphuret* and *carburet* of iron, signify compounds of sulphur and carbon with iron. The different oxides or sulphurets of the same substance were distinguished from one another by some epithet, which was commonly derived from the colour of the compound, as black and red oxides of iron, black and red sulphurets of mercury. Though this practice is still continued occasionally, it is now more customary to distinguish degrees of oxidation by the use of derivatives from the Greek or Latin. Thus the *protoxide* of a metal denotes the compound containing the minimum of oxygen, or the first oxide which the metal is known to form, *bin*oxide the second, *ter* or *trit*oxide the third; and when *per*oxide is employed, it denotes the highest degree of oxidation. The Latin word *sesqui*, one and a half, is used as an affix to an oxide, the oxygen in which is to that in the first oxide as 1½ to 1, or as 3 to 2. The sulphurets, carburets, &c., of the same substance are designated in a similar way.

Acids.

324. The name of an acid was derived from the substance acidified by the oxygen, to which was added the termination in *ic*. Thus sulphur*ic* and carbon*ic* acids, signify acid compounds of sulphur and carbon with oxygen. If sulphur or any other body should form two acids, that which contains the least quantity of oxygen is made to terminate in *ous*, as sulphur*ous* acid.

Salts.

325. Compounds consisting of acids in combination with metallic oxides, or any alkaline bases, were termed *salts*, the names of which were so contrived as to indicate the substances contained in them. If the acidified substance contained a maximum of oxygen, the name of the salt terminated in *ate;* if a minimum, the termination in *ite* was employed. Thus the sulph*ate*, phosph*ate*, and arseni*ate* of potassa, are salts of sulphur*ic*, phosphor*ic*, and arsen*ic* acids; while

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[*] For interesting biographies of these eminent men, see Thomson's *History of Chemistry*, vol. ii.

the terms sulph*ite*, phosph*ite*, and arsen*ite* of potassa, denote combinations of that alkali with the sulphur*ous*, phosphor*ous*, and arseni*ous* acids.

Neutral. Super-salts. Atomic composition indicated. 326. After the discovery of the laws of chemical combination, the nomenclature was much improved. What were before called *neutral salts*, from the acid and alkali being in such proportions as to neutralize each other, *super*-salts from the prevalence of acid, and *sub*-salts from the excess of alkali, were named from their atomic constitution. If the salt is a compound of one proportion of the acid and the alkali, the generic name of the salt is employed without any other addition; but if two or more proportions of the acid are attached to one of the base, or two or more of the base to one of the acid, a numeral is prefixed so as to indicate its composition. The two salts of sulphuric acid and potassa are called sulphate and *bi*sulphate; the first containing an equivalent of the acid and the alkali, and the second salt, two of the former to one of the latter. The three salts of oxalic acid and potassa are termed the oxalate, *bi*noxalate, and *quad*roxalate of potassa; because one equivalent of the alkali is united with one equivalent of acid in the first, with two in the second, and with four in the third salt.*

More extended views of salts, &c. 327. The views of chemists in regard to acids, alkalies, and salts, have been much extended. Several of the metals form acids with oxygen, and others alkalies. The acids and alkalies give rise to compounds more complex than themselves, containing at least three elements, and these are known by the name of *salts;* most of them unite in definite proportions with certain substances, and, with other salts, forming *double salts*. Chemists are now inclined to consider as acids all compounds which unite with potassa or ammonia, and give rise to bodies similar in constitution and general character to the salts which the sulphuric or some admitted acid forms with those alkalies.

Alkalies. 328. The characters of alkalies are exhibited most perfectly in potassa and soda; they are causticity, a peculiar pungent taste, alkaline reaction with test paper, and power of neutralizing acids, and especially of forming with them neutral saline compounds. Such are called *alkaline* or *salifiable bases*, which unite definitely with admitted acids, and form compounds analogous in constitution to the salts from admitted alkalies and acids.

Salifiable bases.

Salts are compounds of oxidized bodies. 329. The *salts* are now viewed as compounds of oxidized bodies, both the acid and base containing oxygen. Ammonia, though not an oxide, has all the characters of an alkali, and its compounds with acids are admitted as salts.

Orders. 330. Salts have been divided by Turner into four orders, viz. 1. *oxy-salts;* 2. *hydro-salts;* 3. *sulphur-salts;* and 4. *haloid-salts.* In the first, the acid or base is an oxidized body, in the second it contains hydrogen, in the third the electro-positive or negative ingredient is a sulphuret, and in the fourth it is haloidal.

The nomenclature of the hydro-salts is framed on the same princi-

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Thomson's method. * As the numerals which denote the equivalents of the acid in a super salt are derived from the Latin, it has been proposed by Thomson to employ the Greek numerals *dis*, *tris*, *tetrakis*, to signify the equivalents of alkali in a *subsalt*. Turner has extended this by distinguishing two or more equivalents of the negatively electrical element by Latin numerals, and the positive element by Greek numerals. Thus a *bi*chloride denotes a compound which contains two equivalents of the negative element chlorine; and *di*chloride indicates one equivalent of chlorine with two of some positive body.

ples as those applied to salts which contain oxygen. No general principle of nomenclature has yet been agreed upon with respect to the third and fourth order. Berzelius has extended to them the same nomenclature which he employs for the oxy-salts.

Haloïd salts.

331. The *haloid*-salts of Berzelius (from ἅλς sea-salt, and εἶδος form) are those which, in constitution, are analogous to sea-salt. They are, for the most part, bi-elementary, consisting of a metal, and of chlorine, iodine, bromine, fluorine and the radicals of the hydracids.* The haloid-salts are analogous to oxides and sulphurets.†

Sulphur salts, &c., of Berzelius.

332. In the compounds of metallic sulphurets (double sulphurets) Berzelius has found an exact analogy with the salts, and called them *sulphur-salts*. The union of simple sulphurets forms a *sulphur*-salt analogous in constitution to acids and alkaline bases, and which, like them, are capable of assuming opposite electric energies in relation to each other. Electro-positive sulphurets are termed *sulphur-bases*, and are usually the protosulphurets of electro-positive metals, corresponding to the alkaline bases of those metals. Electro-negative sulphurets, *sulphur acids*, are the sulphurets of electro-negative metals, and are proportional in composition to the acids which the same metals form with oxygen. Hence if the sulphur of a sulphur-salt were replaced by an equivalent of oxygen, an oxy-salt would result.

Characters of salts.

333. Most salts are solid at common temperatures and susceptible of crystallization; they vary in colour. The soluble salts are more or less sapid, the insoluble are insipid; few of them possess odour. They differ in their affinity for water (page 5), and in solubility. Some dissolve in less than their weight of water; others require several hundred times their weight; others are quite insoluble; this difference depends on their affinity for water, and on their cohesion; their solubility being in direct ratio with the first, and in inverse ratio with the second.

Affinity of salts for water determined.

334. The relative degrees of affinity of salts for water may be estimated by dissolving equal quantities of salts in equal quantities of water, and heating the solution. That salt which has the greatest affinity for the menstruum will retain it with most force, and will, therefore, require the highest temperature for boiling.‡

Gas, what,

335. The term *gas* is applied to those elastic fluids, except the atmosphere, which retain their aëriform state at common temperatures, and which cannot be made to change their form unless by much greater pressure than they are naturally exposed to. They differ from vapours in the relative forces with which they resist condensation.

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* The metallic chlorides, iodides, bromides, and fluorides, the cyanurets, sulphocyanurets, and ferrocyanurets, are included by Berzelius among the haloid salts. (*Ann. de Chim. et de Phys.* xxxii. 60.)

† On this subject consult Turner's *Elements*, 404. The haloid salts of Berzelius are the haloid acids and bases of Turner, and the double haloid salts of the former are the haloid salts of the latter chemist.

‡ Gay Lussac, *An. de Chim.* lxxxii.

SECTION II. *Apparatus and Manipulation.*

Apparatus. 336. For performing experiments on gases, several articles of apparatus are necessary, consisting partly of vessels fitted for containing the materials that afford them, and partly of vessels adapted to the reception of gases, and for submitting them to experiment.

Gas bottles. For procuring such gases as are producible without a very strong heat, glass vessels, furnished with ground stoppers and bent tubes are sufficient. Of these, several will be required of different sizes and shapes. A Florence flask, with a cork perforated by a bent glass tube, or even a tin pipe, will serve, for obtaining some of the gases. Those gases that require for their liberation a red heat, may be procured by exposing to heat the substances capable of affording them, in coated earthen retorts or tubes,* or in a gun barrel, the touch-hole of which has been accurately closed by an iron pin. To the mouth of the barrel must be affixed a tube bent so as to convey the gas where it may be requisite.†

Fig. 85.

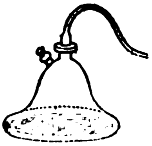


Fig. 86.

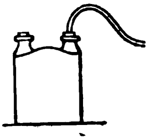
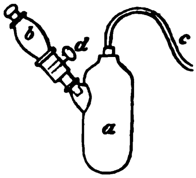


Fig. 87.



Apparatus for gases, requiring red heat. A very convenient apparatus for obtaining such gases as cannot be disengaged without a red heat, consists of a cast-iron retort (Fig 89). This may have a jointed metallic conducting tube fitted to it by grinding (Fig. 90). It is represented as placed, when in actual use, within the bars of a common fire-grate, B. (Fig. 102.) The wrought iron bottles in which quicksilver is imported, form convenient retorts for this purpose, a gun barrel being screwed into the neck of the bottle. When these are used (as for obtaining oxygen gas), the fuel should be charcoal; they are liable to melt if anthracite coal is used.

Coating of vessels. * When a coating must sustain a very high temperature, it should be made of the best Stourbridge clay, made into a paste, beaten until perfectly elastic and uniform. A portion should be flattened out into a cake of the required thickness and size adapted to the vessel. If the vessel be a retort or flask, it should be placed in the middle of the cake, and the edge of the latter be raised on all sides, and gradually moulded and applied to the glass; if it be a tube, it should be laid upon one edge of the plate, and then applied by slowly rolling the tube forward. In all cases the surface to be coated should be rubbed over with a piece of the lute dipped in water, for the purpose of moistening, and leaving a little of the earth upon it; and if any part of the surface becomes dry before the lute is applied, it should be remoistened. The lute should be pressed and rubbed down upon the glass, successively, from the part where the contact was first made to the edges, until all air bubbles are excluded, and an intimate adhesion effected. Care must be taken to exclude all air from between the glass and lute, and the edges should be moistened, made thin, and joined with great care. The general thickness may be from one fourth to one third of an inch. The vessels are afterwards to be placed in a warm situation over the sand bath, or in the sun's rays: they should dry slowly and regularly. To prevent cracking, horse dung, chopped hay, horse hair, and tow cut short may be incorporated with the lute. The addition of sand, renders the lute more fusible, and is not applicable when very high temperatures are to be sustained. In such cases fragments of broken glass pots, or of broken crucibles, may be used, being first well pulverized; but crucibles, soiled by flux or other impurities must not be so employed. For various kinds of lutes and cements, and directions for their application, &c., see Faraday's *Chem. Manip.* p. 467.

† Great convenience often arises from prolonging the tube by means of *flexible* tubes or hoses; and any number of them may be connected by the attached screws Fig. 95.

Fig. 88.

Graduated Vessels

Sect. II.

Fig. 89.

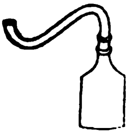
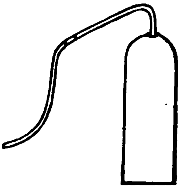


Fig. 90.



Apparatus for receiving gases.

For receiving the gases, glass jars of various sizes are required, some of which should be furnished with necks at the top, fitted with ground stoppers, or to which a circular plate of brass is well ground. (Fig. 91 and 92.)

Fig. 91.

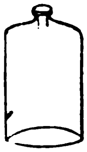
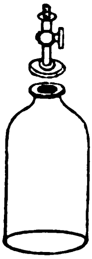


Fig. 92.



Others should be provided with brass caps and screws for the reception of air cocks. (Fig. 93.) Of these air cocks several will be necessary, and to some of them bladders, (Fig. 94, *a*,)[*] or elastic bottles, should be firmly tied for the purpose of transferring gases.

Fig. 93.

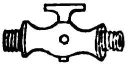


Fig 94.

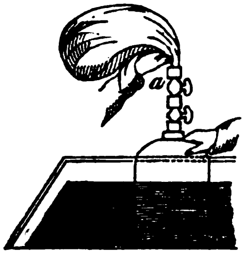
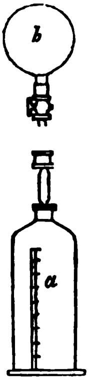


Fig. 95.



Some of the jars should be graduated into cubical inches, (Fig. 95, *a*). To contain these jars, when in use, a vessel will be necessary, capable of holding

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[*] A bladder may be made to continue tight for a considerable period by pouring a little oil into it at first, and allowing it to become saturated. Bladders are not perfectly tight to gases, and are less so when dry than when moist; consequently gases shou'd not be retained long in them, and never longer than is absolutely necessary. Hydrogen gas passes more rapidly through them than any other gas.

Gas bags are made of oiled silk, or of two layers of woven material, having between them a thick layer of caoutchouc. Those made of oiled silk are seldom tight, and rapidly increase in porosity. F.

Pneumatic trough.

a few gallons of water. This is best made of copper, (Fig. 96, *b*,) if of considerable size; or if small, of tin, japanned or painted; *ff*, exhibits a section of this apparatus, which has been termed the pneumato-chemical trough, or pneumatic cistern. Its size may vary with that of the jars employed; and, about one or two inches from the top, it should have a shelf on which the jars may be placed when filled with air, without the risk of being overset. In this shelf should be a few small holes, to which inverted funnels may be soldered. Fig. 97 represents a very convenient form of this apparatus. A glass tube, Fig. 98, about 18 inches long and three fourths of an inch in diameter, closed at one end, and divided into cubic inches and tenths of inches will be required for ascertaining the purity of air. It should be accompanied with a small measure, containing about two cubic inches, and similarly graduated. Glass tubes about five inches long, and half an inch wide, divided decimally, are also necessary. Besides these, the experimentalist should be furnished with air funnels, (Fig. 99), for transferring gases from wide to narrow vessels.

Graduated tubes.

Fig. 96.

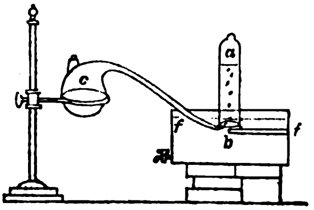


Fig. 97.

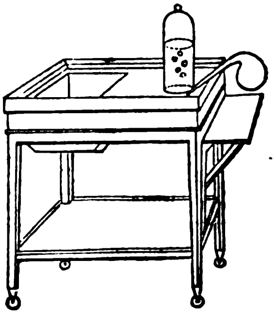


Fig. 98.

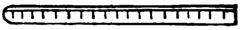
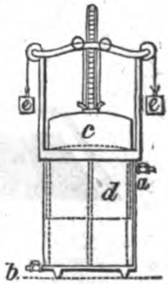


Fig. 99.

Gasometer.

337. An apparatus almost indispensable in experiments on this class of bodies, is a GASOMETER, which enables the chemist to collect and to preserve large quantities of gas, with the aid of only a few pounds of water. In the form of this apparatus there is considerable variety; its general construction and use is as follows. It consists of an outer fixed vessel *d*, (Fig. 100), and an inner movable one *c*, both of copper or japanned iron. The latter slides easily up and down within the other, and is suspended by cords passing over pullies, to which are attached the counterpoises *e e*. To avoid the incumbrance of a great weight of water, the outer vessel *d* is made double, or is composed of two cylinders, the inner one of which is closed at the top and at the bottom. The space of only about half an inch is left between the two cylinders, as shown by the dotted lines. In this space the vessel *c* may move freely up and down. The interval is filled with water as high as the top of the inner cylinder. The cup, or rim, at the top of the outer vessel, is to prevent the water from overflowing, when the vessel *c* is forcibly pressed down, in which situation it is placed, whenever gas is about to be collected. The gas enters from the vessel in which it is produced, by the communicating pipe *b*, and passes along the perpendicular pipe, marked by dotted lines in the centre, into the cavity of the vessel *c*, which continues rising till it is full.

Fig. 100.



Transferring of gases.

338. To transfer the gas or to apply it to any purpose, the cock *b* is to be shut, and an empty bladder, or bottle of elastic gum, furnished with a stop-cock, to be screwed on, *a*. When the vessel *c* is pressed down with the hand, the gas passes down the central pipe, which it had before ascended, and its escape at *b* being prevented, it finds its way up a pipe which is fixed to the outer surface of the vessel, and which is terminated by the cock *a*. By means of an ivory mouth-piece screwed upon this cock, the gas, included in the instrument, may be respired; the nostrils being closed by the fingers. When it is required to transfer the gas into glass jars standing inverted in water, a crook-

ed tube may be employed, one end of which is screwed upon the cock *b;* while the other aperture is brought under the inverted funnel, fixed into the shelf of the pneumatic trough.

Gas-holder.

339. When large quantities of gas are required, (as at a public lecture), the gas-holder (Fig. 101) will be found extremely useful. It is made of copper or tinned iron-plate, japanned both within and without. Two short pipes, *a* and *c*, terminated by cocks, proceed from its sides, and another, *b*, passes through the middle of the top or cover, to which it is soldered, and reaches within half an inch of the bottom. It will be found convenient also to have an air cock with a very wide bore, fixed to the funnel at *b*. When gas is to be transferred into this vessel from the gasometer, the vessel is first completely filled with water through the funnel, the cock *a* being left open and *c* shut. By means of a horizontal pipe, the aperture *a* is connected with *a* of the gasometer. The cock *b* being shut, *a* and *c* are open, and the vessel *c* of the gasometer (Fig. 100), gently pressed downwards with the hand. The gas then descends from the gasometer till the air-holder is full, which may be known by the water ceasing to escape through the cock *c*. All the cocks are then to be shut, and the vessels disunited. To apply this gas to any purpose, an empty bladder may be screwed on *a*; and water being poured through the funnel *b*, a corresponding quantity of gas is forced into the bladder. By lengthening the pipe *b*, the pressure of a column of water may be added: and the gas, being forced through *a* with considerable velocity, may be applied to the purposes of a blow-pipe, &c. &c. The apparatus admits of a variety of modifications. The most useful one appears to be that contrived by Pepys, consisting chiefly in the addition of a shallow cistern (Fig. 102, *c*) to the top of the air-holder, and of a glass register tube *f*, which shows the height of the water, and consequently the quantity of gas, in the vessel. When a jar is intended to be filled with gas from the reservoir, it is placed, filled with water, and inverted in the cistern *c*. The cocks 1 and 2 being opened, the water descends through the pipe attached to the latter, and the gas rises through the pipe *e*. By raising the cistern *a* to a greater elevation, any degree of pressure may be obtained; and a blow-pipe may be screwed on the cock at the left side of the vessel.*

Fig. 101.

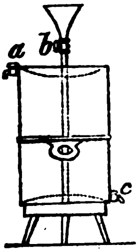
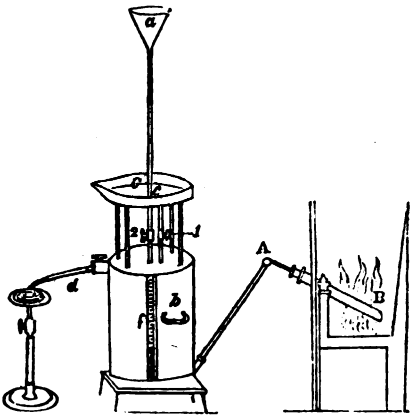


Fig. 102.



Hope's gas-holder.

340. A very convenient apparatus was contrived by Hope, for receiving and storing large quantities of gases most in use, from which a supply may be easily procured as wanted. It consists of a large oil of vitriol bottle *a*, or carboy, (Fig 103.) in which two tubes with stop-cocks are fitted, water being introduced and forced out again when necessary by one, and gas by the other. In the figure i

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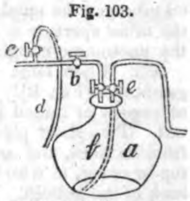
Precautions.

* It is necessary to be aware of the possible entrance of common air with the water, even when there is considerable depth in the cistern. When the gas is passing rapidly out at the lateral stop-cock, and consequently the water rapidly descending through the tube, it will, if unattended to, frequently acquire a rotary motion, which, from mechanical causes easily explained, will at last produce an aperture commencing at the surface of the water and descending to the very bottom of the tube. Down this, air is rapidly carried by the descending water, which, mixing with the gas in the instrument, deteriorates it, and with inflammable gases may lead to dangerous results. Hence this rotary motion when observed, should be disturbed. The formation of the central channel for air may easily be prevented by allowing a large bung or piece of light wood to swim on the surface of the water. If rotation does take place, it will draw the floating mass to the centre, and prevent the air from passing down by hindering the formation of a channel, if water be plentifully supplied. F. 352.

Fig. 103.



may be supposed in connexion with the extremity of a bent gun barrel fixed in an iron retort, from which oxygen is passing. To prevent accident and render it more easily movable when full of water, it should be placed in a tub, the space between the bottle and sides as well as the bottom are packed with saw dust. After filling it with water, a bent tube is connected with the gun barrel by a flexible lead or tin pipe two or three feet in length. No gas is allowed to pass in unless pure, the stop-cock at the extremity of the gun barrel, *b*, being kept shut, while the other one *c*, is open. The gas first passing over can be collected by means of a bent tube *d* fitted to it, in a small jar over water, so that its purity can be tested. When it is thought proper to commence collecting it, the stop-cock *c* is to be shut and the other *b* opened. As the gas enters, the water will be forced up the tube seen in the interior of the bottle continuous with the stop-cock *e* attached to the cap of the carboy; and another bent tube being placed over it a syphon will be formed, through which the water will continue to flow as the gas enters. By using a large quantity of materials at a time, several bottles may be filled successively without undoing any part of the apparatus, except the leaden pipe that connects them directly with the gun barrel; one bottle may be detached and another attached in a few seconds. If wanted, jars of gas may be collected from the tube *d* in the pneumatic trough.

Transferring from.

Fig. 104.

To transfer a gas from this apparatus, detach the syphon, place a tin funnel *x*, (Fig. 104,) above the stop-cock *e*, pour in water and open the stop-cocks; it will descend and force the gas out at the stop-cock *g*, to which a flexible pipe may be attached. In the same manner the air is expelled and the carboy filled with water before connecting it with the retort furnishing the gas.

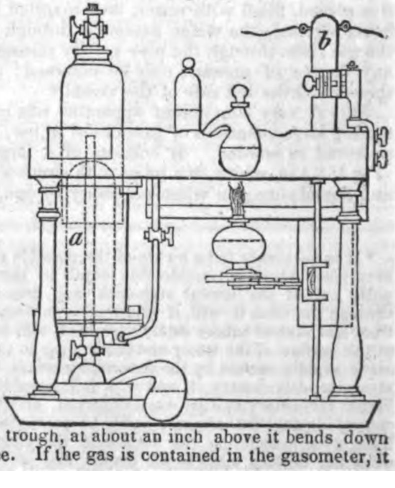
Mercurial gasometers.

341. The gasometers already described, are fitted only for the reception of gases that are confinable by water; because quicksilver would act on the tinning and solder of the vessels; and would not only be spoiled itself, but would destroy the apparatus. Yet an instrument of this kind, in which mercury can be employed, is peculiarly desirable, on account of the great weight of that fluid; and two varieties of the mercurial gasometer have therefore been invented. In that invented by Pepys, the cistern for the mercury is of cast iron. Newmann has joined a gasometer of this kind to an improved mercurial trough, by means of which the advantage of both are obtained with only 60 or 70 pounds of quicksilver.* Fig. 105.

Newmann's mercurial trough.

* It is not more than 18 inches in length and height; and it is placed in a large japanned tray to collect scattered mercury.

Fig. 105.



When gas is to be collected in the gasometer, the beak of the retort is placed below the surface of the mercury, in the cup at the bottom of the apparatus, and having a bell shaped vessel immersed in the mercury immediately over it. The trough has a cavity in the middle, large enough to fill a jar 10 inches long, and 2¼ wide; and there is a shelf on each side, three inches in width, to support vessels containing gas. Opposite to three indentations on the edge of the trough, are three holes in one of the shelves, into which the beaks of retorts liberating gas are to be introduced; or a sliding shelf with apertures may be fitted across the cavity for the same purpose. The gasometer is at one end, *a*, and sunk below the level of the trough. It is capable of containing 50 cubic inches. A tube, connected with the gasometer at the lower part is made to ascend, and passing up through the mercury in a corner of the trough, at about an inch above it bends down again and terminates beneath its surface. If the gas is contained in the gasometer, it

For the mere exhibition of a few experiments, a small trough, eleven inches long, two wide, and two deep, cut out of a solid block of mahogany, (or soapstone) is sufficient.

342. The materials from which some gases are to be obtained, require the aid of a high temperature and a suitable furnace. Various kinds of furnaces are required by the chemist, of which figures and descriptions will be seen in Faraday's *Chemical Manipulation*.*

Furnaces.

For many processes a very convenient furnace may be formed out of the large crucibles known as *blue pots*, and may be had of almost every size less than the height of 22 inches, and of 12 to 14 inches diameter at the top. One of these vessels, of the height of 12 inches, and 7 inches wide at the top, will make a very useful furnace for the igniting of a small crucible, heating a tube, or small retort. Fig. 107. A number of holes are pierced in it, by a gimlet or brad awl, and enlarged by a round rasp. The pot is now bound round with iron or copper wire, to strengthen and hold it together when it cracks, an effect which is sure to take place after it has been a few times heated. This wire should be carried round in three different places, and secured by notches made in the pot with the edge of a rasp, and the ends should then be twisted together. It is also convenient to have a handle to these furnaces.

Fig. 107.

A movable grate like that figured in the wood cut, makes this furnace complete for many operations. Fig. 108. If it be required to heat a crucible, the grate should be of such a size as to drop into the furnace, and rest between the bottom and the second row of holes. The part below then forms the ash-pit to be supplied with air by the four holes; and the part above forms the body of the furnace to receive the fire and the crucible. If a shallow fire only is wanted, as in the process of distillation or the heating of tubes, the grate should be of such size as, when dropped

Fig. 108.

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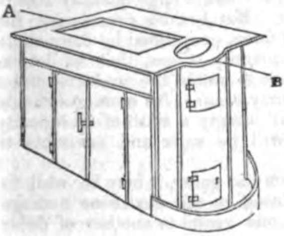
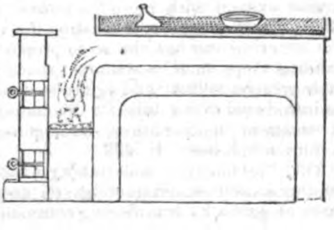
may be transferred to air-jars in the trough, by filling them with mercury, placing them over the end of the bent tube, and giving pressure to the gasometer. The air will pass from it along the tube into the jar. By the bend in the tube, the mercury is prevented from passing into the lower part of the gasometer, while at the same time the gas is allowed a free passage. All inconvenience is prevented by means of a stop-cock, which shuts off the communication between the receiver and the trough, preventing at the same time the escape of air from the gasometer, and of mercury into it. A sliding shelf is fixed beneath the trough to support a spirit-lamp under a retort, or for other purposes. A detonating tube *b*, (Fig 106) and spring are also attached to the apparatus by a clamp and screws, and may be fixed on any side of the trough. The whole apparatus is of iron, excepting sometimes the pillars which support it, and which may be of brass. See another form Fig. 110.

Fig.106.

* A work which should be in the possession of every chemical student. A furnace for general laboratory use which has been found powerful and convenient, was originally constructed for the Royal Institution* of the form and section represented in the annexed figures. It warms and airs the laboratory, heats water, tubes, gas bottles, a sand bath, &c. The principal part is of brick work, the top plate A B, sand bath, plate under the same and front may be of iron or soap stone. The flue is carried horizontally





under the sand bath, and a warm chamber is left beneath, which is closed by doors, in which crucibles or other vessels may be kept warm, ready for introduction into the furnace, and slow evaporations be carried on. The circular opening in front, over the fire chamber, is adapted to receive various vessels, by means of concentric iron rings of various diameters, on a cast iron pot.

* Furnaces of this kind have for several years past, been in use in the laboratory of the University at Cambridge, and in that of the Medical College in Boston, and proved admirably adapted for all purposes. For minute description see Faraday, p. 90.

into the furnace, to descend only a little below the first tier of holes, the ash-pit having two tiers of holes entering it. Half a dozen of these small grates will be required in the laboratory, for the purpose of fitting at different times into different parts of the same furnace, and also for use in different sized furnaces of the kind now described.

When we wish to diminish the intensity of the fire, the holes or a portion of them may be closed with soft brick or clay stoppers. On the contrary, when it is desirable to increase the temperature, or to increase the body of fuel, additions are made at the top of the furnace. A very useful one consists of the upper part of an old crucible cut off so as to form a ring, (Fig. 109,) which should be bound round with wire, as was directed in regard to the furnace.

Fig. 109.

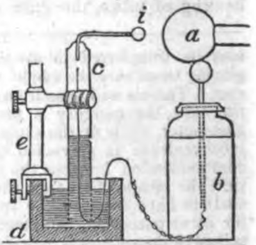
A most useful accompaniment to these small portable furnaces, is a piece of straight funnel pipe, about two feet long, four inches in width, and opening out below until it is about eight inches in diameter. Fig. 110. This will easily rest upon any furnace not more than eight inches nor less than four or five inches wide; is quickly put on or off; stands steadily of itself, and increases the draught powerfully. A wooden handle may be attached to it for convenience; or without it, the tongs will serve to remove it. It may either be taken off when the fire requires to be made up, or the pieces of charcoal may be dropped in from above. There is no difficulty in raising a crucible two inches and a half in diameter to a white heat, by a furnace of this kind, and that in any situation which may be convenient, upon the tables or the floor, and with all the advantage of arranging or dismounting the apparatus with extreme facility.*

Fig. 110.

Apparatus for submitting gases to electricity.

343. A useful apparatus, *for submitting gases to the action of electricity*, is shown in Fig. 111; where *a* represents the knob of the prime conductor of an electrical machine; *b*, a Leyden jar, the ball of which is in contact with it, as when in the act of charging; and *c*, the tube standing inverted in mercury, and partly filled with gas. The mercury is contained in a strong wooden box *d*, to which is screwed the upright iron pillar *e*, with a sliding collar for securing the tube *c* in a perpendicular position. When the jar *b*, is charged to a certain intensity, it discharges itself between the knob *a* and the small ball *i*, which, with the wire connected with it, may be occasionally fitted on the top of the tube *c*. The strength of the shocks is regulated by the distance between *a* and *i*.

Fig. 111.



By the same apparatus, or the tube, Fig. 106, inflammable mixtures of gases may be exploded by electricity.

Quantity of gas to be detonated.

344. The proportion of gas which may be detonated with safety in a glass tube, depends considerably upon the explosive power of the particular mixture under examination, and also upon the quantity detonated at once. A mixture of oxygen with carbonic oxide expands, when inflamed, with much less force than a mixture of oxygen with hydrogen or olefiant gas; and a large quantity will of course expand with more force than a smaller. But besides considering the efficiency of the tube in resisting the expansive force, occasioned by detonation, the experimenter has also so to proportion the quantity of gas, that whilst expanding there shall be abundant space in the tube to retain the products under their greatest volume and agitation, that no loss may occur. No more gas should be introduced into a tube for detonation than will occupy a sixth of its capacity at common temperatures, and, generally, it will be safer and advisable to employ much less. F. 433.

Methods of transferring gases.

345. Previously to undertaking experiments on the gases, it may be well for an unpractised experimentalist to accustom himself to the dexterous management of gases, by transferring common air from one vessel to another of different sizes.

1. When a glass jar, closed at one end, is filled with water, and held with its

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* Faraday: who remarks that all the ignitings and heatings which belong to the analysis of siliceous and other minerals, have long been made in furnaces of this kind at the Royal Institution.

mouth downwards, in however small a quantity of water, the fluid is retained in its place by the pressure of the atmosphere on the surface of the exterior water. Fill in this manner, and invert, on the shelf of the pneumatic trough, one of the jars, which is furnished with a stopper (Fig. 91,). The water will remain in the jar so long as the stopper is closed; but immediately on removing it, the water will descend to the same level within as without; for it is now pressed, equally upwards and downwards, by the atmosphere, and falls therefore in consequence of its own gravity.

Directions for practice.

2. Place the jar, filled with water and inverted, over one of the funnels of the shelf of the pneumatic trough. Then take another jar, filled (as it will be of course) with atmospherical air. Place the latter with its mouth on the surface of the water; and on pressing it in the same position below the surface, the included air will remain in its situation. Bring the mouth of the jar beneath the funnel in the shelf, and incline it gradually. The air will now rise in bubbles, through the funnel, into the upper jar, and will expel the water from it into the trough.

3. Let one of the jars, provided with a stop-cock at the top, be placed full of air on the shelf of the trough. Screw upon it an empty bladder; open the communication between the jar and the bladder, and press the former into the water, (Fig. 94.) The air will then pass into the bladder, till it is filled; and when the bladder is removed from the jar, and a pipe screwed upon it, the air may be again transferred into a jar inverted in water.

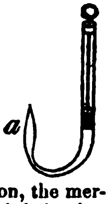
Cavendish's method.

4. For the purpose of transferring gases from a wide vessel standing over water, into a small tube filled with and inverted in mercury, the following contrivance of Cavendish may be used. A tube, eight or ten inches long, and of very small diameter, is drawn out to a fine bore, and bent at one end, so as to resemble the italic letter *l*. The point is then immersed in quicksilver, which is drawn into the tube till it is filled, by the action of the mouth. Placing the finger over the aperture at the straight end, the tube is next conveyed through the water, with the bent end uppermost, into an inverted jar of gas. When the finger is removed, the quicksilver falls from the tube into the trough, or into a cup placed to receive it, and the tube is filled with the gas. The whole of the quicksilver, however, must not be allowed to escape; but a column must be left, three or four inches long, and must be kept in its place by the finger. Remove the tube from the water; let an assistant dry it with blotting paper; and introduce the point of the bent end into the aperture of the tube standing over quicksilver. On withdrawing the finger from that aperture which is now uppermost, the pressure of the column of quicksilver, added to the weight of the atmosphere, will force the gas from the bent tube into the one standing in the mercurial trough.*

Pepys' instrument for transference.

346. For the transference of small quantities of gas from one vessel to another, the instrument contrived by Pepys is convenient. It is made of a piece of glass tube, about half an inch in diameter and five inches long, attached to a piece of smaller diameter, which, after bending as in Fig. 112, terminates in a chamber at *a*, which being cylindrical for the greater part of its length, terminates in a capillary tube and aperture. A small piston, rendered air-tight by tow and tallow, is fitted into the cylindrical tube; it is moved by a rod and ring, the rod passing through a box which closes the upper aperture of the instrument, but which should not be air-tight. A portion of mercury is placed above the piston, the space between it and the capillary opening of the chamber, is filled with the same metal when the piston is in the position depicted. Upon raising the piston, the mercury follows it, and descends into the chamber *a*, the space left by it being immediately filled with the air or gas which has access to the capillary opening. The rod has a graduation upon it, by which it is known when a tenth of a cubical inch of air has entered the chamber. F. 340.

Fig. 112.



Manipulation with tubes.

347. The manipulation with jars and glasses is comparatively easy to that which occurs in transference from them to tubes, or from tubes to each other. One circumstance with tubes which occasions difficulty, in addition to the narrowness of their mouths, is, their contracted capacity within, by which the easy

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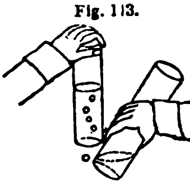
* In collecting and transferring gases over quicksilver, especially where the quicksilver is impure or dirty, the gas will escape on the outside of the jar, there being so little adhesion between the quicksilver and the glass; this, I have found, may be partially guarded against by slightly smearing the edge of the jar with pomatum. W.

passage of a bubble of gas upwards, and water downwards, at the same time, is interfered with; this effect is greatest in tubes of the smallest diameters. No great difficulty will occur in the transference of gas from a tube to another that is wider. (Fig. 113.) The second tube is to be filled in the usual manner with water, and held in the well of the trough, in a considerably inclined position: the tube containing the gas is to be brought near it, the upper edge of its mouth inserted as it were into the mouth of the first, and then its position slowly altered, until the gas passing towards the mouth be gradually delivered in distinct bubbles into the first tube. During this transfer, the mouth of the second tube should be retained as much as possible within the first; the latter should not be raised to a perpendicular position, but be considerably inclined, for then the edges of its mouth meet better with, and are adapted to, those of the second tube, so as to confine the gas, and the motion of the bubbles is less sudden and less subject to derangement. Occasionally it is advantageously placed in almost a horizontal position, its closed extremity being but little raised. One bubble of gas should be allowed to rise to some height in the tube before another is permitted to follow.

Fig. 113.



Transferring from large to small tubes,

348. When the delivering tube is larger than the receiving tube, more care is required in the transfer. The first tube should be inclined as before, and the upper edge of the mouth of the second placed within it, and to assist in uniting as it were the two tubes for the moment, the finger and thumb of the left hand (which holds the receiving tube) should be applied at the sides of the junction, so as to confine the gas and prevent its escape laterally. For this purpose, and generally in tube transference, the tube is best held in the hand, with its open extremity passing out between the thumb and fore finger, so that when sustained in the water in an inclined position the back of the hand may be upwards, the hand being as it were over the vessel; the tube is then easily supported by the two or three last fingers of the hand, and the fore finger and thumb are left at liberty to guide the mouths of the vessels or to close the lateral opening, as has been just described. At other times it may be held as a pen is retained in the hand, the mouth being confined and guided between the thumb and two fore fingers. The tubes should at all times be retained by a light and easy, though secure hold, and not in a stiff rigid manner, and the arms may often be allowed to rest with advantage on the edge of the trough, whilst the hands are immersed in the water.

From jars.

349. An intermediate lipped glass should be used for the transference of gas from a large jar to a tube. The tube being filled with water is to be held under the surface as before described (347); the lip is to be introduced into it, the junction made by the fingers if necessary, as in the former case, and the gas allowed to pass in distinct bubbles. It will be found easier to transfer from a glass that is from a third to five-sixths full of gas, than from one containing more or less. When a glass is nearly empty, it is often exceedingly difficult to transfer from it into a narrow tube. Advantage may therefore occasionally be taken of the circumstance above mentioned, to replenish the glass with gas.

Removing tubes containing gas.

350. Tubes containing gases are easily transferred from one trough to another, or to other situations, merely by closing their mouths with the finger or thumb, and carrying them to the required situation. The student should very early attain the habit of closing the mouth of a tube by the finger with facility and security. The accurate manipulation of gas in tubes, so that none shall escape and be lost, is often essential in experiments of research, where only small portions of gas are evolved for examination as to many of its properties. F. 326.

SECTION III. *Methods of estimating Specific Gravities.*

Specific gravities.

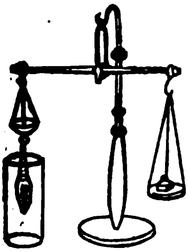
351. Water has been fixed upon as the standard of comparison in estimating specific gravities; and its specific gravity has been called 1.

352. In all experiments for ascertaining the specific gravities of different substances, particularly of gases, great attention must be paid to the temperature, as their volume varies with the degree of heat to which they are exposed.

Specific gravity of solids,

353. To find the specific gravity of a solid body heavier than water,—First, weigh the solid in air; then weigh it in water by a hydrostatic balance in the manner represented in Fig. 114, using a very fine thread, or a hair to suspend it from the bottom of one of the scales. The difference in the results will express the weight of a quantity of water equal in bulk to the solid whose specific gravity is to be determined, and the following proportion will give its specific gravity in relation to water: As the weight of the water equal in bulk to that of the solid is to the weight of the solid itself, so is the specific gravity of water to the specific gravity of the solid. Thus,

Fig. 114.



If the solid weigh 100 grains in air, and 60 grains in water, then 100—60, or 40 : 100 : : 1 : 2.5. The specific gravity of the solid is therefore 2.5 compared with that of water.

Of light bodies,

354. If the solid should be lighter than water, a more complicated process will be necessary. Attach to the light solid by a slender thread another body of such a weight that when tied together they shall sink in water, having previously weighed the heavier solid in water, and each in air; then weigh them together in water, and from the difference between their weight in water and their weight in air, subtract the difference between the weight of the heavy solid in air and its weight in water; the remainder will show the weight of a quantity of water equal in bulk to the light body, and we can then find its specific gravity in the way directed above. Thus,

If the weight in air of the light solid be 10 and of the heavy solid 20; and if the weight of the heavy solid in water be 18, and of the two together 7,—then

From their weight in air, ... $20 + 10 = 30$
Subtract their weight in water, ... 7
—
23
And from this subtract $20—18 = 2$ . . 2
—
The remainder 21

expresses the weight of a quantity of water equal in bulk to the light solid, and the following proportion will give us its specific gravity,

21 : 10 : : 1. : 0.47619,—the specific gravity of the lighter solid.

Another method,

355. Where a hydrostatic balance cannot be procured, the following method may be adopted: Weigh the solid and put it into a vessel full of water, the weight of which with the water is known; the solid will displace a quantity of water equal in bulk to its own; weigh the vessel again, having either taken out the solid body, or put an equal weight in the opposite scale;—the difference between the present weight of the vessel and its former weight will express the weight of a quantity of water equal in bulk to the solid body, from which, by the same proportion as in the former instances, we can estimate the specific gravity of the solid body. Thus, if the vessel when full of water weighed 1000, and after some of the water had been displaced by the solid body and the solid removed, or a counterpoise placed in the opposite scale, it weighed 900 grains,—100 grains of water were displaced by the solid body—and if the solid body in air weighed 300 grains, then the following proportion will give its specific gravity:

100 : 300 : : 1 : 3.

Of soluble bodies,

356. If the solid body be soluble in water, some other fluid, as oil, alcohol, ether, or a saturated solution of the substance itself must be used, its specific gravity being previously ascertained. We must first find the specific gravity of the solid, considering the fluid used as a standard of comparison, and making the number representing its specific gravity the third term in the proportion, in the same manner as when water is used; and then, by simple proportion, reduce the product to the standard of water. Thus, if the specific gravity of the fluid used be 1.2, and, considering it as a standard of comparison, the specific gravity of the solid be 1.8, then the following proportion will give us its real specific gravity:

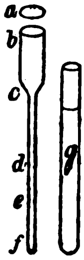
1.2 : 1.8 : : 1. : 1.5.

Of powders,

357. When the substance, the specific gravity of which is to be ascertained, is in the form of a powder, the following method, recommended by Leslie, will be found most convenient. (Fig. 115.) Take a glass tube *b f*, three feet in

Chap. II.

Fig. 115.



length, and open at both ends. The wide part *b c* is to be about $\frac{4}{10}$ of an inch in diameter, and the narrow part *c f* about $\frac{2}{10}$, communicating with each other by a very small aperture at *c*, which allows air to pass, but is sufficiently small to prevent any powder from going through. The upper opening at *b* is to be ground, so that it can be accurately closed by a glass plate *a*. The substance whose specific gravity is to be determined, is put into the wide part of the tube *b c*, which is then to be placed in a wider tube containing mercury *g*, making it descend till the fluid metal shall have reached the aperture at *c*. Then fix the cover, making it air-tight with a very small quantity of lard, and lift it perpendicularly out of the mercury, till the aperture at *c* shall have been raised above the surface of the mercury in the tube to a height exactly equal to half the height of the barometer at the time the experiment is made, and mark the point at which the smaller tube is cut by the fluid, which we shall suppose in the present instance to be *d*. The air within that part of the tube in which the powder has been placed being now subjected to the pressure of only half an atmosphere, it expands to double its former volume, one half still remaining within *b c*, while the rest occupies *c d*, the space it includes representing therefore the total bulk of air included at first along with the powder in *b c* at the ordinary pressure. The powder is now withdrawn, and the process repeated with *b c* full of air only, when it is obvious that the mercury will not stand so high within the tube *c f* as before, and supposing it to rise only to *e*, then the space *c e* will contain a quantity of expanded air, equal in bulk exactly to what would be contained in *b c* before lifting up the tube. Since *c e* then represents a space exactly equal to that within *b c*, and *c d* a space equal to the volume of air in *b c* when the powder was in it, then *d e*, the difference between them, shows the space occupied by the powder when it was in *b c*. In this manner, then, we are enabled to find out a space exactly equal in bulk to that of the solid matter in the powder, and if the stem be graduated so as to express in grains the quantity of water which it can contain, we have only to weigh the powder in air and compare its weight with that of the equal bulk of water to ascertain its specific gravity.

Of liquids.

358. Take a bottle of a known weight, fill it with distilled water, and weigh it carefully; then pour out the water, and after drying the bottle, fill it with the liquid to be tried. The following proportion will give its specific gravity: As the weight of the distilled water is to the weight of the liquid, so is 1 to the specific gravity required. Thus, if the weight of the distilled water be 300 grains, and that of the liquid 600, the following is the proportion we must use:—

300 : 600 : : 1. : 2.

Areometer.

The areometer is a convenient instrument for ascertaining the specific gravities of liquids. It consists of a long, straight, graduated stem, on which numbers are marked at the points to which the instrument sinks in liquids of the specific gravities marked at these points. Thus, in distilled water it will sink to 1, and in nitric acid to 1.48. It is made of different materials according to the nature of the liquids whose specific gravities are to be ascertained with it.

Lovi's beads.

Lovi's beads are also very useful for ascertaining the specific gravities of liquids. These are small balls made of glass, with numbers marked on them indicating the specific gravity of those liquids in which they float without any tendency either to sink or rise to the top. Those that float on the surface show that the liquid has a greater specific gravity than the number marked on them expresses, while those that sink indicate the reverse, being heavier than an equal bulk of the fluid.

Of Gases.

359. Atmospheric air is taken as a standard of comparison in estimating the specific gravity of gases, and represented by the number 1. Their specific gravities are found out in the same manner as those of other substances, viz. by comparing the weight of equal bulks of them and of the substance which is taken as a standard of comparison.

For this purpose, a flask provided with a stop-cock is accurately weighed and attached to an air-pump or exhausting syringe, which is worked in the usual manner; and, when the gas whose specific gravity is to be tried has no action on atmospheric air, it is not necessary to exhaust it to a very great degree. The stop-cock fixed to the flask is then turned, when it is weighed again to ascertain the quantity of air extracted. It is then screwed on to a jar (placed over a pneumatic trough) containing the gas whose specific gravity is to be determined, and on opening the stop-cock, a quantity of gas is forced by the pressure of the atmosphere into the flask, exactly equal in bulk to the air which had been withdrawn, if the jar be depressed in the liquid till it shall be level both within and without.

If the flask be then detached from the jar, it is obvious that by weighing it again we can find out the weight of a measure of gas exactly equal in bulk to that of the air whose weight was found out by the first operation.

Example.

For example, if the flask should weigh 570 grains when full of air, and 560 after the exhaustion, then the quantity of air which has been withdrawn weighs 10 grains.

Weight of flask with air	570 grains.
Weight of flask after exhaustion	560 do.
Weight of air withdrawn, ...	10 do.

And if it shall weigh 580 grains after admitting an equal volume of the gas whose specific gravity is to be determined, then it must be twice as heavy, or its specific gravity must be twice as great as that of atmospheric air.

Weight of flask with gas	580 grains.
Weight of flask after exhaustion, ...	560 do.
Weight of gas introduced	20 do.

When the gas whose specific gravity is to be ascertained acts chemically on atmospheric air, the latter must be withdrawn as completely as possible by repeated exhaustions, filling it after each with some gas which is not affected by the other, and then proceeding in the usual manner.

360. In operating with gases, it is also necessary to attend to the pressure of the atmosphere as indicated by the barometer, and the quantity of watery vapour which they may contain. Formulæ have been given for making corrections when the barometer is not at the point adopted as the standard of comparison, and for the quantity of watery vapour which the gases may contain, for which see Faraday's *Chem. Manip.* 375, and Turner, 48.

361. It may be necessary, to remark, that when the specific gravity of a gas is ascertained, and no variation in the pressure of the atmosphere of any consequence takes place in the short space of time necessary for this purpose, and equal bulks of air and the gas whose specific gravity is to be found out having been weighed in this manner, precisely under the same circumstances with respect to pressure, no corrections on this account are required.*

Tube apparatus.

362. Many operations upon the gases may be performed in apparatus formed partly or altogether of glass tube, for a particular description of which, the precautions to be attended to in taking specific gravities, and many other details, the student is referred to Faraday's *Chemical Manipulation.*

363. The experiments of Davy and Faraday have shown that many substances, which had previously been known, when uncombined, only as gases, may be obtained in a liquid state by generating them under pressure.

Liquefaction of gases.

When thus compressed, a very moderate heat is sufficient to make them boil; and on the removal of pressure they re-assume the elastic form, most of them with such violence as to cause a report like an explosion, and others with the appearance of brisk ebullition. An intense degree of cold is produced at the same time, in consequence of caloric becoming latent.

Process.

The process for condensing the gases consists in exposing them to the pressure of their own atmospheres.†

The materials for producing them are put into a strong glass tube about eight inches long, which is afterwards sealed hermetically; then, being softened in the flame of a lamp, at about five inches from the closed end, it is to be bent, not sharply, but obtusely and roundly, until the two limbs make an angle of about 130° or 140°. The gas is generated, if necessary, by the application of heat,

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* Reid's *Elements of Pract. Chem.*

† See *Carbonic Acid.*

and when the pressure becomes sufficiently great, the liquid forms and collects in the free end of the tube, which is kept cool to facilitate the condensation.*

Pressures required. The pressure required to liquefy the gases is very variable, as will appear from the following table of results obtained by Faraday:

			Atmospheres.	
Sulphurous acid gas		. . . .	2	at 45° F.
Sulphuretted hydrogen gas		. .	17	" 50°
Carbonic acid	"	. .	36	" 32°
Chlorine	"	. .	4	" 60°
Nitrous oxide	"	. .	50	" 45°
Cyanogen	"	. .	3,6	" 45°
Ammoniacal	"	. .	6,5	" 50°
Muriatic acid	"	. .	40	" 50°

CHAPTER III.

INORGANIC CHEMISTRY.

SECTION I. *Oxygen.*

Symb.	*Sp. Gr.*	*Equiv.*
O	1.1024 air =1	By Vol. 50.
	16.00 Hyd.=1	" Wgt. 8.

Discovery. 364. Oxygen has never been obtained in a state of complete separation. In the state of gas, it was discovered in 1774 by Priestley, who gave it the name of *dephlogisticated* air. It was called *Empyreal air*, by Scheele, and *Vital air* by Condorcet.

How obtained. 365. It may be obtained from various substances. 1. From the black or peroxide of manganese, heated to redness in a gun-barrel, or in an iron retort (Fig. 89); or from the same oxide, heated by a lamp in a retort, (Fig. 96, *c*,) or gas bottle, (Fig. 87,) with half its weight of strong sulpuric acid. One pound of manganese is capable of furnishing from 40 to 50 wine pints of gas. But as manganese is often contaminated with a small proportion of carbonate of lime, it is advisable, before using it, to wash it with hydrochloric acid diluted with 15 or 20 parts of water; then with distilled water; and afterwards to dry it at a moderate heat.

Theory. To understand the theory of these processes, it is necessary to bear in mind the composition of the three following oxides of manganese:

	Manganese.	*Oxygen.*	
Protoxide .	27.7 or 1 equiv.	+ 8 .	=35 7
Sesquioxide	27 7 . .	+ 12 .	=39.7
Peroxide	27.7 . .	+ 16 .	=43.7

On applying a red heat to the last, it parts with half an equivalent of oxygen, and is converted into the sesquioxide. Every 43.7 grains of the peroxide will, therefore, lose, if quite pure, 4 grains of oxygen, or nearly 12 cubic inches; and one ounce will yield about 128 cubic inches of gas. The action of sulphuric acid is different. The peroxide loses a whole equivalent of oxygen, and is converted into protoxide, which unites with the acid, forming a sulphate of the protoxide of manganese. Every 43.7 grains of peroxide must consequently yield 8 grains of oxygen and 35.7 of protoxide, which by uniting with one equivalent (40.1) of the acid, forms 75.8 of the sulphate. The first of these processes is the most convenient in practice.

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* These experiments are dangerous and should not be undertaken without attending to the directions given by Faraday in Sect. xvi. *Chem. Manip.*

2. From various other oxides, as will be hereafter mentioned.

3. From nitrate of potassa (common saltpetre) made red-hot in a gun-barrel, or in a coated earthen retort.

4. From the salt called chlorate of potassa. For this purpose, the salt should be put into a retort of green glass, or of white glass made without lead, and be heated nearly to redness. It first becomes liquid, though quite free from water, and then, on increase of heat, is wholly resolved into pure oxygen gas, which escapes with effervescence, and into a white compound, called chloride of potassium, which is left in the retort. The composition of the chloric acid and potassa which constitute the salt, is stated below;—

Chlorine	35.42 or 1 eq.	Potassium	39.15 or 1 eq.
Oxygen	40 or 5 eq.	Oxygen	8 or 1 eq.
Chloric acid	75.42 or 1 eq.	Potassa	47.15 or 1 eq.

Hence the oxygen which passes over from the retort, is derived partly from the potassa and partly from the chloric acid; while chlorine and potassium enter into combination. Thus are 122.57 grains of the chlorate resolved into 74.57 grains of chloride of potassium, and 48 grains, or about 161 cubic inches, of pure oxygen.

Properties of oxygen gas.

366. Oxygen gas is insipid, colourless, and inodorous. It is so sparingly absorbed by water, that when agitated in contact with it, no perceptible diminution takes place. 100 cubical inches at mean temperature and pressure, weigh 34.1872 grains. It refracts the rays of light less than any other gas. When suddenly and strongly compressed, heat is evolved, and a luminous appearance observed from the combustion of the oil with which the compressing tube is lubricated.*

Effect of compression.

Supports respiration.

367. It is a powerful supporter of respiration and combustion. No animal can live in an atmosphere which does not contain a certain portion of uncombined oxygen; for an animal soon dies if put into a portion of air from which the oxygen has been previously removed by a burning body. It may, therefore, be anticipated that oxygen is consumed during respiration. Respiration and combustion have the same effect. An animal cannot live in an atmosphere which is unable to support combustion; nor, in general, can a candle burn in air which contains too little oxygen for respiration.

Effect on animals.

It is singular that, though oxygen is necessary to respiration, in a state of purity it is deleterious. When an animal is supplied with an atmosphere of pure oxygen gas, no inconvenience is at first perceived; but after the interval of an hour or more, the circulation and respiration become very rapid, and the system in general is highly excited. Symptoms of debility subsequently ensue, followed by insensibility: and death occurs in six, ten, or twelve hours. On examination after death, the blood is found highly florid in every part of the body, and the heart acts strongly even after the breathing has ceased.†

The absorption of oxygen gas by the blood, and the change of colour that results, may be shown by passing up a little dark venous blood into a jar filled with the gas, or by agitating a portion in a phial filled with it.

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* Thenard.

† Broughton.

Chap. III.

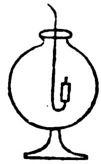
Supports combustion.

All combustible bodies burn in oxygen gas with greatly increased splendour.

Exp.

A lighted wax taper, fixed to an iron wire, and plunged into a vessel of this gas, burns with great brilliancy. (Fig. 116.) If the taper be blown out, and let down into a vessel of the gas while the snuff remains red hot, it instantly rekindles, with a slight explosion.

Fig. 116.



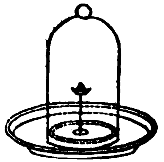
A red-hot bit of charcoal, fastened to a copper wire, and immersed in the gas throws out beautiful sparks.

Combustion of phosphorus,

The light of phosphorus burning in this gas, is exceedingly bright.

Let the phosphorus be placed in a small hemispherical tin cup, which may be raised by means of a wire stand, (Fig. 117,) two or three inches above the surface of water contained in a broad shallow dish. Fill a bell-shaped receiver, having an open neck at the top, to which a stopper is ground, with oxygen gas; and as it stands inverted in water, press a circular piece of pasteboard, rather exceeding the jar in diameter, over its mouth. Cover the phosphorus instantly with the jar of oxygen gas, retaining the pasteboard in its place, till the jar is immediately over the cup. When this has been skilfully managed, a very small portion only of the gas will escape. The stopper may now be removed, when the water will rise to the same level within as without the jar, and the phosphorus may be kindled by a heated copper wire.*

Fig. 117.



Exp.

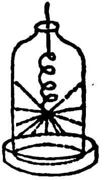
Of zinc and other metals,

Substitute for the phosphorus a small ball formed of turnings of zinc, in which about a grain of phosphorus is to be enclosed. Set fire to the phosphorus as before. The zinc will be inflamed, and will burn with a beautiful white light. A similar experiment may be made with metallic arsenic, which may be moistened with spirit of turpentine. The filings of various metals may also be inflamed, by placing them in a small cavity, formed in a piece of charcoal, igniting the charcoal, and blowing, on the part containing the metal, a stream of oxygen gas from a bladder, or the gas-holder, Fig. 102, *d.*

Of Iron.

The combustion of iron or steel wire in this gas is remarkably brilliant. The wire best suited for this experiment is the fine guitar wire; it should be doubled several times so as to form a bundle, which is easily done by passing it round two nails fixed in the table about eighteen inches apart, and securing the bunch by loosely winding the last turn round it. Before removing it from the nails, the flame of a spirit lamp should be slowly passed along the wire so as to give a low red heat to every inch, and thus diminish its elasticity. When cool, the bunch is to be coiled round a tube or rod of about ¾ths of an inch in diameter. Attach one end to a metallic plate,† and to the other fix a small piece of cotton dipped in melted sulphur. A large jar (Fig. 118) having been filled with the gas, remove the stopple, light the sulphur, and introduce the coil.‡ The iron will burn with a most brilliant light, throwing out a number of sparks, which fall to the bottom; if a bottle is used the bottom is liable to be broken, this accident, however, may frequently be prevented by pouring sand into the bottle, so as to lie about half an inch deep on the bottom. By directing the flame of a spirit lamp, by means of a current of oxygen gas, upon a small ball of lime, the most intense light is produced. An apparatus for this purpose has been described by Drummond in *Edin Jour. of Sci.* v. 319.§

Fig. 118.



Exp.

A little of Homberg's pyrophorus, a substance to be hereafter described, when poured into a bottle full of this gas, immediately flashes like inflamed gunpowder. H. 1. 208.

Oxygen diminishes during combustion.

368. During every combustion in oxygen gas it suffers a considerable diminution.‖ The fact may be shown by the combustion of

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* For Hare's apparatus see his *Compendium*, p. 103.

† The wire should never be suspended from a cork, as it may take fire.

‡ Watch springs, partially deprived of their elasticity in the same way, may be used.

§ The light and heat of an Argand lamp supplied with oxygen, as contrived by Dr C. T. Jackson, are intense. See plate second.

‖ To exhibit this, experimentally, in a manner perfectly free from all sources of error, would require such an apparatus as few beside adepts in chemistry are likely to possess. The apparatus required for this purpose, is described in the 6th chapter of Lavoisier's *Elements*.

phosphorus, in the manner which has been already described. The first effect of the combustion will be a depression of water within the jar; but when the combustion has ceased, and the vessel has cooled, a considerable absorption will be found to have ensued.*

In this process a white dense vapour is produced, which condenses on the inner surface of the jar in solid flakes. This substance has strongly acid properties; and, being formed by the union of oxygen with phosphorus, is termed the phosphoric acid. In the instance of charcoal, though that substance undergoes combustion, no absorption ensues; because, as will appear in the sequel, the product is a gas, occupying exactly the same bulk as the oxygen gas submitted to experiment.

Stahl's idea of combustion.

369. The phenomena of combustion were referred by Stahl and his associates, to a peculiar principle which they called *phlogiston;* it was supposed to exist in all combustibles, and combustion was said to depend upon its separation; but this explanation was absurdly at variance with the well known fact, that bodies during combustion increase in weight.

Bodies increase in weight.

370. All bodies, by combustion in oxygen gas, acquire an addition to their weight; and the increase is in proportion to the quantity of gas absorbed, viz. about one third of a grain for every cubic inch of gas.—To prove this by experiment, requires a complicated apparatus. But sufficient evidence of this fact may be obtained by the following very simple experiment.

Exp.

Fill the bowl of a common tobacco pipe, with iron wire coiled spirally, and of known weight: let the end of the pipe be slipped into a brass tube, which is screwed to a bladder filled with oxygen gas: heat the bowl of the pipe, and its contents, to redness in the fire, and then force through it a stream of oxygen gas from the bladder. The iron wire will burn; will be rapidly oxidized; and will be found, when weighed, to be considerably heavier than before. When completely *oxidized* in this mode, 100 parts of iron wire gain an addition of about 30.

Theory of Lavoisier,

371. After the discovery of oxygen gas, it was adopted by Lavoisier as the universal supporter of combustion. The basis of the gas was supposed to unite to the combustible, and the heat and light which it before contained in the gaseous state, were said to be evolved in the form of flame. But in this case, several requisites are not fulfilled; the light depends upon the combustible, and not upon the quantity of oxygen consumed; and there are very numerous instances of combustion, in which oxygen, instead of being solidified, becomes gaseous during the operation; and, lastly, in others, no oxygen whatever is present. Combustion, therefore, cannot be regarded as dependent upon any peculiar principle or form of matter.

Insufficient.

Berzelius' view.

Berzelius, in adopting the electro-chemical theory, regards the heat of combination as an electrical phenomenon, believing it to arise from the oppositely electrical substances neutralizing one another, in the same manner as the electric equilibrium is restored during the discharge of a Leyden jar. There are, indeed, strong grounds for believing that electrical action is an essential part of every chemical change, and it is probable that the heat developed during the latter may be due to the former; but this part of science is as yet too imperfect for indicating the precise mode by which the effect is

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* Those persons who are possessed of a mercurial apparatus may repeat this experiment in a less exceptionable manner, as described in Henry's *Chemistry*, I. 210.

produced. The heat emitted during combustion varies with the nature of the material.* T. 157.

Products. 372. The substances, capable of uniting with oxygen, afford *acids* and *oxides*.

373. The name oxygen, from *οξὺς acid*, and *γεννάω I generate*, was proposed by Lavoisier, from the supposition that it was the sole cause of acidity. But oxygen is not essential to the acidity of a compound, for some bodies are rendered acid by union with chlorine, others by hydrogen; and the theory of Lavoisier which considered oxygen as the essential principle of acidity, can no longer be received as correct.

Oxygen not essential to acidity.

In many instances, a combustible body, which affords an acid when united with a certain quantity of oxygen, gives an *oxide* when combined with a less quantity; and the acid may be brought back to the state of an oxide by separating part of its oxygen. Some of the metals also, combined with a small proportion of oxygen, give oxides capable of uniting with acids and of composing *salts*, and again united with more oxygen yield an acid which is susceptible, with oxides, of forming saline compounds.

Action of acids containing oxygen. 374. When acids, containing much oxygen, are poured on substances that have a great affinity for this element, as metals and some inflammable bodies, oxygen is rapidly taken from them. The combination with the liberated oxygen is, in some cases, so rapid, as to give rise to combustion; as when nitric acid is poured upon spirits of turpentine, or phosphorus. See *nitric acid*.

Oxidation of mercury. 375. Mercury is speedily oxidized by the same acid, and also if boiled in sulphuric acid. In both cases, however, the oxide formed by the decomposition of one portion of the acid unites with another portion that has not been decomposed, and the resulting products are a nitrate and a sulphate of the oxide of mercury.

Deoxidation. 376. When oxygen is to be removed from any substance which does not part with it on exposure to heat, the substance is often mixed with charcoal, which, at a high temperature, has a much greater affinity for oxygen than most other substances. It is in this manner that most of the common metallic oxides are deoxidized, and their bases procured in a metallic form; the carbon combining with the oxygen and passing off in the form of carbonic acid gas. F.

Section II. *Hydrogen.*

Symb.	*Sp. Gr.*	*Chem. Equiv.*
H.	0.0689 air =1	By Vol. 100
	1.00 Hyd.=1	" Wgt. 1

Discovery, &c. 377. This gas was formerly termed *inflammable air*, from its combustibility, and *phlogiston*, from the supposition that it was the matter of heat; but the name *hydrogen*, from *ὕδωρ water*, and *γεννειν* to *generate*, has now become general. Its nature and leading properties were first pointed out in the year 1766 by Cavendish.†

The most simple form in which it has hitherto been obtained, is in that of a gas. Of its nature we know but little, but as it has not yet

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* See Dalton's *Chem. Philos.* ii. 309.

† *Phil. Trans.* lvi. 144.

been resolved into any more simple form, it is still arranged among elementary bodies.

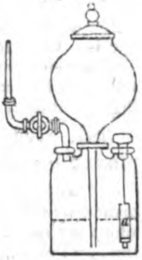
Method of procuring hydrogen gas.

378. To procure hydrogen gas, let sulphuric acid, previously diluted with five or six times its weight of water, be poured on iron filings, or on small iron nails; or (what is still better) pour sulphuric acid diluted with eight parts of water, on zinc, granulated by pouring it melted into cold water, and contained in a gas bottle, Figs. 86, 87, or small retort. An effervescence will ensue, and the escaping gas may be collected in the usual manner over water.

Inflammable air lamp.

379. An ingenious apparatus for obtaining it instantaneously in a laboratory, was contrived by Gay-Lussac.

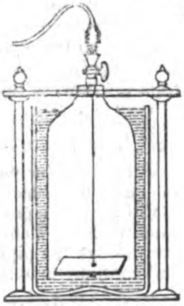
Fig. 119.



It consists of a three necked glass bottle, (Fig. 119,) one of whose openings has a stopper, from which is suspended a small cylinder of zinc *a*. To the opposite aperture is fixed a bent brass tube furnished with a stop-cock, on which may be screwed either a small jet for burning the gas, or a tube to conduct it wherever it may be required. The upper vessel is of glass, and ground to fit the middle neck, its pipe reaching within a small distance of the bottom of the bottle. To use the apparatus, the lower vessel is filled with sulphuric acid properly diluted, aud the zinc cylinder is then introduced, the stopper being closed to which it is affixed, and the cover of the upper vessel removed. The gas which is generated drives the diluted acid into the upper vessel, and the further production of it ceases, when the zinc is completely uncovered. We have then the bottle filled with gas; and can at any time expel it by opening the cock, and allowing the atmosphere to press on the surface of the liquid in the globular vessel.

Self-regulating reservoir.

Fig. 120.



A more convenient modification of this apparatus has been contrived by Hare (Fig. 120.) It consists of two vessels, one withinthe other, the inner one having no bottom is furnished with a stop-cock at the upper part. A piece of zinc is suspended in the inner vessel; acid and water, previously cooled, being poured into the space between the two vessels, (the stop-cock being open,) will expel the air and rise in the inner vessel; coming in contact with the zinc, hydrogen will be given off. The gas should be allowed to escape until all the air has been expelled from the inner vessel. The stop-cock being now closed, the hydrogen will accumulate in the inner vessel, press upon the acid and water, and force it into the space between the two vessels. This will go on until the zinc is no longer in contact with the liquid. The inner vessel will be a reservoir of hydrogen, from which any desired quantity can be drawn on opening the stop-cock. A straight pipe, or flexible tube, being screwed upon the stop-cock, the gas may be conveyed into any other piece of apparatus. As the gas passes out, the acid and water rise in the inner vessel, and again come in contact with the zinc, and more hydrogen is obtained.

Impure as commonly obtained.

380. Hydrogen gas, thus obtained, is not, however, to be considered as absolutely pure.*

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* The gas may be partially purified by passing it through a solution of pure potassa, or obtained purer by using distilled zinc. In order to purify the zinc, Thomson exposes it to a white heat in a stone ware retort, luted to a receiver nearly filled with water. At this temperature, the zinc is sublimed and freed from all its impurities, except a trace of cadmium too minute to occasion any sensible error. The zinc thus distilled over is melted in a crucible and poured upon the surface of a clean smooth sandstone, upon which it forms a thin sheet which can be easily broken into small pieces. T. *First Prin.* 1. 52.

Chap. III.

Properties. 381. Hydrogen is an aëriform fluid, but very slightly absorbable by water. It has no taste, and may be respired for a short time, though it is fatal to small animals. As usually prepared, it has a disagreeable odour, but when pure has none.*

Exp. It may be breathed a few times with safety, and if the experimenter speak *immediately* on removing his lips from the mouth-piece of the bag or bladder, a remarkable change in the voice is perceived.

Weight and specific gravity. 382. It is the lightest body known, and is therefore conveniently assumed as unity in speaking of the specific gravity of gases, as well as in referring to the proportions in which bodies combine. 100 cubic inches weigh 2.1367 grains. It is 16 times lighter than oxygen.

383. The levity of hydrogen may be proved by experiment.

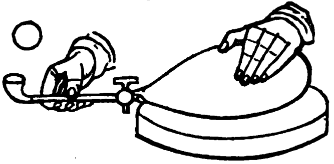
Exp. Let a jar filled with this gas stand, for a few seconds, with its open mouth upwards. On letting down a candle, the gas will be found to have escaped.

Exp. Place another jar of the gas inverted, or with its mouth downwards. The gas will now be found to remain a short time in the jar, being prevented from escaping upwards by the bottom and sides of the vessel.

384. Hydrogen, in consequence of its extreme lightness, is employed for filling air-balloons.

Exp. Fill with hydrogen gas, a bladder furnished with a stop-cock, (Fig. 121;) and adapt to this a common tobacco pipe. Dip the bowl of the pipe into a lather of soap, and, turning the cock, blow up the lather into bubbles; instead of falling to the ground like those commonly blown by children, they will rise rapidly into the air.

Fig. 121.



Exp. The experiment may be varied by filling the bladder with a mixture of two parts of hydrogen gas and one of oxygen gas. Bubbles, blown with this mixture, take fire on the approach of a lighted candle, and detonate with a loud report. It is proper, however, not to set them on fire till they are completely detached from the bowl of the pipe.

Inflammable. 385. Hydrogen is inflammable, and when pure burns with a lambent blue flame at the surface in contact with the air.

Exp. Fill a small jar with the gas, and, holding it with the mouth downwards, bring the gas into contact with the flame of a candle.

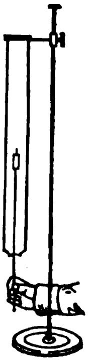
Exp. Fill with this gas a bladder which is furnished with a stop-cock, and with a small pipe, of diameter less than that of a common tobacco pipe. Press the air out through the pipe, and on presenting a lighted candle, the stream will take fire, and continue to burn with a pale and feeble flame.

386. Hydrogen gas does not support combustion.

Exp. Remove a jar, filled with the gas, from the shelf of the pneumatic trough, upon a plate; bring it near a lighted candle, and expeditiously removing the plate, cover the candle; it will be extinguished. At first there will be a slight explosion, from the gas at the mouth of the jar mixing with atmospheric air.

Exp. Suspend a long tube or jar (Fig. 122), with its mouth downward, containing hydrogen gas; remove the stopple and introduce a lighted taper attached to a long wire. The flame of the taper may be extinguished and relighted many times, as the taper is passed up into the gas, or brought down slowly through the portion burning at the mouth of the jar. Care should obviously be taken, that water does not remain about the mouth of the jar.

Fig. 122.



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* Berzelius has shown that the gas generated from iron filings and dilute sulphuric acid, loses its odour by being passed through pure alcohol, and when the alcohol is diluted with water and is kept a few days, an odorous volatile oil is separated, which caused the smell of the gas.

Exp.

Persons who are provided with the jars represented Fig. 94, *a*, may screw to the cock a brass pipe with a small aperture. On pressing the jar, filled with hydrogen gas, into the water, and opening the cock, the gas will be forced out in a stream, which may be set on fire. On this principle are founded the artificial fireworks without smell or smoke. They consist of pipes, having variously sized apertures, some of which have a rotary motion.

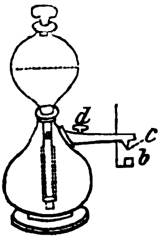
Or the gas may be condensed, by means of a syringe, into a strong copper globe furnished with a stop-cock, to which, on removing the syringe, a brass tube can be screwed, and a variety of jets and revolving burners be attached.

Doebereiner's hydrogen lamp.

387. It has been found by Doebereiner, that when a stream of hydrogen is directed upon spongy platinum, the platinum soon becomes red hot, and the hydrogen is inflamed.*

This discovery has led to various modifications of the inflammable air lamp. A very convenient and ornamental form of which is represented in Fig. 123. It is composed of two glass vessels fitted to each other by grinding, as in the apparatus of Gay-Lussac. The tube *a*, of the upper vessel, is encompassed by a cylinder of zinc, which is supported by a ring of cork on the lower part of the tube. The platinum sponge is contained in a small brass box *b*, attached to a brass wire passing through a collar of leather and which can be placed at any distance from the jet *c*. When a light is required the cock *d* is turned, and the pressure of the acid liquor in the upper vessel expels the hydrogen, as in the apparatus already described.†

Fig. 123.



Detonates with air.

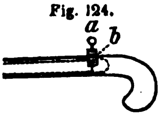
388. If mixed with common air, hydrogen burns rapidly with detonation.

Into a strong phial, capable of holding about 6 ounces of water introduce one part of hydrogen and three parts of common air. On applying a lighted candle or a red hot wire, the mixture will explode.

Inflammable air pistol.

This experiment may be performed by means of an apparatus called the inflammable air pistol. (Fig. 124.) This instrument consists of a cylinder of brass, about three fourths of an inch in diameter, and six inches long, in the form of a small cannon or pistol-barrel, properly mounted, and having a wire *a*, passing through a tube of ivory, *b*, and not quite touching the interior of the cylinder, at the part usually occupied by the touch-hole; an electric spark communicated to this wire inflames the mixture of hydrogen and atmospheric air in its interior. It may be charged, by holding it for a moment over the open jet of the instrument (Fig. 119), always taking care that there is a due admixture of atmospheric air, otherwise the electric spark will not inflame it.

Fig. 124.

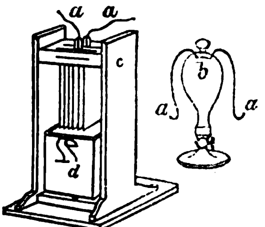


Detonates with oxygen,

389. If the experiment be repeated with oxygen gas instead of atmospherical air; changing the proportions, and mixing only one part of the oxygen gas with two of hydrogen, the report will be considerably louder. The bottle should be a strong one, and should be wrapped round with cloth, to prevent accident.

It may be exploded by igniting a fine platinum wire within a strong glass vessel (Fig. 125, *b*); the wire may be an inch in length, and connected with two stout copper wires *a a* passing in at the sides through a cork: the copper wires should be attached to the vices of a small calorimotor *c*. The acid liquor being contained in a glass or other suitable vessel *d*, is to be raised up sufficiently to have the plates immersed. See *Galvanism.*

Fig. 125.



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* A convenient tinder may be prepared from a piece of cotton cloth, dipped in the solution from which the sponge is obtained, (see *Platinum*,) and then inflamed; it ignites as readily as the platinum sponge; the sponge and tinder should be perfectly dry. W.

† See the subject of *Eudiometry*.

Chap. III.

Exp.

A bladder, filled with hydrogen and oxygen, may be exploded with safety by suspending it from the ceiling, and piercing it with a sharp wire at the end of a long stick, with a little tow about it, dipped in spirits of turpentine and burning.

And by means of the electric spark.

390. The same experiment may be made over water, by means of the electric spark.

Procure a strong tube, about three quarters of an inch in diameter, and 12 inches long, closed at one end. (Fig. 126) About a quarter or half an inch from the sealed end, let two small holes be drilled, opposite to each other, and into each of these let a brass conductor be cemented, so that the two points may be distant from each other, within the tube, about one eighth of an inch. An apparatus, serving the same purpose, and much more easily constructed, may be formed by hermetically sealing a piece of brass wire, or still better, platinum wire, into the end of a glass tube. With this conductor, an interrupted circuit may be formed by introducing into the tube a longer wire, one end of which terminates one tenth of an inch from the upper one, while the other extends beyond the aperture of the tube. (See Fig. 127, *c*.) Into this tube, standing over water, pass about half a cubic inch of a mixture of hydrogen and oxygen gases; in the proportion of two measures of the former to one of the latter. Hold the tube firmly, and pass an electric spark through the mixed gases. For relieving the shock, which is sometimes considerable on firing, an ingenious contrivance of Davy may be employed.* The first effect of the combustion is a sudden and considerable enlargement of volume, which, from some experiments of Davy probably amounts to 15 times the original bulk of the mixture. After this the gases, if perfectly pure and in the proper proportion, will be found to have disappeared entirely. H. 1. 235.

Fig. 126.

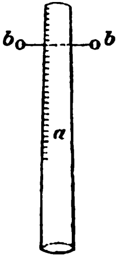
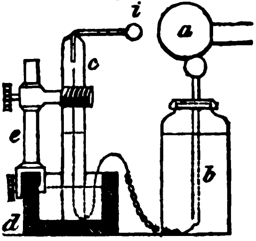


Fig. 127.



Explosion by electricity, flame, &c.

391. The power of flame and electricity, in causing a mixture of hydrogen with air or oxygen gas to explode, is limited; flame occasions a very feeble explosion when the hydrogen is mixed with nine times its bulk of air; and a mixture of four measures of hydrogen with one of air does not explode at all. An explosive mixture, formed of two measures of hydrogen and one of oxygen gas, explodes from all the causes above enumerated. Biot found that sudden and violent compression likewise causes an explosion, apparently from the heat emitted during the operation; for an equal degree of condensation, slowly produced, has not the same effect. The electric spark ceases to cause detonation, when the explosive mixture is diluted with twelve times its volume of air, fourteen of oxygen, or nine of hydrogen; or when it is expanded to sixteen times its bulk by diminished pressure. Spongy platinum acts just as rapidly as flame or the electric spark in producing explosion, provided the gases are quite pure and mixed in the exact ratio of two to one.† Faraday finds that platinum foil, if perfectly clean, produces gradual though rather rapid combination of the gases, often followed by explosion.‡

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* *Phil. Mag.* xxxi. 3.

† For a variety of facts respecting the causes which prevent the action of flame, electricity, and platinum in producing detonation, the reader may consult the essay of Grotthus in the *Ann. de Chimie* vol. lxxxii.; Davy's work on *Flame;* Henry's essay in the *Phil. Trans.* for 1824; and a paper by Turner in the *Edin. Philos. Jour.* for the same year.

‡ *Phil. Trans.* 1834.

Slow combination.

392. When the action of heat, the electric spark, and spongy platinum no longer causes explosion, a silent and gradual combination between the gases may still be occasioned by them. Davy observed that oxygen and hydrogen gases unite slowly with one another, when they are exposed to a temperature above the boiling point of mercury, and below that at which glass begins to appear luminous in the dark. An explosive mixture, diluted with air to too great a degree to explode by electricity, is made to unite silently by a succession of electric sparks. Spongy platinum causes them to unite slowly though mixed with one hundred times their bulk of oxygen gas. T.160.

Musical tones during the combustion of hydrogen.

393. A current of hydrogen may be inflamed when issuing from a small aperture, and if a tube of eighteen or twenty inches in length be held over the flame, a peculiar musical tone is produced. This effect is not peculiar to hydrogen, but is produced by a variety of other flames, and is referable to the succession of explosions produced by the combustion of the gas in the tube.

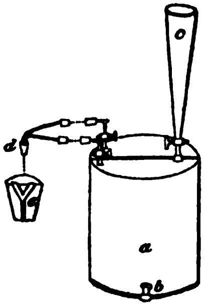
Gases have a powerful tendency to mix together.

394. The tendency which gaseous fluids have to become completely mixed under all circumstances, and as it were to penetrate each other, is well illustrated where hydrogen is employed. Thus, if two small phials, the one containing oxygen and the other hydrogen, be connected perpendicularly by a long glass tube, of small bore, it will be found, that although the hydrogen be uppermost, and much lighter than the oxygen, it will, in the course of a few hours, have perfectly mixed with the oxygen, and the gases will be found in equal proportions in both phials. Dalton has shown that gases, unlike other fluids, do not remain upon each other without admixture.*

Hare's blow-pipe.

395. The flame of hydrogen is occasionally employed for exciting intense heat; and it has been found when mixed with oxygen and burned as the mixture issues from a small jet, to excite a temperature nearly equal to that of the arc of flame in the Voltaic circuit. A blow-pipe upon this construction was first made by Hare:

Fig. 128.



It consists of a cylindrical vessel of tin, (Fig. 128, *a*,) or what is preferable copper, divided in the middle by two partitions, so as to form two distinct reservoirs, one for oxygen and the other for hydrogen. Into the lower part of each reservoir, a tube *b*, is inserted somewhat obliquely, as in the common gas-holder. Above the reservoirs is a conical tin funnel *c*, furnished with a stop-cock and connected with a tube which immediately below divides into two, one passing to each reservoir. A tube passes out from each reservoir, meeting in a cone *d* (a section of which is represented at *e*). The gases are thus mingled and are then made to issue through a capillary tube drilled through a wire of silver and inserted into the cone.† The lower tubes being closed, the apparatus is filled with water, and the gases introduced, as in the usual method of filling a gas-holder. The re-

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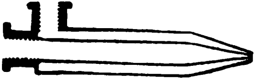
* *Manchester Memoirs*, vol. i. New Series.

† The arrangement, consisting of two separate reservoirs for the gases, is perfectly safe and convenient: the jet may be formed of two concentric cones. In 1824 I devised a jet, which was made for me by Newman of London, to whom I sent a drawing and description. It is the only jet I have been in the habit of using since that time, and it has proved, as anticipated, perfectly safe. It consists of two concentric tubes of brass (Fig. 129), each terminated by platinum, a space being left between the two. By one stop-cock, opening into the space, and another into the cavity of the inner tube, the two gases

Fig. 129.



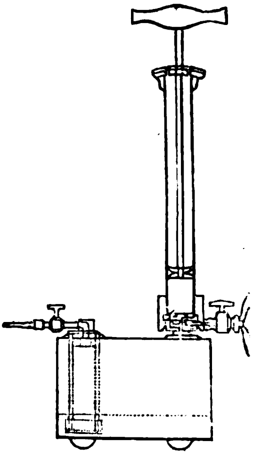
servoirs being filled, the lower tubes are closed, and water poured into the funnel on opening the stop-cocks the gases are propelled through the jet. When substances are tò be exposed to the action of this instrument, the stop-cock connected with the reservoir of hydrogen should be first opened and the gas may be inflamed; the other stop-cock is then gradually opened, and the oxygen mixing with the hydrogen, an intensely high temperature is obtained.

With this instrument Hare and Silliman first effected the fusion of some of the most refractory substances in nature.*

Brooke's blow-pipe.

396. The blow-pipe invented by Brooke depends for its action on the elasticity of compressed air, and consists of a strong copper box (Fig. 130), into which several atmospheres are crowded by means of a condensing syringe. Various expedients have been adopted to render this a safe substitute for the oxy-hydrogen blow-pipe of Hare. It may be done by interposing between the flame and the main reservoir of gases, a cylinder containing a little water or oil, through which by means of a valve at the bottom, the gases are allowed to pass. The safety of the instrument is increased by the safety tube, lately proposed by Hemming.

Fig. 130.



Hemming's safety tube.

It consists of a brass cylinder, about six inches long, and three fourths of an inch wide, filled with very fine brass wire, in length equal to that of the tube. A pointed rod of metal, one eighth of an inch thick, is then forcibly inserted through the centre of the bundle of wires in the tube, so as to wedge them tightly together. The interstices between the wires thus constitute very fine metallic tubes, the conducting power of which is so great as entirely to intercept the passage of flame.† ‡

Burns under water.

397. The flame produced by the oxy-hydrogen blow-pipe continues to burn when submersed in, and in actual contact with, water, with the same splendour as in the atmosphere; the only difference being that under water its figure is conglobated, whereas in air it assumes that of a long, slender, conical pencil. Care is required to introduce the flame slowly into the water. A piece of pine wood or cork when brought within the action of the submerged flame gives out a brilliant light.

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are conveyed along the jet without mingling until they arrive at the orifice where they are burned. Either gas may be made to surround the other at pleasure merely by changing the connexion with the reservoirs In the *Phil. Mag.* ii. third series, Daniell has described a similar jet. I was not aware until these pages were passing through the press that a jet of similar construction had been early employed by Hare. W.

* *Amer. Jour. of Sci.* vol. ii. p. 281, &c. † *Phil. Mag.* third series, i. 82.

‡ In some recent experiments with mixtures of the gases, contained in bladders attached to the extremities of this tube, I have found it impossible to explode *both* by firing one, and have been led to attach it to a large globe of copper in which the gases are condensed, and with a simple jet at the other extremity, use the apparatus with perfect safety. W.

Hydrogen and Oxygen. Protoxide of Hydrogen—Water.

Sect. II.

Composition.

Symb. $H+O$ or $\dot{H}$,	*By Wght.*			*By Vol.*	
sometimes aq.	Hyd.	Oxy.	Equiv.	Hyd.	Oxy.
from *aqua*.	1 or 1 eq. +	8 or 1 eq. =	9	100	50

Union with oxygen gas, produces water.

398. *Hydrogen and Oxygen, Water.*—When two volumes of hydrogen gas are mixed with one volume of oxygen gas, and the mixture inflamed in a proper apparatus by the electric spark, the gases totally disappear, and the interior of the vessel is covered with drops of pure water, equal in weight to that of the gases consumed.

Decomposition of water by electricity,

399. If pure water be exposed to the action of Voltaic electricity, it is resolved into two volumes of hydrogen, and one volume of oxygen, so that water is thus proved by synthesis and analysis, to consist of two volumes of hydrogen combined with one volume of oxygen.

By combustion.

400. Cavendish demonstrated the composition of water by burning oxygen and hydrogen gases in a dry glass vessel; when a quantity of pure water was generated, exactly equal in weight to that of the gases which had disappeared. This experiment, which is the synthetic proof of the composition of water, was afterwards made on a much larger scale in Paris by Vauquelin, Fourcroy, and Seguin. Lavoisier first demonstrated its nature analytically.

Composition by weight.

The composition of water by weight was determined with great care by Berzelius and Dulong; and their result is regarded as a nearer approximation to the truth than that of any of their predecessors. They state, as a mean of three careful experiments,* that 100 parts of pure water consist of 11.1 of hydrogen and 88.9 oxygen, which is the ratio of 1 to 8.009, very nearly that of 1 to 8 above stated.

Theory of formation of hydrogen.

401. The processes for procuring hydrogen gas will now be intelligible. The first is the method by which Lavoisier made the analysis of water. It is founded on the fact, that iron at a red heat decomposes water, the oxygen of that liquid uniting with the metal, and the hydrogen gas being set free. The hydrogen which is evolved when zinc or iron is put into dilute sulphuric acid must be derived from the same source. The product of the operation, besides hydrogen, is sulphate of the protoxide of iron, if iron is used, or of the oxide of zinc, when zinc is employed. The knowledge of the combining proportions of these substances will give the exact quantity of each product. These numbers are—

Water (8 oxy + 1 hyd.	9
Sulphuric acid	40.1
Iron	28
Protoxide of iron (28 iron + 8 oxygen) .	36
Sulphate of the protoxide of iron (40.1+36) .	76.1

Hence for every 9 grains of water which are decomposed, 1 grain of hydrogen will be set free; 8 grains of oxygen will unite with 28 grains of iron, forming 36 of the protoxide of iron; and the 36 grains of protoxide will combine with 40.1 grains of sulphuric acid, yielding 76.1 of sulphate of the protoxide of iron. A similar calculation may be employed when zinc is used, merely by substituting the equiva-

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* *Ann. de Chim. et de Phys.* vol. xv.

Chap. III.

lent of zinc (32.3) for that of iron. According to Cavendish, an ounce of zinc yields 676 cubic inches, and an equal quantity of iron 782 cubic inches of hydrogen gas.

Action of zinc, &c.

402. The action of dilute sulphuric acid on metallic zinc affords an instance of what was once called *Disposing Affinity.* Zinc decomposes pure water at common temperatures with extreme slowness; but as soon as sulphuric acid is added, decomposition of the water takes place rapidly, though the acid merely unites with oxide of zinc. The former explanation was, that the affinity of the acid for oxide of zinc disposed the metal to unite with oxygen, and thus enabled it to decompose water; that is, the oxide of zinc was supposed to produce an effect previous to its existence. The obscurity of this explanation arises from regarding changes as consecutive, which are in reality simultaneous. There is, as it were, but one chemical change, which consists in the combination at one and the same moment of zinc with oxygen, and of oxide of zinc with the acid: and this change occurs because these two affinities, acting together, overcome the attraction of oxygen and hydrogen for one another. T.

403. The experiments illustrating the composition of water may be divided into synthetic and analytic. Among these the following may be selected.

Fig. 131.

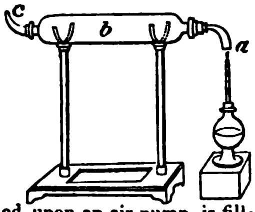
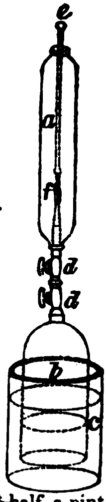


Fig. 132.



Exp.

Burn a current of hydrogen under the funnel *a*, (Fig 131), by uniting with the oxygen of the atmosphere it will produce aqueous vapour, which passing into the glass cylinder *b*, will condense in drops.

Burns with oxygen gas and forms water,

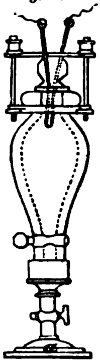
Fig. 132 represents an apparatus for showing the production of water by burning a current of hydrogen in an atmosphere of oxygen. *a* is a glass cylinder, which, after having been exhausted upon an air-pump, is filled with pure oxygen. *b* is a receiver of hydrogen immersed in the vessel of water *c*, by which the gas is compressed, so as to be urged through the capillary opening *f*, when the stop-cocks *d d* are open. *e* is a platinum wire by which the gas may be inflamed by an electric spark. It burns with the production of intense heat, and water is soon collected in drops upon the interior of the cylinder.

The mixture explodes.

Exp.

If two measures of pure hydrogen be mixed with one of pure oxygen, and detonated in the graduated glass tube *a*, (Fig. 106), standing over water, by an electric spark passed through the platinum wires *b b*, the gases will entirely disappear. If there be any excess of either of the gases, the portion in excess will remain unconsumed.

Fig. 133.



Exp.

The same experiment may be thus varied: Fig. 133 is a very strong glass vessel, capable of holding ~~about half~~ a pint and furnished (besides the proper contrivance at top for taking the electric spark in it) with a brass cap and cock, by means of which it can be screwed to the transfer plate of an air pump. When exhausted, it may be filled with a mixture of oxygen and hydrogen gases, in the proportion of one measure of the former to two of the latter, and an electric spark may be passed through the mixture. After the explosion, when time has been given to the vessel to cool, a sensible quantity of moisture will have condensed on the inner surface of the vessel, and by repeating the operation frequently, a sufficient quantity of fluid may be collected to show that water is the only product.

Water a compound of the bases of the gases.

404. The water produced in this mode, is not, however, to be considered as a compound of the two gases, but

only of their bases, for the light and caloric, which constitute the gases, escape, in considerable part during the combustion. Every gas, it must be remembered, has at least two ingredients; the one, gravitating matter, which, if separated, would probably exist in a solid or liquid form; the other, an extremely subtile fluid, termed caloric and perhaps electricity and light. The compound, water, is therefore said to be composed of hydrogen and oxygen, the *bases* of the gases, and not of the hydrogen and oxygen *gases*.

Analysis of water,

405. Water may be decomposed or resolved into its elements by a variety of processes, the most important of which are the following:

By iron,

Exp.

Fig. 134.

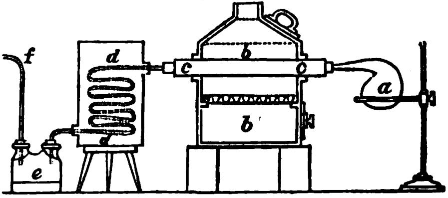


Fig. 134, *a*, is a glass retort, into which is introduced a given weight of water; *b b*, a small furnace through which passes the earthen, or iron, tube *c c*, which terminates in the spiral pewter tube *d d*, immersed in water. A given weight of pure iron coiled up, is introduced into the tube *c*, and the whole made red-hot; the water in *a* is then made to boil, and the vapour, on coming into contact with the red hot iron, is in part decomposed; the oxygen is retained by the iron, and the hydrogen escaping through the tube *f*, may be collected as usual. Any undecomposed portion of water is condensed in the worm pipe *d*, and drops into the vessel *e*.

After this experiment the iron will be found to have increased in weight; and if attention be paid to the quantity of water which has collected in *e*, and to the weight of the hydrogen gas evolved, it will be found that the weight gained by the iron, added to that of the hydrogen, will be equal to the weight of the water which has disappeared.

406. The processes, by which the elementary parts of water are separated from each other, and are *both* obtained in an aëriform state, as a mixture of hydrogen and oxygen gases, are dependent on the agency of electricity.

By electricity,

The first of these experiments requires for its performance the aid of a powerful electrical machine. This fact was the discovery of a society of Dutch chemists; and the principal circumstance in the experiment, is the transmission of electrical shocks through a confined portion of water. If these shocks be sufficiently strong, bubbles of air will be formed at each explosion, and the mixed gases being exploded, the water will rise again in the tube, a very small quantity of gas remaining. In this experiment we may safely infer, that the evolved hydrogen and oxygen gases arise from decomposed water.

By voltaic electricity,

407. The decomposition of water by galvanic electricity is a process singularly adapted to demonstrate the fact in a simple and elegant manner, since it exhibits both the oxygen and hydrogen in the gaseous form.

Fig. 135.

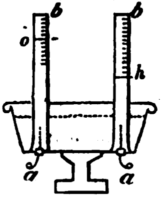


Fig 135 represents a section of an apparatus for this purpose. It is a glass vessel containing water, having two wires of platinum passing through its bottom: over these are inverted the tubes, also filled with water. The wires are connected with a moderately powerful Voltaic apparatus. Oxygen is evolved at the positive wire, and hydrogen at the negative wire, which gases rise into the tubes, and it is seen that one volume of oxygen, *o*, and two volumes of hydrogen, *h*, are the constant results. If these gases be mixed and detonated, pure water is again formed.

By living vegetables. 408. Another mode of effecting the decomposition of water, is by the action of living vegetables, either entire or by means of their leaves only.

Exp. Fill a clear glass globe with water, and put into it a number of green leaves from almost any tree or plant. A sprig or two of mint will answer the purpose perfectly well. Invert the glass, or place it, with its mouth downwards, in a vessel of water. Expose the whole apparatus to the direct light of the sun, which will then fall on the leaves surrounded by water. Bubbles of air will soon begin to form on the leaves, and will increase in size, till at last they rise to the top of the vessel. This process may be carried on as long as the vegetable continues healthy; and the gas, when examined, will prove to be oxygen gas.

In this experiment, the hydrogen combines with the plant to the nourishment and support of which it contributes, while the oxygen is set at liberty. H. 1. 253.

Impurities of water. 409. Water, in its ordinary state, such as spring and river water, is always so far contaminated with foreign substances as to be unfit for any chemical purposes, and frequently as will be more fully shown hereafter, even for domestic use. Rain water is much more pure, but it always contains a portion of carbonic acid and of the elements of atmospheric air, besides appreciable traces of vegetable or animal matter;* to the latter it owes its property of becoming putrid when kept. The distinction of water into hard and soft has reference to its less or greater purity. The impurities of water are partially separated by distillation.†

410. *Distilled Water*, as commonly prepared, always affords minute traces of foreign matter, especially when subjected to Voltaic decomposition, and can only be considered as perfectly pure when re-distilled at a low temperature in silver vessels.

Properties. 411. Pure water is transparent, and without either colour, taste or smell. In consequence of the facility of obtaining it pure, it is assumed as a standard to which the relative weight of all other bodies may be compared, its specific gravity being called = 1,000, and hence the importance of estimating its weight with precision. At the temperature of 62° F., barom. 30, a cubic inch of distilled water weighs 252.458 grains.‡

Standard of specific gravity.

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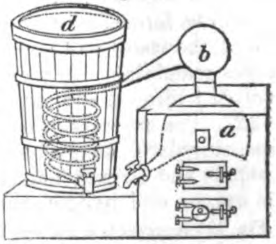
* The existence of organic matter in atmospheric water, has been ascribed by Ehrenberg to the ova of a particular class of infusoria, and to them the presence of the substance termed *pyrrhine*. There is evidence also of the presence of salts and of acids. See Daubeny's *Report* on Watet, in Vol. v. of *Reports of Brit. Assoc.*

Fig. 136.



† This process is usually conducted upon the large scale in a copper boiler, (Fig. 136,) placed either in a portable furnace, or set in brickwork, according to its dimensions, to which is annexed a head *b*, of the same material, or of pewter, connected with a spiral tube or worm, which is immersed in the worm-tub, or refrigerator *d*, its lower end passing out. The water in the worm-tub must always be retained of a low temperature to effect the condensation of the vapour in the spiral tube.

‡ According to the parliamentary standard of Great Britain, the pint of water consists of 8750 grains of water at 62° F. barometer at 30 inches, and the cubic inch of 252,458 grains. The gallon contains 277,274 cubic inches, or 70,000 grains of distilled water; the pint 34,65925 inches, or 8750 grains.

Ice.

412. At the temperature of 32° water congeals into ice, which, if slowly formed, produces needles crossing each other at angles of 60° and 120°. The specific gravity of ice is 0,94. Exposed to the air, ice loses considerably in weight by evaporation.

Compressible.

413. Water is susceptible of compression, as was originally shown by Canton, and more lately by Perkins, who has estimated, in an ingenious series of experiments, the rate of its compression.* If submitted to very sudden compression, water becomes luminous, as has been shown by Desaignes.† According to Despretz the compression of water by a force equal to 20 atmospheres, causes the evolution of $\frac{1}{66}$th part of a degree of heat.

State of combination.

414. Water enters into combination with a variety of substances, and is retained with various degrees of force. Sometimes it is contained in a variable ratio, as in ordinary solution; in other compounds it is present in a fixed definite proportion, as in its union with several of the acids, the alkalies, and all salts that contain water of crystallization. These combinations have been termed *hydrates*.

Hydrates.

Water contains air.

415. Water, which has been exposed to the atmosphere, always contains a portion of air, as may be proved by boiling it, or by exposing it under the exhausted receiver of the air-pump. To separate the air, the water must be boiled for about two hours. It absorbs oxygen gas in preference to atmospheric air or nitrogen, and when the air is expelled by boiling, the last portions contain more oxygen than those first given off.‡

Absorption of gases by water.

416. Every gas is absorbed by water, which has been deprived of all or the greatest part of its air by long boiling. The quantity, however, which water is capable of absorbing, varies considerably with respect to the different gases. Those gases, of which only a small proportion is absorbed, require violent and long continued agitation in contact with water. H. i. 253. In the common process of manufacturing soda-water a large quantity of carbonic acid gas is absorbed by the water, and an additional portion is mechanically united with it by powerful compression.§

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* *Phil. Trans.* 1820.

† Thenard, *Traité de Chimie*, i. 432.

‡ Humboldt and Gay-Lussac, *Jour. de Phys.* 1805.

§ The following table from Henry's *Chemistry* shows the absorbability of different gases by water deprived of all its air by ebullition.

100 cubic inches of such water, at the mean temperature and pressure, absorb of

	Dalton and Henry.			Saussure.
Sulphuretted hydrogen	100	cubic	inches	253
Carbonic acid	100	"	"	166
Nitrous oxide	100	"	"	76
Olefiant gas	12,5	"	"	15,3
Oxygen	3,7	"	"	6,5
Carbonic oxide	1,56	"	"	6,2
Nitrogen	1,56	"	"	4,1
Hydrogen	1,56	"	"	4,6

The estimate of Saussure is in general too high. That of Dalton and Henry for nitrous oxide is considerably beyond the truth, according to the experiments of Davy. T.

Chap. III.

Binoxide or Peroxide of Hydrogen.

Composition.

	By Wght.			By Vol.		
Chem. Symb.	Hyd.	Oxy.	Equiv.	Hyd.	Oxy.	*Sp. Gr.*
$H + 2O$, or $\ddot{H}$	1 or 1 eq. +	16 or 2 eq. =	17	100	100	1.452.

Discovered by Thenard, in the year 1818.

There are two oxides of barium; when the peroxide of that metal is put into a dilute acid, oxygen gas is set at liberty, and the peroxide is converted into protoxide of barium or baryta, which combines with the acid. The oxygen which is set free, unites with the hydrogen of the water, and brings it to a maximum of oxidation.*

Properties. 417. The peroxide of hydrogen is a colourless transparent liquid without odour. It acts as a caustic upon the skin, thickens the saliva, and tastes like certain metallic solutions. It destroys the colour of litmus and turmeric paper. It continues liquid at all degrees of cold to which it has hitherto been exposed.

At the temperature of 59° F. it is decomposed, being converted into water and oxygen gas. It effervesces from the escape of oxygen at 59° F. and the sudden application of a higher temperature, as of 212° F. gives rise to such a rapid evolution of gas as to cause an explosion. **Action of metals,** All the metals except iron, tin, antimony and tellurium, have a tendency to decompose it, converting it into oxygen and water; especially when the metals have been previously reduced to a state of minute division. The metals which have a strong affinity for oxygen are at the same time oxidized.

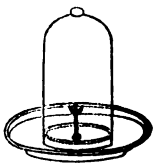
Use. 418. It has been employed to remove the black spots that paintings acquire from the conversion of carbonate of lead into sulphuret. It converts the black sulphuret into white sulphate of lead.

SECTION III. *Nitrogen.*

Symb.	*Sp. Gr.*	*Equiv.*
N.	0.9727 air = 1	By Vol. 100
	14.15 Hyd. = 1	" Wght. 14.15

Discovery. 419. This was first recognised as a distinct aëriform fluid by Rutherford, in 1772. It may be obtained by heating phosphorus in a confined portion of dry air, which consists of nitrogen and oxygen; the phosphorus absorbs the latter, and the former gas remains.

Fig. 137.



How obtained. Phosphorus is placed in a small metallic cup, supported on a stand on the shelf of the pneumatic trough, and covered with a bell glass the moment the phosphorus is kindled. Eight or ten grains of phosphorus may be taken for every 100 cubic inches of air; and the cup containing the phosphorus must be raised to a proper height, as the water rises afterwards in the jar to supply the place of the oxygen removed; after repeated washing with a solution of potassa, it may be considered as pure. Or by inverting a jar full of common air over a mixture of equal weights of iron filings and sulphur made into a paste with water. But this process requires much time.

A quicker process consists in filling a bottle, about one fourth, with a solution of binoxide of nitrogen, in liquid protosulphate of iron, or with liquid sulphur-

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* From the complicated nature of the process it is not likely to be the subject of experiment with the beginner. For details consult the original memoir of Thenard *Ann. de Chim. et de Phys.* vol. viii. ix. x.; *Ann.* of *Philos.* vol. xiii. and xiv.; Thenard's *Traité de Chim.* and Turner's *Elem.* 163.

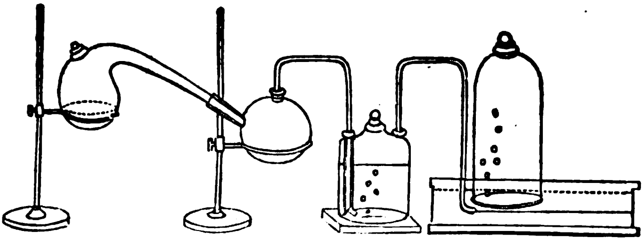
et of calcium, and agitating it with the air, which fills the rest of the bottle. During the agitation, the thumb must be firmly placed over the mouth of the bottle; and, when removed, the mouth of the bottle must be immersed in a cup full of the same solution, which will supply the place of the absorbed air. The agitation and admission of fluid must be renewed, alternately, as long as any absorption takes place.

Other processes.

Nitrogen mixed with carbonic acid, may be procured from the lean part of flesh meat, which may be put into a gas bottle, along with very dilute nitric acid. By a heat of about 100°, the gas is disengaged, and may be collected over water. Its source is the animal substance.*

420. One of the easiest methods of preparing nitrogen, is to pass a current of chlorine gas through liquid ammonia; the ammonia is decomposed, hydrochloric acid is formed from the union of the chlorine and the hydrogen of the ammonia, and its nitrogen liberated. The arrangement of the apparatus is shown in the cut annexed.† Emmett has described another process, which consists in fusing nitrate of ammonia in a retort with fragments of zinc. The metal decomposes the nitric acid of the salt, and nitrogen and ammonia are given off; when collected over water, the latter gas is absorbed. The emission of the gas can be regulated by using a small cylinder of zinc attached to a rod passing through the tubulure of the retort, which can be raised or depressed into the fused salt.‡

Fig. 138.



Derivation of azote.

421. This gas is fatal to animal life and was, on this account, named by Lavoisier *Azote* or *Azotic gas*, derived from the Greek privative α and ζωή, *life*. This being but a negative property, the term nitrogen has been substituted, because one of the most important properties of its base is, that by union with oxygen, it composes nitric acid. It is not inflammable; and a lighted taper is extinguished by it. Even phosphorus in a state of active inflammation is instantly extinguished by it.

422. When mixed with pure oxygen gas, in the proportion of four parts to one of the latter, it composes a mixture resembling atmospheric air in all its properties, and in which a taper will burn. One hundred cubic inches weigh 30.1650 grains. T.

Composition of nitrogen.

423. That nitrogen is not an element, but itself a compound, has been long suspected, and various attempts have been made to discover its ingredients. Berzelius has inferred that nitrogen is compounded of oxygen and an unknown base. This base, however, is purely hypothetical; and has never yet been exhibited in a separate state. Berzelius has proposed for it the name of *nitricum*.

General view of the compounds of nitrogen and oxygen.

424. *Nitrogen and oxygen.*—When nitrogen and oxygen gases

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[*] It appears from the remarks of Daubeny, that nitrogen gas is given off from many thermal springs.—Report on mineral and thermal waters in vol. v. of *Rep. Brit. Assoc.* 39.

[†] Johnson's *report* in *Rep. Brit. Assoc.* 1831-2. 455.

[‡] *Roy. Instit. Jour.* 1. 384.

are mingled together, no combination ensues. The result is a simple mixture of the two gases, which do not, like inelastic fluids, separate on standing, but remain diffused through each other for an indefinite length of time. When, however, either one or both of these elements is in a condensed state, they unite and form compounds, distinguished by very striking properties. According to the proportions in which the oxygen and nitrogen exist in these compounds, their qualities undergo a remarkable variation; so that from two elementary bodies, variously united, we have several compounds, totally unlike each other in external qualities, as well as in their chemical relations.

425. Nitrogen and oxygen are the two most important constituents of the atmosphere; the thin, transparent and elastic fluid which surrounds our planet.

Atmospheric air.

426. The atmosphere reaches to a considerable height, probably about 45 miles.[*] It may be diminished in volume to a great extent by compression.

Weight.

That air is a ponderous body, was first suspected by Galileo, who found that a copper ball, in which the air had been condensed, weighed heavier than when the air was in its ordinary state of tension. The fact was afterwards demonstrated by Toricelli.

Barometer.

In 1643, he filled a glass tube, three feet long, and closed at one end with quicksilver, and inverted it in a basin of the same fluid; he found that the mercury fell about six inches, so that the atmosphere appeared capable of counterbalancing a column of mercury 30 inches in height. The empty space, in the upper part of the tube, has hence been called the *Torricellian vacuum*, and is the most perfect that can be formed.

Paschal and Toricelli afterwards observed, that upon ascending a mountain, the quicksilver fell in the tube, because there was less air above to press upon the surface of the metal in the basin; and thus a method of measuring the heights of mountains by the *barometer*, as the instrument is now called, was devised.

Density of the atmosphere indicated.

427. The barometer indicates, by its rise and fall, a corresponding change in the density of the atmosphere.[†] At the surface of the earth, the mean density or pressure is considered equal to the support of a column of quicksilver 30 inches high.[‡]

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[*] See Wollaston "*on the Finite Extent of the Atmosphere.*"—*Bost. Jour.* I. 15.

[†] From causes at present not understood, the pressure varies at the same place. On this depend the indications of the barometer as a weather-glass; the weather is commonly fair and calm when the barometer is high, and usually wet and stormy when the mercury falls.

	Inches.
[‡] At 1000 feet above the surface the column falls to	28,91
2000	27,86
3000	26,85
4000	25,87
5000	24,93
1 Mile	24,67
2	20,29
3	16,68
4	13,72
5	11,28
10	4,24
15	1,60
20	0,95

See Camb. *Mechanics*, page 351.

Sect. III.

Air-pump.

428. The general mechanical properties of the air are best illustrated by the *air pump*,[*] the construction of which much resembles that of the common pump used for raising water, excepting that all the parts are more accurately and nicely made, the object being to exhaust the air as completely and expeditiously as possible.[†]

Specific gravity.

429. The specific gravity of atmospheric air, at mean temperature and pressure, that is, the thermometer being at 60°, and the barometer at 30 inches, is, usually considered as $= 1$. It is about 815 times as light as its bulk of water, 100 cubical inches weighing 31,0117 grains.

Chemical effects dependent on oxygen.

Lavoisier's experiments.

430. Atmospheric air has already been stated to consist essentially of oxygen and nitrogen gases: whether it should be considered a mere mixture or a chemical compound, is a question which has been much discussed.[‡] The oxygen seems to be the only ingredient on which the effects of the air, as a chemical agent, depend. Hence combustible bodies burn in atmospheric air, only in consequence of the oxygen gas which it contains; and when this is exhausted, air is no longer capable of supporting combustion. Its analysis is satisfactorily demonstrated by the action of heated mercury, but the process is tedious.[§] By exposure, during 12 days to mercury heated in a retort, a given quantity of atmospheric air was found to be diminished in bulk, and to have lost its property of supporting combustion. The mercury was changed into red scaly particles, and it had acquired an increase of weight. When these red particles were submitted to heat, in a retort, oxygen gas was evolved equal in bulk to what the air had lost in the first part of the experiment.

431. There are various ways of learning the proportion which the oxygen bears to the nitrogen; and as the relative fitness of the air for breathing has sometimes been considered as depending upon the quantity of oxygen contained in a given volume, the instruments used in these experiments have been called *eudiometers*.

Eudiometry.

432. From facts already stated it is obvious, that if atmospheric air, mixed with a certain quantity of hydrogen, be detonated by the electric spark, the absorption will be proportionate to the quantity of oxygen present.

When 100 measures of pure hydrogen are mixed with 100 of pure oxygen, the diminution of bulk after detonation will amount to 150 parts, that is, one volume of oxygen requires for its saturation two of hydrogen. If we introduce into the graduated detonating tube (Fig. 106) 300 measures of common air, and 200 of pure hydrogen, there will remain, after detonation, 305 measures; so that 195 measures will have disappeared, of which one third may be estimated as pure oxygen; hence 300 parts of air have thus lost 65 of oxygen, or about 21 per cent.

General rule.

433. The general rule, therefore, for estimating the purity of air by hydrogen gas may be stated as follows:—Add to 3 measures of the air under examination 2 measures of pure hydrogen; detonate;

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[*] See Frontispiece.

[†] See Camb. *Mechanics*, page 403.

[‡] See statement in *Turner*, 171.

[§] See Lavoisier's *Elements*, chap. iii.

and, when the vessel has cooled, observe the absorption; divide its amount by 3, and the quotient is the quantity of oxygen.

Purity of other gases ascertained.

434. Upon the same principle, detonation of mixtures of oxygen and hydrogen is often resorted to, with a view of ascertaining the purity of those gases.

To ascertain the purity of hydrogen, it may be detonated with excess of pure oxygen.

Thus, if we add 100 of pure oxygen to 100 of hydrogen, and detonate, there will be a diminution equal to two thirds, or 150 parts if the hydrogen be pure. If, however, we suppose 100 of pure oxygen, mixed with 100 of hydrogen, to produce, after detonation, a residue of 80 measures, the diminution will then have been only 120 measures, of which two thirds, or 80 measures, are hydrogen; so that the inflammable gas will have contained 20 per cent. of some other gaseous body, not condensable by detonation with hydrogen.*

Eudiometer of Volta.

435. This mode of ascertaining the purity of atmospheric air was first resorted to by Volta, and it is susceptible of great accuracy, since pure hydrogen and pure oxygen are easily procured.†

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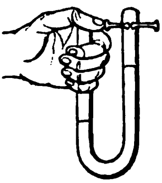
* For a particular description of several points in eudiometry, see Faraday's *Chem. Manip.* sect. xvii. paragraph 919, &c.

Ure's eudiometer.

† In the eudiometer of Ure, the atmospheric air, the most elastic and economical of all springs, is employed to receive and deaden the recoil. This eudiometer consists of a glass syphon (Fig. 139), having an interior diameter of from 2-10ths to 4-10ths of an inch. Its legs are of nearly equal length, each being from six to nine inches long. The open extremity is slightly funnel-shaped, the other hermetically sealed; and has inserted near it, by the blow-pipe, two platinum wires. The outer end of the one wire is incurvated across, so as nearly to touch the edge of the aperture; that of the other is formed into a little hook, to allow a small spherical button to be attached to it when the electrical spark is to be transmitted. The two legs of the syphon are from one-fourth to one-half inch asunder. The sealed leg is graduated by introducing successively equal weights of mercury from a measure glass tube. Seven ounces troy and 66 grains, occupy the space of a cubic inch; and 34 1-4 grains represent $\frac{1}{100}$ part of that volume. The other leg may be graduated also, though this is not necessary.

Fig. 139.



To use this instrument, we first fill the whole syphon with mercury or water; the open leg is then plunged into a pneumatic trough, and any convenient quantity of the gases is introduced from a glass measure tube containing them in determinate proportions. Applying the finger to the orifice we next remove it from the trough, like a simple tube, and by a little dexterity transfer the gas into the sealed leg of the syphon. When we conceive enough has been passed up, the finger is removed and the mercury brought to a level in both legs, either by the addition of a few drops, or by the displacement of a portion, by thrusting down into it a small cylinder of wood. We now ascertain, by careful inspection, the volume of included gas. Applying the forefinger again to the orifice, so as also to touch the end of the platinum wire, we then approach the ball to the electrical machine, and transmit a spark, but a slight push or pressure on the tip of the finger is felt, even when the gas is in considerable quantity and of a strongly explosive power. After explosion on gradually sliding the finger to one side and admitting the air, the mercurial column in the sealed leg will rise more or less above that in the other. The equilibrium is then restored by adding mercury, when we read off, without any reduction, the true resulting volume of gas. As two inches or more of air should always be left between the finger and the mercury, this atmospheric column serves as a perfect recoil spring, enabling us to explode very large quantities without danger.

We may analyze the residual gaseous matter, by introducing, either a liquid or solid re-agent. We first fill the open leg nearly to the brim with quicksilver, and then place over it the substance whose action on the gas we wish to try. If liquid, it may be passed round into the sealed leg among the gas; but if solid the gas must be brought round into the open leg, its orifice having been previously closed with a cork or stopper. After a proper interval the gas having been transferred back into the graduated tube, the change of its volume may be accurately determined.—Ure's *Dict.* 440—*Edin. Phil. Trans.* 1818.—See, also, *Faraday*, p. 434. Several new eudiometers have been described by Hare, in the *Amer. Jour. of Sci.* vols. ii. and x.

Analysis with platinum,

436. Instead of electricity, spongy platinum may be employed for causing the union of oxygen and hydrogen gases; and while its indications are very precise, it has the advantage of producing the effect gradually and without detonation. The most convenient mode of employing it with this intention is the following:

Process.

A mixture of spongy platinum and pipe-clay, in the proportion of about three parts of the former to one of the latter, is made into a paste with water, and then rolled between the fingers into a globular form. In order to preserve the spongy texture of the platinum, a little hydrochlorate of ammonia is mixed with the paste; and when the ball has become dry, it is cautiously ignited at the flame of a spirit-lamp. The sal ammoniac, escaping from all parts of the mass, gives it a degree of porosity which is peculiarly favourable to its action. The ball, thus prepared, should be protected from dust, and be heated to redness just before being used.

To insure accuracy, the hydrogen employed should be kept over mercury for a few hours in contact with a platinum ball and a piece of caustic potassa. The first deprives it of traces of oxygen which it commonly contains, and the second of moisture and hydrosulphuric acid. The analysis must be performed in a mercurial trough. The time required for completely removing the oxygen depends on the diameter of the tube. If the mixture is contained in a very narrow tube, the diminution does not arrive at its full extent in less than twenty minutes or half an hour; while in a vessel of an inch in diameter, the effect is complete in the course of five minutes.*

Priestley's method.

437. When nitric oxide gas (binoxide of nitrogen) and atmospheric air are mixed, there is a production of nitrous acid, in consequence of the union of oxygen with the oxide; and if the mixture be made over water, an absorption ensues. Upon this principle this gas was used in eudiometrical experiments, by Priestley and Cavendish.† There are, however, several sources of error for which, and the precautions required to ensure accuracy, see *Binoxide of Nitrogen*, ‡ (454.)

Lavoisier's, &c.

438. If a stick of phosphorus be confined in a portion of atmospheric air it will slowly absorb the oxygen present. The rapid combustion of the same substance may also be conveniently resorted to. These eudiometrical methods were used by Lavoisier, Berthollet, and Seguin.§

Uniformity in composition of air.

439. The analyses of atmospheric air, collected at various elevations and in different latitudes, show that the proportion of oxygen is between 20 and 21 volumes, and of nitrogen 79 or 80. The average of a number of analyses by Hare's eudiometer, gave the proportion of oxygen at 20,66 per cent. The air which Gay-Lussac brought from an altitude of 21,735 feet above the earth, had the same composition as that collected near its surface. But Faraday found a decided difference between the air from the arctic regions and that of London. Dalton has inferred that the proportion of oxygen to nitrogen in the air on the surface of the earth, is not pre-

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* See Henry's Essay in *Philos. Trans.* 1824.—Henry's *Chemistry*, 1. 237.

† *Phil. Trans.* 1783. ‡ See Dalton's Remarks, *Phil. Mag.* Vol. xxviii. For the details of this process see Henry's *Chemistry*, vol. 1. p. 312, edit. 10th.

§ *Ann. de Chim.* tom. ix. and xxxiv.

cisely the same at all places and times, and that in elevated regions, the proportion is somewhat less.

The miasmata of marshes and the effluvia of infected places, are supposed to owe their noxious qualities to some peculiar subtle principle, and not to a deficiency of oxygen.*

Carbonic acid in air.

440. Though oxygen and nitrogen are the essential component parts of atmospheric air, it contains other substances, which, however, may be regarded as adventitious, and the quantity of which is liable to vary: of these, carbonic acid and aqueous vapour are the most important and constant. The quantity of the former may usually be considered as amounting to less than 1 per cent.

Water in air,

441. The presence of aqueous vapour in the atmosphere is shown in a variety of ways, but most easily by exposing to it certain deliquescent substances which liquefy and increase in weight, in consequence of its absorption.†

Its quantity.

The quantity of water contained in air and gases is subject to variation. From the experiments of Saussure and Dalton, it appears that 100 cubic inches of atmospheric air at 57°, are capable of retaining 0,35 grains of watery vapour; in this state the air may be considered at its maximum of humidity: it would also appear that all the gases take up the same quantity of water when under similar circumstances, and that it consequently depends, not upon the density or composition, but upon the bulk of the gaseous fluid.

State in which components of the air exist,

442. Berthollet considered that the elements of the air are retained together by chemical attraction; but Dalton maintains that they are merely mechanically mixed, and proved that gases mingle mechanically that have no attraction, and that even carbonic acid rises through a small tube into a bottle of hydrogen placed above it, though much heavier, a corresponding quantity of hydrogen descending into the carbonic acid bottle. This proves a power of *diffusion* among the gases. Dalton concluded that particles of the same gases repel each other, but that those of different gases do not, and that one gas acts as a vacuum to another, though they diffuse themselves more slowly through each other than in a vacuum.

Dalton's view,

Graham's experiments.

443. Graham has ascertained that each gas has a *diffusiveness* peculiar to itself, which is inversely proportional to the square root of its density, and has drawn up tables representing their diffusive power, air being taken as a standard of comparison.‡ He used a tube with the gas under examination, open at one end, and closed with plaster-of-paris at the other, the diffusion taking place readily through the pores of this substance when moderately dry; it also takes place through membranes, small cracks in glass vessels, and through numerous porous bodies.§ From all these considerations,

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* According to Prout there was a peculiar state of the air during the prevalence of the cholera in London, in 1832. See *Reports of Brit. Assoc.* 1832.

† As the gases in general, unless artificially dried, also contain vapour, it is necessary, in delicate experiments, and in ascertaining their specific gravity, to take this ingredient into the account, or to separate it by proper means, such as exposure to very deliquescent substances, among which fused chloride of calcium is especially useful.

‡ *Phil. Trans. Edin.* 1831.

§ See Mitchell's experiments in *Amer. Jour. Med. Sci.* vii. 36.

Dalton's view of the constitution of the air is now generally adopted. R. 54.

Hygrometers.

444. *Hygroscopes* and *Hygrometers* are instruments which show the presence of water in the air, its variation in quantity, and its actual quantity existing in a given bulk of air at any given time. Daniell's hygrometer shows the constituent temperature of the moisture in the atmosphere, by its precipitation upon a cold surface.†

Loss of oxygen, how compensated.

445. Since oxygen is necessary to combustion, to the respiration of animals, and to various other natural operations, by all of which that gas is withdrawn from the air, it is obvious that its quantity would gradually diminish, unless the tendency of those causes were counteracted by some compensating process. The only source by which oxygen is known to be supplied, is the action of growing vegetables. A healthy plant absorbs carbonic acid during the day, appropriates the carbonaceous part of that gas to its own wants, and evolves the oxygen with which it was combined. During the night, indeed, an opposite effect is produced. Oxygen gas then disappears, and carbonic acid is eliminated; but it follows from the experiments of Priestley, Davy, and Daubeny, that plants during 24 hours yield more oxygen than they consume. Whether living vegetables make a full compensation for the oxygen removed from the air by the processes above mentioned, is uncertain.

Nitrogen and Oxygen. Protoxide of Nitrogen—Nitrous Oxide.

Composition.

Symb.	*Sp. Gr.*			*Nit.*		*Oxy.*	*Chem. Equiv.*
$N + O$ or $\dot{N}$	1.5239	Air =1	By Vol.	100	+	50	100
	22.15	Hyd. =1	" Wght.	14.15	+	8	22.15

Process,

Precautions,

446. This gas was termed, by its discoverer, Priestley, *dephlogisticated nitrous air;* by the Dutch chemists *gaseous oxide of azote.* It is obtained by several processes, but that most usually adopted is the following. The salt obtained by neutralizing nitric acid with carbonate of ammonia, called *Nitrate of Ammonia*‡ is heated in a glass retort. When all the salt is liquefied, it should be kept gently simmering, avoiding violent ebullition. The temperature should not be raised above 500° F. If a white cloud appears within the retort, due to some of the salt subliming undecomposed, the heat should be checked.§ The management of the heat is to be carefully attended to; when the heat is too great, the gas is apt to be impure.

Collected over water,

447. The gas may be collected over water and allowed to stand an hour or two before it is used, during which time it will deposit a

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† See *Quart. Jour. Sci.* vols. viii. ix. x.

‡ See *Nitrate of Ammonia.*

§ A chauffer with ignited charcoal affords the best heat, and the retort is less liable to be broken than when a lamp is employed. An iron or tin plate will be found useful to check the ebullition if too great, as it can be interposed between the chauffer and the retort, and withdrawn at pleasure.

Chap. III.

white substance and become transparent. When a large quantity is wanted, it may be received in a gasholder, and much gas will be saved if the vessel be filled with water which has been once used for the same purpose.

Theory of the process.

448. The products of this operation, when carefully conducted, are water and protoxide of nitrogen. The nature of the change will be understood by comparing the composition of nitrate of ammonia with that of the products derived from it. These, in round numbers, are as follows:

Nitric Acid.	*Ammonia.*	*Water.*	*Prot. of Nitrogen.*
Nitrogen 14 or 1 eq.	Nitrogen 14 or 1 eq.	Hyd. 3 or 3 eq.	Nit. 28 or 2 eq.
Oxygen 40 or 5 eq.	Hydrogen 3 or 3 eq.	Oxy. 24 or 3 eq.	Oxy. 16 or 2 eq.
54	17	27	44

The same expressed in symbols is

$$\mathrm{N}+5\mathrm{O}; \qquad \mathrm{N}+3\mathrm{H}; \qquad | \qquad 3(\mathrm{H}+\mathrm{O}); \qquad 2(\mathrm{N}+\mathrm{O}).$$

The hydrogen in the ammonia takes so much oxygen as is sufficient for forming water, and the residual oxygen converts the nitrogen both of the nitric acid and of the ammonia into protoxide of nitrogen: 71 grains of the salt will thus yield 44 grains of protoxide of nitrogen and 27 of water.

Properties.

449. Protoxide of nitrogen is a colourless gas, which does not affect the blue vegetable colours, even when mixed with atmospheric air. Recently boiled water, which has cooled without exposure to the air, absorbs nearly its own bulk of it at 60° F. and gives it out again unchanged by boiling. The solution, like the gas itself, has a faint agreeable odour and sweet taste. The action of water affords a ready means of testing its purity; removing it readily from all other gases, such as oxygen and nitrogen, which are sparingly absorbed by that liquid.

May be respired.

450. Davy discovered that this gas may be taken into the lungs with safety,* and that it supports respiration for a few minutes. A few deep inspirations of it are followed by feelings of excitement, similar to the early stages of intoxication. The experiment, however, cannot be made with impunity by all persons, especially by those who are liable to a determination of blood to the head.†

Supports combustion.

451. Protoxide of nitrogen supports combustion, and a taper introduced into it has its flame much augmented and surrounded by a purplish halo. Phosphorus and sulphur, when introduced in a state of vivid ignition into this gas, burn with the same appearance nearly as in oxygen; but, if when put into the gas, they are merely burning dimly, they do not decompose it and are extinguished, so that they may be melted in the gas, or even touched with a red-hot wire without inflaming, (but when wire intensely heated, or made white-hot, is applied, the phosphorus burns, or rather detonates, with prodigious violence. H.) Charcoal, and many of the metals, also decompose protoxide of nitrogen at high temperatures.

Detonates with hydrogen.

452. A mixture of this gas with an equal bulk of hydrogen gas detonates, on applying a lighted taper, or passing an electric spark,

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* *Researches on the nitrous oxide.*

† See report of remarkable cases in *Amer. Jour.* vol. v.

and is decomposed also by spongy platinum at common temperatures. The product of the combustion is the same as when oxygen gas or atmospheric air is used. The protoxide is decomposed; the combustible matter unites with its oxygen, and the nitrogen is set free.

Decomposition.

453. At a red heat this gas is decomposed and converted into nitrogen, oxygen and nitrous acid.* It was analyzed by Davy, by means of hydrogen gas. He mixed 39 measures of the former with 40 measures of hydrogen, and fired the mixture by the electric spark. Water was formed; and the residual gas, which amounted to 41 measures, had the properties of pure nitrogen. As 40 measures of hydrogen require 20 of oxygen for combustion, it follows that 39 volumes of the protoxide of nitrogen contain 41 of nitrogen and 20 of oxygen. According to Gay-Lussac's law of gaseous combination, it may be inferred that protoxide of nitrogen contains its own bulk of nitrogen and half its volume of oxygen. The analysis of this compound by Henry,† by means of carbonic oxide gas, has proved beyond a doubt that this is the exact proportion. Now,

Analysis.

100 cubic inches of nitrogen gas weigh	-	30.1650 grains
50 do. oxygen	- - - -	17.0936 "
These numbers added together amount to	-	47.2586

which must be the weight of 100 cubic inches of the protoxide; and its specific gravity is, therefore, 1.5239. Its composition by weight is determined by the same data, being 17.0936 of oxygen to 30.1650 of nitrogen, or as 8 to 14.117, nearly the number already stated. T.

Binoxide of Nitrogen—Nitric Oxide.

				Composition.				
Symb.	*Sp. Gr.*			*Nit.*		*Oxy.*		*Chem. Equiv.*
$N+2O$ or $\ddot{N}$	1,0375	air =1	By Vol.	100	+	100	=	200
	15.75	Hyd.=1	" Wght.	14.15	+	16	=	30.15

454. This gas, discovered by Hales, was first examined by Priestley, and called by him *nitrous* air a term afterwards changed to *nitrous gas*, then to *nitric oxide*, and more lately to *Binoxide of Nitrogen*, which last appears to be its most appropriate title. It is more generally known, however, under the name of nitrous gas.

How obtained.

455. It is usually obtained by presenting certain substances to nitric acid, which abstract a portion of its oxygen, leaving the remaining elements in such proportions as to constitute the gas in question; for this purpose copper may be put into a gas bottle, (Fig. 87)

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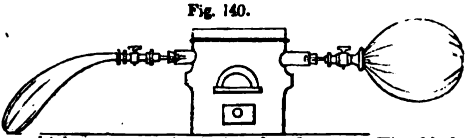
* For experiments of this kind the following simple apparatus may be used: It consists of two bladders, (Fig. 140,) one of which is filled with the gas, and the other empty, attached to the extremities of a porcelain tube which traverses the body of a furnace. The bladders are supplied with stop-cocks, and the gas is squeezed from one to the other when the tube is red-hot.

Fig. 140.



† *Ann. of Phil.* viii. 299, N. S.

with nitric acid, diluted with thrice its bulk of water; an action ensues, red fumes are produced, and there is a copious evolution of the gas, which may be collected and preserved over water. The first portions should be rejected. It is presently recognised by the red fumes which it produces when brought into the contact of air. During this process part of the nitric acid gives oxygen to the copper; and passes to the state of binoxide of nitrogen, the remaining acid unites with the oxide of copper, and composes a nitrate of that metal.

Theory of the process.

Quicksilver may be substituted for the copper; but in the latter case it will be found necessary to apply heat to the materials.

Effect of oxygen,

456. When mixed with oxygen gas red fumes arise, heat is evolved, a diminution takes place, and if the two gases be in proper proportion, and perfectly pure, they disappear entirely. The product of this union is possessed of acid properties, which may be shown by the following experiments.

Exp. 1. Paste a slip of litmus paper within a glass jar, near the bottom; and into the jar, filled with and inverted in water, admit as much of the gas, previously well washed, as will displace the water below the level of the paper. The colour of the litmus will remain unchanged; but on adding oxygen gas it will be immediately reddened.

Exp. 2. Pass up into a jar filled with the vegetable infusion, (56 Note) a quantity of oxygen gas sufficient to displace about one half of the infusion; to this admit binoxide of nitrogen, absorption and reddening will ensue.

Analysis.

457. Binoxide of nitrogen is rather heavier than common air. It is partially resolved into its elements by being passed through red-hot tubes. A succession of electric sparks has a similar effect. It is converted into protoxide of nitrogen by substances which have a strong affinity for oxygen. Davy ascertained its composition by the combustion of charcoal.* Two volumes of the binoxide yielded one volume of nitrogen, and about one of carbonic acid, whence it was inferred to consist of equal measures of oxygen and nitrogen gases united without any condensation. Gay-Lussac also proved that this proportion is exact. He decomposed 100 measures of the gas, by heating potassium in it; when 50 measures of pure nitrogen were left, and the potassa formed corresponded to 50 measures of oxygen. The same fact has been lately proved by Henry.† Hence, as

50 cubic inches of oxygen gas weigh	- -	17.0936 grains.
50 do. nitrogen	- - -	15.0825 "
100 cubic inches of the binoxide must weigh		32.1761

Its composition stated at page 143 is drawn from these facts. Its density ought to be 1.0375, which closely agrees with the direct experiments of Davy, Thomson, and Bérard. T.

Properties.

458. When washed with water it is not acid. Water absorbs the binoxide sparingly; 100 measures of that liquid, cold and recently boiled, take up about 11 of the gas. It extinguishes most burning bodies; but phosphorus readily burns in it if introduced in intense ignition. It is quite irrespirable, exciting strong spasms of the glottis, as soon as an attempt is made to inhale it. The experiment, however, is a dangerous one.

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* *Elem. Chem. Phil.* p. 200.

† *Ann. of Phil.* N. S. viii. 299.

Sec. III.

Decomposition.

459. It is decomposed by exposure to almost all bodies that attract oxygen; thus iron filings decompose it, and become oxidized, affording a proof of the presence of oxygen in it. During this process, water, ammonia, and protoxide of nitrogen are generated. Mixed with sulphurous acid, it is decomposed, and this acid is changed into the sulphuric, but not unless water is present. With an equal bulk of hydrogen, it forms a mixture which cannot be made to explode, but which is kindled by contact with a lighted candle, and burns rapidly with a greenish white flame, water and pure nitrogen gas being the sole products. The action of freshly ignited spongy platinum on a mixture of hydrogen and binoxide of nitrogen gases leads to the slow production of water and ammonia.

Use in Eudiometry.

460. From the formation of red coloured acid vapours, whenever binoxide of nitrogen and oxygen are mixed, these gases detect the presence of each other; and since the product is wholly absorbed by water, either of them may be entirely removed from any gaseous mixture by adding a sufficient quantity of the other. Priestley, who first observed this fact, supposed that combination takes place between them in one proportion only; and inferring on this supposition, that a given absorption must always indicate the same quantity of oxygen, he was led to employ binoxide of nitrogen in Eudiometry. But in this opinion he was mistaken. Dalton and Gay-Lussac have described the precautions which are required to insure accuracy.*

Hyponitrous Acid.

Composition.

Symb.		*Nit.*		*Oxy.*		*Equiv.*
	By Vol.	100	+	150		
N+3O or $\dddot{N}$	" Wght.	14.15	+	24	=	38.15

Process.

461. On adding binoxide of nitrogen in excess to oxygen gas, confined in a glass tube over mercury, Gay-Lussac found that 100 measures of the latter combine with 400 of the former forming an acid which unites with the potassa. The compound so formed is hyponitrous acid.

Properties.

462. The anhydrous liquid acid is colourless at 0° F. and green at common temperatures. It is so volatile, that in open vessels the green fluid wholly and rapidly passes off in the form of an orange vapour, which is said to have a density of 1.72. On admixture with water it is converted into nitric acid and binoxide of nitrogen, the latter escaping with effervescence; but when much nitric acid is present, the hyponitrous is changed into nitrous acid, which imparts

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Method of Gay-Lussac.

* Dalton in *Ann. of Phil.* x. 38; and further directions have been published by Henry in his *Elements*. Instead of employing a narrow tube, such as is commonly used for measuring gases, Gay-Lussac advises that 100 measures of air should be introduced into a very wide tube or jar, and that an equal volume of binoxide of nitrogen should then be added. The red vapours, which are instantly produced; disappear very quickly; and the absorption after half a minute, or a minute at the most, may be regarded as complete. The residue is then transferred into a graduated tube and measured. The diminution almost always, according to Gay-Lussac, amounts to 84 measures, one-fourth of which is oxygen. Gay-Lussac has applied this process to the analysis of various mixed gases, in which the oxygen was sometimes in a greater, at others in a less proportion than in the atmosphere, and the indications were always correct. For other details see Turner's *Elements*, 177, and Dana on *Nitrous Gas, Amer. Jour.*, vii. 338.

several shades of colour, orange, yellow, green, and blue, according to its quantity. One equivalent of hyponitrous and one of nitric acid, yield two equivalents of nitrous acid: thus $N+3O$ and $N+5O$ contain the elements for forming $2(N+4O)$.

463. Hyponitrous acid does not unite directly with alkalies, being then resolved principally into nitric acid and binoxide of nitrogen; but the hyponitrites of the alkalies and alkaline earths may be obtained by heating the corresponding nitrates to a gentle red heat.

Action of sulphuric acid.

464. Hyponitrous acid forms with water and sulphuric acid a crystalline compound, which is generated in large quantity during the manufacture of sulphuric acid, and the production of which is an essential part of that process. It is generated whenever moist sulphurous acid gas and nitrous acid vapour are intermixed, being instantly deposited in the form of white acicular crystals. T. 179.

Nitrous Acid.

Symb.		Composition. *Nit.*		*Oxy.*		*Equiv.*
....	By Vol.	100	+	200		
$N+4O$ or $\overset{....}{N}$	" Wght.	14.15	+	32	=	46.15

Nitrous acid gas.

465. When binoxide of nitrogen is presented to oxygen, the two gases combine, and a new gaseous compound of a deep orange colour results.

Exp.

Into a large glass globe, or other convenient vessel, previously filled with water, introduce sufficient nitrous gas to displace about two thirds of the water. On passing into it oxygen gas the vessel will become filled with deep orange coloured nitrous acid gas.

Not easily examined.

This compound is absorbed both by quicksilver and water, so that to preserve it for examination, we are obliged to resort to exhausted glass vessels. When we thus mix two volumes of binoxide of nitrogen with one volume of oxygen, the gases become condensed to one third their original volume, and form *nitrous acid vapour*.

Properties.

466. This gas supports the combustion of the taper, of phosphorus, and of charcoal, but extinguishes sulphur.* 100 measures of nitrous acid vapour contain 100 of nitrogen gas and 200 of oxygen. The specific gravity of this vapour ought to be 3.1775, formed of 0.9727 the sp. gr. of nitrogen+2.2048 twice the sp. gr. of oxygen.

Liquid nitrous acid.

467. Nitrous acid may exist in the liquid as well as in the gaseous form. To form liquid nitrous acid, its vapour may be condensed by a freezing mixture. It is readily absorbed by water; the water becomes first green, then blue, and finally an orange colour, more or less deep. The latter may be brought to the state of green or blue by adding more or less water. Hence the colour depends partly on the circumstance of density; but there can be little doubt that it is materially affected also by the proportions of nitric, nitrous, and hyponitrous acids, which according to Gay-Lussac, compose nitrous acid, as it is ordinarily obtained in a liquid state. H. 1. 321.

From nitrate of lead.

468. It may be procured by exposing nitrate of lead carefully dried to a heat sufficient to decompose the salt. The nitric acid of the salt is resolved into nitrous acid and oxygen; and if the products

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* It reddens litmus paper, has a sour taste, a strong smell, and turns animal substances yellow.

are received in vessels kept moderately cool, the greater part of the former condenses into a liquid. This substance was first obtained by Gay-Lussac.

Properties. 469. The liquid anhydrous acid is powerfully corrosive, has a strong acid taste and pungent odour, and is of a yellowish orange colour. Its density is 1.451. It remains liquid at ordinary temperatures and pressure, and boils at 82° F. Exposed to the air it evaporates with great rapidity, forming the common nitrous acid vapours, which, when once mixed with air or other gases, require an intense cold to condense them.

Oxidizes. 470. Nitrous acid is a powerful oxidizing agent, readily giving oxygen to the more oxidable metals, and to most substances which have a strong affinity for it. The acid is decomposed at the same time, being commonly changed into binoxide of nitrogen, though sometimes the protoxide and even pure nitrogen gases are evolved. When transmitted through a red hot porcelain tube, it suffers decomposition, and a mixture of oxygen and nitrogen gases is obtained.

Action of water. When nitrous acid is mixed with a considerable quantity of water, it is instantly resolved into nitric acid, which unites with the water, and binoxide of nitrogen which escapes with effervescence.

Nitric Acid.

Composition.

Symb.		*Nit.*		*Oxy.*		*Equiv.*
$N+5O$ or $\overset{\cdot\cdot\cdot\cdot\cdot}{N}$	By Vol.	100	+	250		
	" Wght.	14.15	+	40	=	54.15

Nitric acid formed. 471. If a succession of electric sparks be passed through a mixture of oxygen and nitrogen gases confined in a glass tube over mercury, a little water being present, the volume of the gases will gradually diminish, and the water after a time will be found to have acquired acid properties. On neutralizing the solution with potassa, or what is better, by putting a solution of pure potassa, instead of water, into the tube, a salt is obtained which possesses all the properties of the nitrate of potassa (nitre.) This experiment was performed by Cavendish in 1785, who inferred from it that nitric acid is composed of oxygen and nitrogen.

The nitric acid may be formed more conveniently by adding binoxide of nitrogen slowly over water to an excess of oxygen gas. It cannot exist in an insulated state. The most simple form under which chemists have hitherto procured nitric acid is in solution with water. It is usually obtained by the distillation of purified nitre with sulphuric acid, of which materials different proportions are employed. Usual process for obtaining nitric acid,

Into a glass retort, which may be either tubulated or not, put four parts by weight of nitrate of potassa, reduced to a coarse powder, and pour upon it three parts of concentrated sulphuric acid. Apply a tubulated receiver of large capacity between which and the retort, an adopter may be interposed; these junctures being luted with a mixture of pipe-clay, sifted sand, and cut tow or flax. To the tubulure of the receiver, a glass tube may be fixed by means of the fat lute,[*] and may terminate in another receiver, containing a small quantity of water.

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[*] Formed by heating perfectly dry and finely sifted tobacco pipe clay, with painters' drying oil.

If the operator wishes to collect the gaseous products also, this second receiver should be provided with a tubulure, to which a bent pipe may be luted, terminating under one of the inverted funnels in the shelf of the pneumatic trough. Apply heat to the retort, through the intervention of the sand-bath. The first product that passes into the receiver, is generally of a red colour, and of a smoking quality. These appearances gradually diminish; and if the materials used were clean, the acid will come over pale, and even colourless. Afterwards it gradually re-assumes a red colour, and smoking property; which appearances go on increasing till the end of the operation; and the whole product mingled together, has either a yellow or an orange colour, according to the temperature employed. H. 1. 318.

On the large scale.

472. The nitric acid of commerce, which is generally red and fuming in consequence of the presence of binoxide of nitrogen, is procured by the distillation of two parts of nitre with one of sulphuric acid; these proportions afford about one part of orange-coloured nitric acid of the specific gravity of 1.48.*

Purification of nitric acid.

473. The nitric acid of commerce, as usually obtained is impure. It frequently contains portions of sulphuric and hydrochloric acid. The former is derived from the acid which is used in the process; and the latter from sea-salt, which is frequently mixed with nitre. These impurities may be detected by adding a few drops of a solution of chloride of barium and nitrate of silver to separate portions of nitric acid, diluted with three or four parts of distilled water. If chloride of barium cause a cloudiness or precipitate, sulphuric acid must be present; if a similar effect be produced by nitrate of silver, the presence of hydrochloric acid may be inferred. Nitric acid is purified from sulphuric acid by redistilling it from a small quantity of nitrate of potassa, with the alkali of which the sulphuric acid unites, and remains in the retort. To separate hydrochloric acid, it is necessary to drop a solution of nitrate of silver into the nitric acid as long as a precipitate is formed, and draw off the pure acid by distillation.†

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* Upon the large scale 112 lbs. of nitre, and 56 of sulphuric acid yield from 50 to 52 lbs. of nitric acid. Some manufacturers employ three parts of nitre and two of sulphuric acid, and the *London Pharmacopœia* directs equal weights, by which a nearly colourless nitric acid is afforded.

† The distillation of nitric acid may be conducted upon the small scale in a tubulated glass retort *a*, with a tubulated receiver *b*, passing into the bottle *c*, (Fig. 141.) The requisite heat is obtained by the lamp *d*, and the whole apparatus supported by the brass stands with sliding rings *e e*.

Fig. 141.

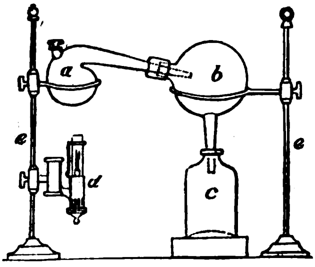
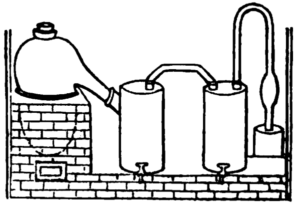


Fig. 142.



Preparation of nitrous acid, or aqua-fortis.

The manufacturer who prepares nitric acid upon a large scale, generally employs distillatory vessels of stone ware. Fig. 142 represents the arrangement of the distillatory apparatus, employed at Apothecaries' Hall, London, for the production of common *aqua-fortis*: it consists of an iron pot, set in brick-work, over a fire-place; an earthenware head is luted upon it, communicating with two receivers of the same material, furnished with earthen ware stop cocks, the last of which has a tube of safety dipping into a basin of water.

For pharmaceutical purposes, the ordinary acid is generally sufficiently pure. If, however, pure nitre, and pure sulphuric acid be employed in its production, and the latter not in excess, there is little apprehension of impurity in the resulting acid.

Specific gravity.

474. Liquid nitric acid is heavier than water, in the proportion of 1.5 or upwards to 1. The specific gravity of real nitric acid, which cannot, however, be obtained separately, may be calculated at 1.75. In its heaviest form, it still contains a portion of water, which is essential to its existence in a liquid state. In acid of the sp. gr. 1.5 the water amounts to 20 per cent. It possesses acid properties in an eminent degree. A few drops of it diluted with a considerable quantity of water form an acid solution, which reddens litmus paper permanently. It unites with and neutralizes alkaline substances, forming with them salts which are called *nitrates*.

475. Nitric acid is usually coloured by nitrous acid.

Coloured by nitrous acid gas.

To expel which, put the acid into a retort to which a receiver is applied, the two vessels not being luted, but joined merely by paper. Apply a very gentle heat for several hours to the retort, changing the receiver as soon as it becomes filled with red vapours. The nitrous gas will thus be expelled, and the nitric acid will remain in the retort limpid and colourless. It must be kept in a bottle secluded from light. H. 327.

Decomposes animal matters.

476. Nitric acid emits white fumes when exposed to the air, and is extremely sour and corrosive. It effects the decomposition of animal matters. The cuticle and nails receive a permanent yellow stain when touched with it; and if applied to the skin in sufficient quantity it acts as a powerful cautery, destroying the organization of the part entirely.

Boiling point.

477. It boils at 248° F., and may be distilled over without any essential change. An acid, weaker than 1.42, is strengthened by being boiled; while an acid, stronger than 1.42, becomes weaker by boiling. All the varieties of nitric acid, therefore, are brought, by sufficient boiling, to the specific gravity, 1.42, which appears to be the most energetic combination of acid and water.

Freezing.

478. Nitric acid may be frozen by cold. The temperature at which congelation takes place, varies with the strength of the acid. The strongest acid freezes at about 50° below zero. When diluted with half its weight of water, it becomes solid at—1½° F. By the addition of a little more water, its freezing point is lowered to—45° F. Strong nitric acid absorbs moisture from the atmosphere; in consequence of which it increases in weight, and diminishes in specific gravity.

Absorbs moisture.

Mixed with water, temperature rises.

479. When two parts of the acid are suddenly diluted with one of water, an elevation of temperature is produced to about 120° F.; and the admixture of 58 parts by weight of acid of specific gravity 1.50 with 42 parts of water, both at 60° F., gives a temperature of 140°.* When more water is added to this diluted acid, its temperature is reduced. Snow or ice added to the cold dilute acid is instantly liquefied and an intense degree of cold produced.

Effect of solar light.

480. When very concentrated it becomes coloured by exposure to the sun's light, passing first to a straw colour, and then to a deep orange. This effect is produced by the union of the light of the sun

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* Ure. See table of strength of diluted acid in Appendix.

Affords oxygen.

with oxygen, in consequence of which the proportion of that principle to the nitrogen is diminished. By exposing it to the sun's rays in a gas bottle, the bent tube of which terminates under water, oxygen gas may be procured. H. 1. 321.

Decomposed by combustibles,

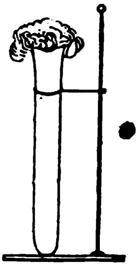
481. This acid retains its oxygen with but little force, and hence is much employed by chemists for bringing bodies to their maximum of oxidation. It is decomposed by all combustible bodies, which are oxygenized by it, with more or less rapidity in proportion to their affinity for oxygen.

Poured on perfectly dry and powdered charcoal it excites the combustion of the charcoal, which becomes red-hot, and emits an immense quantity of fumes.

Exp. Action on phosphorus,

Its action on phosphorus is often extremely violent, and great care should be taken to avoid accident. A few pieces of phosphorus may be placed in the bottom of a tall and strong glass, and the acid be poured upon it from a vessel attached to the end of a long rod of wood.* (Fig. 143.)

Fig. 143.



All vegetable substances are decomposed by it. In general the oxygen of the nitric acid enters into direct combination with the hydrogen and carbon of those compounds, forming water with the former, and carbonic acid with the latter. This happens remarkably in those compounds in which hydrogen and carbon are predominant, as in alcohol and the oils.

It inflames essential oils when suddenly poured on them.

Exp.

Into a gallipot, placed upon a hearth and containing about a table spoonful of oil of turpentine, pour about half the quantity of the strong acid, previously mixed with a few drops of sulphuric acid. The moment the acids come in contact with the turpentine, a large quantity of dense smoke will be produced, often accompanied with flame. The acid should be poured from a bottle tied to the end of a long stick, otherwise the operator's eyes may be severely injured.

Caution.

Metals,

482. It is also decomposed by metals, with different phenomena, according to the affinity of each metal for oxygen.

This may be seen by pouring some strong nitric acid on iron filings, or powdered tin. The acid must be of greater density than 1.48, otherwise it will not produce the effect. Violent heat, attended with red fumes, will be produced, and the metals will be oxidized.

When oxidation is effected through the medium of nitric acid, the acid itself is commonly converted into binoxide of nitrogen. This gas is sometimes given off nearly quite pure; but in general some nitrous acid, protoxide of nitrogen, or pure nitrogen, is disengaged at the same time.

and by a red heat.

483. Nitric acid may be decomposed by passing its vapour through a red hot porcelain tube; oxygen is given off, nitrous acid gas is produced, and a quantity of diluted acid passes over into the receiver, having escaped decomposition; so that it is thus proved to consist of nitrous acid gas, oxygen and water.

For experiments of this kind the form of apparatus, described for the decomposition of water by iron (405), may be employed, omitting the condensing worm-pipe, and substituting a porcelain tube.

484. All the salts of nitric acid are soluble in water, and, there-

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* See Hare's *Compend*, 171.

Tests of.

fore, it is impossible to precipitate that acid by any re-agent. The presence of nitric acid, when uncombined, is readily detected by its strong action on copper and mercury, emitting ruddy fumes of nitrous acid, and by its forming with potassa a neutral salt, which crystallizes in prisms, and has all the properties of nitre. Gold-leaf is a still more delicate test. When hydrochloric acid is added to the solution of a nitrate, chlorine is disengaged, and the liquid hence acquires the property of dissolving gold-leaf; but as the action of hydrochloric acid on the salts of chloric, bromic, iodic, and selenic acids likewise yields a solution capable of dissolving gold, no inference can be drawn from the experiment, unless the absence of these acids shall have been previously demonstrated. A very delicate test has been proposed by O'Shaugnessy, founded on the orange-red followed by a yellow colour, which nitric acid communicates to morphia. The supposed nitrate is heated in a test tube with a drop of sulphuric acid, and then a crystal of morphia is added.[*] It is advisable to try the process in a separate tube with the sulphuric acid alone, in order to prove the absence of nitric acid. T.

Uses.

Aqua-fortis.

485. Nitric acid is of considerable use in the arts. It is employed for etching on copper, as a solvent of tin to form with that metal a mordant for some of the finest dyes; in metallurgy and assaying; in various chemical processes, on account of the facility with which it parts with oxygen and dissolves metals; in medicine as a tonic, &c. For the purposes of the arts it is commonly used in a diluted state, and contaminated with the sulphuric and hydrochloric acids, by the name of *aqua-fortis*.[†]

Section IV. *Carbon.*

Symb.	*Sp. Gr.* (*hypothetical.*)	*Chem. Equiv.*
C.	0.4215 air =1	By Vol. 100
	6.12 Hyd.=1	" Wght. 6.12

Purest form.

486. The purest form of carbon is the diamond; from its powers of refracting light, Newton inferred that it was a combustible body. The diamond is the hardest substance in nature. Its texture is crystalline in a high degree, and its cleavage very perfect. Its primary form is the octohedron. Its specific gravity is 3.52. Acids and alkalies do not act upon it; and it bears the most intense heat in close vessels without fusing or undergoing any perceptible change. Heated to redness in the open air, it is entirely consumed. Lavoisier first proved it to contain carbon by throwing the sun's rays, concentrated by a powerful lens, upon a diamond contained in a vessel of oxygen gas. The diamond was consumed entirely, oxygen disappeared, and carbonic acid was generated. It has since been demonstrated by the researches of others, that carbonic acid is the product of its combustion.[‡]

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[*] *Lancet,* 1829—30.

[†] This is often prepared by mixing common nitre with an equal weight of sulphate of iron, and half its weight of the same sulphate calcined, and distilling the mixture; or by mixing nitre with twice its weight of dry powdered clay, and distilling in a reverberatory furnace. Two kinds are found in the shops, one called *double aqua-fortis*, which is about half the strength of nitric acid; the other simply *aqua-fortis*, which is half the strength of the double.

[‡] For a description and plates of the various forms of apparatus contrived for the combustion of the diamond, see Henry's and Brande's vols. i.; also 1st and 2d editions of this *Manual.*

487. Guyton-Morveau inferred from his experiments that the diamond is pure carbon, and that charcoal is an oxide of carbon. Tennant burned diamonds by heating them with nitre in a gold tube; and comparing his own results with those of Lavoisier on the combustion of charcoal, he concluded that equal weights of diamond and pure charcoal, in combining with oxygen, yield precisely equal quantities of carbonic acid. He was thus induced to adopt the opinion, that charcoal and the diamond are chemically the same substance; and that the difference in their physical character is solely dependent on a difference of aggregation.* This conclusion was confirmed by the experiments of Allen and Pepys,† and Davy.‡ §

Charcoal. Another form of carbon is *charcoal*, the purest variety of which is *lamp-black.*||

Method of preparing charcoal. 488. Charcoal may be prepared by heating pieces of wood, covered with sand, to redness, and keeping them in that state for about an hour. They are converted into a black brittle substance, which appears to be the same from whatever kind of wood it has been procured.

Lamp-black. Lamp-black is prepared from refuse and residuary resin. When lamp-black has been heated red-hot in a close vessel, it may be considered as very pure carbon. A very pure charcoal is obtained from spirits of wine.

Animal charcoal. Animal charcoal, or *ivory black*, is a mixture of charcoal and phosphate of lime, prepared by exposing bones to heat in a close vessel. The quantity of charcoal obtained from different kinds of wood is liable to much variation.

Its properties. 489. Charcoal is black, insoluble, inodorous, insipid, and brittle; an excellent conductor of electricity, but a bad conductor of heat; unchanged by the combined action of air and moisture at common temperatures; and easily combustible in oxygen gas. The combustion of charcoal in oxygen has been already noticed. (367) The product of the combustion is carbonic acid gas, the oxygen neither increasing nor diminishing in volume, but becoming heavier by the quantity of carbon which combines with it; every sixteen parts of oxygen take up six of carbon.

Combustion in oxygen.

Absorbing power. 490. Charcoal likewise absorbs the odoriferous and colouring principles of most animal and vegetable substances. When coloured infusions of this kind are digested with a due quantity of charcoal, a solution is obtained, which is nearly if not quite colourless. Tainted flesh may be deprived of its odour by this means, and foul water be purified by filtration through charcoal. The substance commonly employed to decolorize fluids is animal charcoal reduced to a fine powder. It loses the property of absorbing colouring matters by use, but recovers it by being heated to redness.

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* *Phil. Trans.* for 1797. † Ibid, 1807. ‡ Ibid, 1814.

§ The latter chemist did indeed observe the production of a minute quantity of water during the combustion of the purest charcoal, indicative of a trace of hydrogen; but its quantity is so small, that it cannot be regarded as a necessary constituent. It proves only that a trace of hydrogen is retained by charcoal with such force, that it cannot be expelled by the temperature of ignition. T.

|| *Graphite*, or, as commonly called *black lead*, is a natural compound of carbon and iron; some varieties appear to be a peculiar form of carbon, leaving very little residuum when burned. *Anthracite* is another variety.

Use in the arts. 491. The charcoal of wood, besides its use as a fuel, is necessary to the preparation of that kind of iron which is used for wire; to the cementation of steel; and to the preparation of gunpowder. From the powerful affinity which it has for oxygen at a high temperature, it is constantly employed for deoxidating the metals and many other substances.

Coke. The charcoal prepared from pit-coal, called *coke*, is less pure, and, besides other substances, generally contains sulphur, but it has the advantage of being heavier and more compact, in consequence of which it is better adapted for burning in furnaces in which there is a powerful blast of air. H. i. 330.

Spontaneous combustion of charcoal. 492. When large quantities of charcoal, in a state of minute division, are left undisturbed, spontaneous combustion generally ensues, and occasionally with charcoal in fragments of considerable size. This has been attributed to the action of air and moisture on minute quantities of potassium present in the coal.*

Density. 493. The hypothetical density of the vapour of carbon, calculated as explained at page 33, is 0.4215, and 100 cubic inches of it should weigh 13.0714 grains.

Carbon and Oxygen.

Compounds of carbon and oxygen. 494. There are two compounds of carbon and oxygen; carbonic oxide and carbonic acid gases. Carbonic oxide gas is theoretically considered as a compound of 100 measures of the vapour of carbon and 50 of oxygen condensed into 100 measures; and carbonic acid gas, of 100 measures of the vapour of carbon and 100 of oxygen condensed into 100 measures.

Composition. The composition of these compounds of carbon is as follows:—

	Carbon.		Oxygen.		*Equiv.*	*Formula.*
Carbonic oxide	6.12 or 1 eq.	+	8 or 1 eq.	=	14.12	$C+O$ or $\dot{C}$.
Carbonic acid	6.12 or 1 eq.	+	16 or 2 eq.	=	22.12	$C+2O$ or $\ddot{C}$.

Carbonic Acid.

Carbonic acid. 495. *Carbonic acid* was discovered by Black in 1757, and described by him under the name of *fixed air*. He observed the existence of this gas in common limestone and magnesia, and found that it may be expelled from these substances by the action of heat. It may be obtained by burning carbon, either pure charcoal or the diamond, in oxygen gas. **Processes.** The best mode of procuring it for experiment consists in acting upon marble (*carbonate of lime*) by dilute hydrochloric acid. The hydrochloric acid takes the lime, and carbonic acid gas escapes with effervescence.

For this purpose the marble, in fragments, is placed in the gas bottle (Fig. 85 or 86) and hydrochloric acid, previously diluted with water, poured upon it: im-

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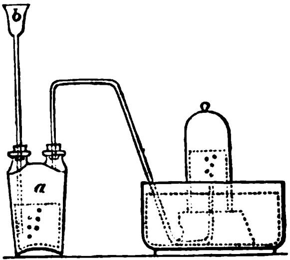
* See Aubert's paper on this subject in *Phil. Mag.* and *Ann.* N. S., Vol. ix. 148, and Hadfield's and Davies's papers in *Lond. and Edin. Phil. Mag.* iii.

mediate effervescence ensues, and the gas is conveyed by the bent pipe to an inverted jar on the shelf of the pneumatic trough, (Figs. 96, 97.) When the action ceases, it may be renewed by the addition of fresh acid until the marble is dissolved.

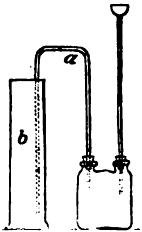
Or the apparatus, (Fig. 144,) may be employed, the acid being poured down the tube *b*, which passes to the bottom of the two necked bottle, *a*.

Fig. 144.



As carbonic acid gas is heavier than atmospheric air it may also be obtained by means of the apparatus, (Fig. 145) ; *a* is a long glass tube proceeding from the bottle containing the marble and acid, and passing down to the bottom of the jar *b*, which stands with its mouth uppermost. The carbonic acid will expel the common air from the jar.

Fig. 145.



Properties. 496. Carbonic acid, as thus procured, is a colourless, inodorous, elastic fluid, which possesses all the physical characters of the gases in an eminent degree, and requires a pressure of thirtysix atmospheres to condense it into a liquid. The exact knowledge of its density is still an important desideratum: it is estimated at 1.524 by Dulong and Berzelius, and at 1.5277 by Thomson.* If its specific gravity is estimated as 1.5239, 100 cubic inches should weigh 47.2586 grs. T.

Absorbed by water. 497. Carbonic acid may be collected over water, but must be preserved in vessels with glass-stoppers, since water, at common temperature and pressure, takes up its own volume.

Exp. Fill partly a jar with this gas, and let it stand a few hours over water. An absorption will gradually go on, till at last none will remain. This absorption is infinitely quicker when agitation is used. Repeat the above experiment, with this difference, that the jar must be shaken strongly. A very rapid diminution will now take place. In this manner, water may be charged with rather more than its own bulk of carbonic acid gas; and it acquires, when thus saturated, a brisk and pleasant taste.

Water impregnated. 498. The effervescent quality, and brisk, pungent taste of fermented liquors is due to the presence of this gas, as is likewise that of many mineral waters. The latter are often imitated by condensing carbonic acid into water, either by a condensing pump, of which a description is given by Pepy's,† or by a Nooth's apparatus, as represented in Fig. 146.‡

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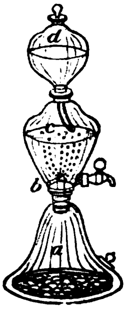
* *First Principles*, i. 143.

† *Quar. Jour. of Sci. and the Arts*, vol. iv. p. 305.

Nooth's apparatus. ‡ It consists of three vessels, the lowest, *a*, flat and broad, so as to form a steady support: it contains the materials for evolving the gas, such as pieces of marble and dilute hydrochloric acid, of which fresh supplies may occasionally be introduced through the stopped aperture. The gas passes through the tube *b*, in which is a glass valve opening upwards, into the vessel *c*, containing the water or solution intended to be saturated with the gas, and which may occasionally be drawn off by the glass stop-cock. Into this dips the tube of the uppermost vessel *d*, which occasions some pressure on the gas in *c*, and also produces a circulation and agitation of the water. At the top of *d* is a conical stopper, which acts as an occasional valve, and keeps up a degree of pressure in the vessels.

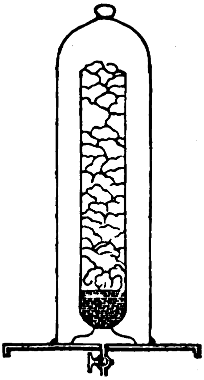
Fig. 146.



Exp.

The escape of carbonic acid from fermented liquors may be shown by placing three or four ounces of ale or porter in a jar or tube, (Fig. 147) twenty or more inches in height, on the plate of the air-pump, covering it with a tall receiver, and exhausting the air. The foam will rise and entirely fill the jar or tube.

Fig. 147.



Under a pressure of two atmospheres water dissolves twice its volume of this gas, and so on. It thus becomes brisk and tart, and reddens delicate vegetable blues. By freezing, boiling, or exposure to the vacuum of the air-pump, the gas is given off.

Exp.

Place a tumbler of water which has been impregnated with this gas (the soda-water of the shops for example) under the receiver of the air-pump, and exhaust it; the gas will escape so rapidly as to present the appearance of ebullition; and will be much more remarkable than the discharge of air from another vessel of common spring water, confined at the same time under the receiver.

Expelled by freezing.

499. If the impregnated water be rapidly congealed, by surrounding it with a mixture of snow and salt, the frozen water has more the appearance of snow than of ice, its bulk being prodigiously increased by the immense number of air bubbles. When water, thus congealed, is liquefied again, it is found, by its taste, and other properties, to have lost nearly the whole of its carbonic acid.

Does not support combustion.

500. Carbonic acid extinguishes burning substances of all kinds, and the combustion does not cease from the want of oxygen only. It exerts a positive influence in checking combustion, as appears from the fact that a candle cannot burn in a gaseous mixture composed of four measures of atmospheric air and one of carbonic acid.

Exp.

This may be shown by setting a vessel filled with the gas, with the mouth upwards, and letting down a lighted candle.

The experiment may be varied by placing near the vessel containing the carbonic acid gas, a similar one filled with oxygen gas, and if the candle, after being extinguished by the carbonic acid be speedily immersed in the oxygen gas it will be relighted, and this may be repeated as long as the gases remain in the vessels.

Fatal to animals.

501. It is not better qualified to support the respiration of animals; for its presence, even in moderate proportion, is soon fatal.* An animal cannot live in air which contains sufficient carbonic acid for extinguishing a lighted candle; and hence the practical rule of letting down a burning taper into old wells or pits before any one ventures to descend. If the light is extinguished, the air is certainly impure; and there is generally thought to be no danger if the candle continues to burn. But instances have been known of the atmosphere being sufficiently loaded with carbonic acid to produce insensibility, and yet not so impure as to extinguish a burning candle.† When an attempt is made to inspire pure carbonic acid, violent spasm of

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* By means of this gas, butterflies, and other insects, the colours of which it is desirable to preserve, for the purpose of cabinet specimens, may be suffocated better than by the common mode of killing them by the fumes of sulphur. H.

† Christison on *Poisons*, 2d ed. 707.

Two instances recently occurred at Cambridge, where a candle continued burning in an apartment in which two men were found insensible, one was with great difficulty recovered, the other died. W.

the glottis takes place, which prevents the gas from entering the lungs. If it be so much diluted with air as to admit of its passing the glottis, it then acts as a narcotic poison on the system. It is this gas which has often proved destructive to persons sleeping in a confined room with a pan of burning charcoal.

Heavier than atmospheric air. 502. Carbonic acid gas is heavier than atmospheric air, and may be poured from one vessel into another like water.

Exp. Place a lighted taper at the bottom of a tall glass jar, and pour the gas out of a bottle into it; it descends and extinguishes the flame, and will remain a long time in the lower part of the jar.

Hence in wells and in some caverns, carbonic acid gas frequently occupies the lower parts, while the upper parts are free from it. The miners call it *choak damp.*

Possesses acid properties. 503. When combined with water this gas reddens vegetable colours. This may be shown by dipping into water, thus impregnated, a bit of litmus paper, or by mixing, with a portion of it, about an equal bulk of the infusion of litmus. This establishes the title of the gas to be ranked among acids. When an infusion of litmus which has been thus reddened, is either heated, or exposed to the air, its blue colour is restored, in consequence of the escape of the carbonic acid. This is a marked ground of distinction from most other acids, the effect of which is permanent, even after boiling.

Test of its presence. 504. Carbonic acid gas precipitates lime-water—this character of the gas affords a ready test of its presence, whenever it is suspected.

Exp. Pass the gas as it proceeds from the materials, through a portion of lime-water. This, though perfectly transparent before, will grow milky: Or, mix equal measures of water saturated with carbonic acid, and lime-water.

By means of lime-water, the whole of any quantity of carbonic acid, existing in a mixture of gases, cannot, however, be removed, but recourse must be had, in order to effect an entire absorption, to a solution of caustic potassa or soda.*

A product of combustion, 505. As all common combustibles, such as coal, wood, oil, wax, tallow, &c. contain carbon as one of their component parts, so the combustion of these bodies is always attended by the production of carbonic acid.

Exp. 1. Let the chimney of a portable furnace, in which charcoal is burning terminate, at a distance sufficiently remote to allow of its being kept cool, in the bottom of a barrel, provided with a moveable top, or of a large glass vessel, having two openings. A small jar of lime-water being let down into the tube or vessel, and agitated, the lime-water will immediately become milky. The gas will also extinguish burning bodies, and prove fatal to animals that are confined in it.

Exp. 2. Fill the pneumatic trough with lime-water, and burn a candle, in a jar filled with atmospheric air, over the lime-water till the flame is extinguished. On agitating the jar, the lime-water will become milky. The same appearances will take place, more speedily and remarkably if oxygen gas be substituted for common air. H. 1.351.

And of respiration. 506. It is also produced by the respiration of animals; hence it is detected often in considerable proportion, in crowded and illuminated rooms, which are ill-ventilated, and occasions difficulty of breathing, giddiness, and faintness.

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* If excess, either of the gas or of its aqueous solution, be added to the lime-water, the precipitate is re-dissolved, carbonate of lime being soluble in carbonic acid.

The production of carbonic acid, by respiration, may be proved by blowing the air from the lungs, with the aid of a quill, through lime-water, which will become milky.

Retards putrefaction.

Its effects on vegetables.

507. Carbonic acid retards the putrefaction of animal substances. It exerts powerful effects on living vegetables. These effects, however, vary according to the mode of its application. Water saturated with this gas, proves highly nutritive when applied to the roots of plants. The carbonic acid is decomposed, its carbon forming a component part of the vegetable, and its oxygen being liberated in a gaseous form.

On the contrary, carbonic acid, when a living vegetable, is confined in the undiluted gas over water, is injurious to the health of the plant, especially in the shade.

It is this process of nature that appears to be the principal means of preventing an excess of carbonic acid in the general mass of the atmosphere, which, without some provision of this kind, must gradually, in the course of ages, be rendered less and less fit for respiration.

Liquefaction of carbonic acid,

508. Carbonic acid was first obtained in a liquid form by Faraday, from carbonate of ammonia and sulphuric acid. Very strong tubes are required, and even those which have held fluid carbonic acid for many days, have, upon a slight elevation of temperature, spontaneously exploded with great violence. Great care is necessary, and the protection of a glass mask, goggles, &c., in repeating the process with glass tubes. The liquid acid is a limpid, colourless body, extremely fluid, distilling readily at the difference of temperature between 32° and 0°. Its refractive power is much less than that of water. Its vapour exerts a pressure of thirtysix atmospheres at a temperature of 32°.*

Solidification of.

A safer method of obtaining the liquid acid as contrived by Thillorier, is with the aid of a strong metallic apparatus in which it may be condensed mechanically. When allowed to escape from a stopcock attached to the receiver, the liquid gas expands with so much rapidity that great absorption of caloric attends, and a part of the gas is rendered solid, resembling snow. A reduction of temperature to —162° is said to have been obtained by this means; hence mercury can be readily frozen by it.†

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* Faraday, *Phil. Trans.*

† See *Lond. and Edin. Phil. Mag.* x. 158.

The experiments of Thillorier have been repeated by Mitchell of Philadelphia, by means of an apparatus consisting of two strong vessels of cast iron. The two vessels can be firmly attached, a stop-cock being interposed. The gas is generated in the larger vessel. The materials employed, are 1¼ lbs. of bicarbonate of soda, 24 ounces of water, and 9 ounces of sulphuric acid; the latter, being placed in a smaller vessel which is enclosed in the cylinder, is not allowed to come in contact with the bicarbonate of soda until the aperture by which it is introduced has been firmly secured, when the cylinder is brought to a horizontal position and the liquids are mingled. The receiver, previously cooled by ice, is now attached, and the liquid carbonic acid allowed to pass into it, from which it may be permitted to escape as wanted.

The pressure at 32° was found by Mitchell to be 36 atmospheres, at 66°, 60 atmospheres, and at 86°, 72 atmospheres. The condensed acid obtained by Mitchell, when recently formed was about the weight of carbonate of magnesia, perfectly white, and of a soft and spongy texture. It evaporates rapidly, becoming colder, and the mass may be kept for some time. A quantity weighing 346 grains lost from three to four grains per minute at first, but did not entirely disappear for three hours and a half. The na-

Carbonates.

509. Carbonic acid combines with bases, and the compounds are termed *carbonates:* as it is usually retained in combination by very feeble affinity, so it is evolved from most of the carbonates by the simple operation of heat. Thus chalk, when heated, gives out carbonic acid, and becomes *quicklime.* It is also evolved from its combinations by most of the other acids, with *effervescence.*

Effervescence.

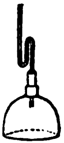
Methods of ascertaining quantities of carbonic acid.

510. The quantity of carbonates in any saline mass, may be ascertained by noting the quantity of carbonic acid disengaged. This may be done by measuring the volume of gas, or by ascertaining its weight.

In the first case, the easiest method of proceeding is to fill a long tube (closed at one end, and capable of containing two or three cubic inches), nearly full of mercury, filling it completely afterwards with hydrochloric acid diluted with an equal quantity of water. The thumb is placed over this, after dipping it in oil, or rubbing it over with a little gas lute,* the tube inverted, and placed in a cup of mercury. One or two grains of the solid salt are then introduced into the tube, (the experiment is most easily performed with a fragment of some carbonate,) and the moment it rises to the top, and comes in contact with the acid, the carbonic acid is disengaged with effervescence, depressing the mercury, and its amount is estimated by examining the volume which it occupies and making the usual corrections; one equivalent of carbonic acid indicating one equivalent of a carbonate, whatever may be the nature of the base.

In the other method, a thin glass flask or bottle, of the form shown in Fig. 148, is placed on one of the scales of a balance with some hydrochloric acid, and accurately counterpoised along with a given weight of the substance under examination, and the bent tube passing through a cork, which fits to the mouth of the flask. This tube is put in when the acid and carbonates are mixed together, to prevent any loss from particles of liquid that may be thrown up during the effervescence, and it is evident that, by adding weights to the scale on which the glass vessel is placed (when the effervescence has finished), till it is again counterpoised, they will indicate the quantity of carbonic acid that has been evolved; before weighing it the second time, the cork and tube should be taken out till the carbonic acid gas in the interior has been blown out gently by a pair of bellows.†

Fig. 148.



Alkalimeter.

A convenient mode is by means of an *alkalimeter.* Into a tube sealed at one end, 9½ inches long, ¾ths of an inch in diameter, and as cylindrical as possible in its whole length, pour 1000 grains of water, and with a file or diamond, mark the place where its surface reaches, divide the space occupied by the water into

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tural temperature was 76°—79°. The temperature of the mass continued to decrease, which was accelerated by any means for increasing the evaporation. At its formation the carbonic snow depressed the thermometer to about —85. The greatest cold produced by the solid acid in the air was —109°, under an exhausted receiver —136°.

Mercury placed in a cavity in it and covered up with the same substance, was frozen in a few seconds. At about —110° liquid sulphurous acid was frozen, and at —130° alcohol of .798 assumed a viscid and oily consistence, and at —146° was like melted wax. Alcohol of .820 froze readily. A piece of solid carbonic acid applied to the skin produced a ghastly white spot, and in fifteen seconds raised a blister.

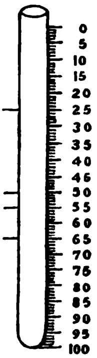
Its specific gravity at 32° F. was .93, at 43° 5, .8825. Liquid carbonic acid did not appear to act upon any of the metals or oxides. When the liquid acid has been frozen in a tube of glass, the tube may be melted off and hermetically sealed. Such a tube will always retain the liquid, or gas; the former, if in sufficient quantity, at all temperatures, if not, the latter alone will be found in it at high temperatures. In such a tube moisture appears at 56°, and a constantly elongating cylinder of liquid forms as the coldness increases: at 32° the cylinder is about half an inch in length. See Mitchell's paper and plate in the *Jour. of Franklin Institute,* vol. xxii, and *Amer. Jour.* xxxv. 346.

* This is a very convenient lute for rendering joints in apparatus tight, and is composed of one part of wax and three of lard heated together until of uniform consistence.

† Reid.

100 equal parts, as shown in Fig. 149. Opposite to the numbers 23, 44, 48, 96, 54, 63, and 65 draw a line, and at the first write soda, at the second potassa, at the third carbonate of soda, and at the fourth carbonate of potassa. Prepare a dilute acid having the specific gravity of 1.127 at 60°, which may be made by mixing one measure of concentrated sulphuric acid with four measures of distilled water. This is the standard acid to be used in all the experiments, being of such strength that when poured into the tube till it reaches either of the four marks just mentioned, we shall obtain the exact quantity necessary for neutralizing 100 grains of the alkali written opposite to it. If, when the acid reaches the words *carb. potassa*, and when, consequently, we have the exact quantity which will neutralize 100 grains of that carbonate, pure water be added until it reaches 0, or the beginning of the scale, each division of this mixture will neutralize one grain of carbonate of potassa. All that is now required, in order to ascertain the quantity of real carbonate in any specimen of pearlash, is to dissolve 100 grains of the sample in warm water, filter to remove all the insoluble parts, and add the dilute acid in successive small quantities, until, by the test of litmus paper, the solution is exactly neutralized. Each division of the mixture indicates a grain of pure carbonate. It is convenient in conducting this process, to set aside a portion of the alkaline liquid, in order to neutralize the acid, in case it should at first be added too freely.*

Fig. 149.



Carbonic Oxide.†

Carbonic oxide.

511. *Carbonic Oxide*, discovered by Priestley, is usually obtained by subjecting carbonic acid to the action of substances which abstract a portion of its oxygen. Upon this principle, carbonic oxide gas is produced by heating in an iron retort a mixture of chalk and charcoal; or of equal weights of chalk and iron or zinc filings. It is also obtained by the distillation of the white oxide of zinc with one eighth of its weight of charcoal, in an earthen or glass retort; from the scales which fly from iron in forging, mixed with a similar proportion of charcoal; from the oxides of lead, manganese, or, indeed, of almost every imperfect metal, when heated in contact with powdered charcoal. It may also be obtained from the substance which remains after preparing acetic acid from acetate of copper. But the mixture that affords it most pure, is equal parts of carbonate of baryta and clean iron filings; these should be introduced into a small earthen retort, so as nearly to fill it, and exposed to a red heat: the first portion of gas being rejected as mixed with the air of the retort, it may afterwards be collected quite pure.

How obtained,

Dumas's process.

512. A very elegant mode of preparing carbonic oxide has been suggested by Dumas.‡ The process consists in mixing binoxalate of potassa with five or six times its weight of concentrated sulphuric acid, and heating the mixture in a retort or other convenient glass vessel. Effervescence soon ensues, owing to the escape of gas, consisting of equal measures of carbonic acid and carbonic oxide gases; and on absorbing the former by an alkaline solution, the latter is left in a state of perfect purity. To comprehend the theory of the process, it is necessary to premise, that oxalic acid is a compound of carbonic acid and carbonic oxide, or at least its elements are in the proportion to form these gases; and that it cannot exist unless in combination with water or some other substance. Now the sulphuric acid unites both with the potassa and water of the binoxalate,

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* Faraday's *Chem. Manip.*

† For Composition, &c. see (494.)

‡ *Edin. Jour. of Sci.* vi. 360.

and the oxalic acid being thus set free, is instantly decomposed. Oxalic acid may be substituted in this process for binoxalate of potassa.

It may also be obtained by transmitting carbonic acid gas over charcoal ignited in a porcelain tube. The acid gas combines with an additional dose of charcoal, loses its acid properties, and is converted into carbonic oxide.

Properties. 513. Carbonic oxide gas is colourless and insipid. It does not affect the blue colour of vegetables in any way; nor does it combine, like carbonic acid, with lime or any of the pure alkalies. It is very sparingly dissolved by water. Lime-water does not absorb it, nor is its transparency affected by it.

514. The nature of this gas was first made known by Cruickshank, of Woolwich, in 1802,* and about the same time it was examined by Clement and Desormes.†

It extinguishes flame, and burns with a pale blue lambent light, when mixed with, or exposed to atmospheric air. The temperature of an iron wire heated to dull redness was found by Davy sufficient to kindle it.

Explodes with oxygen. 515. A mixture of carbonic oxide and oxygen gases may be made to explode by flame, by a red-hot solid body, or by the electric spark. If they are mixed together in the ratio of 100 measures of carbonic oxide and rather more than 50 of oxygen, and the mixture is inflamed in Volta's eudiometer by electricity, so as to collect the product of the combustion, the whole of the carbonic oxide, together with 50 measures of oxygen, disappears, and 100 measures of carbonic acid gas occupy their place. From this fact, first ascertained by Berthollet, and since confirmed by subsequent observation, it follows that carbonic oxide contains half as much oxygen, and as much carbon, as carbonic acid. Accordingly its density should be 0.4215 (sp. gr. of carbon vapour)+0.5512 (half the sp. gr. of oxygen gas) =0.9727, which is the number found experimentally by Dulong and Berzelius. Hence 100 cubic inches should weigh 30.1650 grains. T. Density.

516. It is extremely noxious to animals, and fatal to them if confined in it. When respired for a few minutes it produces giddiness and fainting. If pure it almost instantly causes profound coma.

517. When a mixture of hydrogen and carbonic acid gases is electrified, a portion of the latter yields one half of its oxygen to the former; water is generated, and carbonic oxide produced. On electrifying a mixture of equal measures of carbonic oxide and protoxide of nitrogen, both gases are decomposed without change of volume, and the residue consists of equal measures of carbonic acid and nitrogen gases. The carbonic oxide should be in very slight excess, in order to ensure the success of the experiment. On this fact is founded Henry's method of analyzing protoxide of nitrogen. Analysis.

518. When a mixture of carbonic oxide with more than half its volume of oxygen gas, is exposed over mercury, in contact with spongy platinum, to a temperature between 300° and 310° F., it begins to be converted into carbonic acid, and at a heat of a few de- And spongy platinum,

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* Nicholson's 4to *Jour.* v.

† *Ann. de Chim.* xxxix.

grees higher, is wholly acidified in the course of a few minutes. Mixtures of these two gases are, however, very slowly acted upon by the platinum sponge at common temperatures.*

By potassium and sodium.

519. None of the metals exert any action upon this gas, except potassium and sodium, which at a red heat, burn in it by abstracting its oxygen, and carbon is deposited.

Section V. *Sulphur.*

Symb.	*Sp. Gr.*†	*Equiv.*
S.	6.6558 air = 1	By Vol. 16.66
	96.60 Hyd. = 1	" Wght. 16.1

Properties.

520. Sulphur is a brittle substance, of a pale yellow colour; insipid and inodorous, but exhaling a peculiar smell when heated. Its specific gravity is 1.99. It becomes negatively electrical by heat and by friction.

Sulphur is principally a mineral product,‡ and occurs massive and crystallized in the form of an oblique rhombic octohedron. Its crystals are in a high degree doubly refractive.

Native sulphur,

Massive sulphur is chiefly brought from Sicily; it occurs native, and is found associated with sulphate of lime, sulphate of strontia, and carbonate of lime: it is common among volcanic products. Sulphur occurs also in some mineral waters, partly in a free and partly in a combined state, in combination with soda.§

Roll,

Roll-sulphur is chiefly obtained from native metallic sulphurets, which are roasted and the fumes received into a long chamber of brick-work, where the sulphur is gradually deposited: it is then purified by fusion, and cast into sticks. It conducts heat imperfectly, and, if grasped by the warm hand, splits with a crackling noise.

Action of heat.

521. The fusing point of sulphur is 216° F. Between 230° and 280° it is as liquid as a clear varnish, and of the colour of amber; at about 320° it begins to thicken, and acquire a red colour; on increasing the heat, it becomes so thick that it will not pour. From 482° to its boiling point it becomes thinner, but never so fluid as at 248°.

Use.

When the most fluid sulphur is suddenly cooled, it becomes brittle, but the thickened sulphur, similarly treated, remains soft, and more soft as the temperature has been higher. In this state it is applied to taking impressions from engraved stones, &c.‖

Crystallization of,

522. Fused sulphur has a tendency to crystallize in cooling, and by good management regular crystals may be obtained.

For this purpose several pounds of sulphur should be melted in a crucible; and when partially cooled, the outer solid crust should be pierced, and the crucible quickly inverted so that the fluid portion within may gradually flow out, on breaking the solid mass, when quite cold, crystals of sulphur will be found in the interior.

Fused sulphur will remain fluid at common temperatures, and solidify when touched by a fragment of sulphur or a thread of glass.

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* *Phil. Trans.* 1824, p. 271.

† In state of vapour.

‡ It is said to have been detected in several vegetables and in gum arabic.—Jameson's *Jour.* xiv. 172.

§ Johnson's report, *Rep. Brit. Assoc.* 1832.

‖ See directions in Dumas's *Traité de Chim.* 1. 135.

Chap. III.

Vaporization of.

523. Sulphur is very volatile. It begins to rise slowly in vapour even before it is completely fused. At 550° or 600° F. it volatilizes rapidly, and condenses again unchanged in close vessels. Common sulphur is purified by this process; and if the sublimation be conducted slowly, the sulphur collects in the receiver in the form of detached crystalline grains, called *flowers of sulphur*. In this state however, it is not quite pure; for the oxygen of the air within the apparatus combines with a portion of sulphur during the process, and forms sulphurous acid. The acid may be removed by washing the flowers repeatedly with water.

Lac sulphuris.

524. Sulphur is insoluble in water, but has been supposed to unite with it under favorable circumstances, forming what has been called *Lac sulphuris* and hydrate of sulphur, but which is considered by Berzelius as sulphur with a minute portion of hydrogen. It dissolves in boiling oil of turpentine, and is also soluble in alcohol if both substances are brought together in the form of vapour. The sulphur is precipitated from the solution by the addition of water.

Contains hydrogen.

525. Sulphur retains a portion of hydrogen so obstinately that it cannot be wholly freed from it either by fusion or sublimation. Davy detected its presence by exposing sulphur to Voltaic electricity, when some hydrosulphuric acid gas was disengaged. The hydrogen, from its minute quantity, can only be regarded as an accidental impurity, and as not essential to the nature of sulphur.

Density of its vapour.

526. The density of sulphur vapour was found by Dumas to lie between 6.51 and 6.617, and by Mitscherlich to be 6.9:[*] its density by calculation (page 32) is 6.6558. Hence, could the vapour continue as such at 60° F. and 30 bar., 100 cubic inches should weigh 206.4076 grains.

Test of the purity of sulphur.

527. The purity of sulphur may be judged of by heating it gradually upon a piece of platinum leaf; if free from earthy impurities, it should totally evaporate. It should also be perfectly soluble in boiling oil of turpentine.[†]

Products of its combustion.

528. When sulphur is heated in the open air to 300° or a little higher, it kindles spontaneously, and burns with a faint blue light. In oxygen gas its combustion is far more vivid; the flame is much larger, and of a bluish white colour. Sulphurous acid is the product in both instances;—no sulphuric acid is formed even in oxygen gas unless moisture be present.

Equivalent.

The oxygen in the oxide and acid of neutral sulphates is in the ratio of 1 to 3; so that when the composition of a metallic oxide, and the quantity of acid by which it is neutralized are known, the equivalent of sulphur may be calculated. On this principle has Berzelius inferred, from the composition of sulphate of the oxide of lead, that the equivalent of sulphur is 16.12; and the number obtained by Turner in the same way from the same salt and from sulphate of baryta, is 16.09. As a mean of these results, 16.1 may be taken as the equivalent of sulphur. The number 16 is, for many purposes, a sufficient approximation.

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[*] *Ann. de Chim. et de Phys.* lv. 8.

[†] Aikin's *Dict.* article *Sulphur.* It sometimes contains arsenic, for detecting which see Brande's *Jour.* N. S. v.

Sulphur and Oxygen. Sulphurous Acid.

			Composition.		
Form.	*Sp. Gr.*	*Chem. Equiv.*	*Sul.*	*Oxy.*	*Equiv.*
$S+2O$ or $\ddot{S}$	2.2117 air =1	By Vol. 100.	16.1 or 1 eq.+	16 or 2 eq. =	32.1
	32.10 Hyd.=1	" Wght. 32.1.			

529. Sulphurous acid is a gaseous body and may be obtained by burning sulphur in common air or oxygen gas under a bell glass. It is also procured by abstracting part of the oxygen from sulphuric acid. This may be done in several ways. If chips of wood, straw, or cork, oil or other vegetable matters be heated in strong sulphuric acid, the carbon and hydrogen of those substances deprive the acid of a part of its oxygen, and convert it into sulphurous acid. Nearly all the metals, with the aid of heat, have a similar effect.

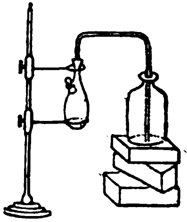
How obtained.

530. The most usual method is by putting two parts by weight, of mercury, and three of sulphuric acid into a glass retort, and then raising the heat; sulphurous acid gas is formed, and may be collected and preserved over quicksilver. Half an ounce of mercury is sufficient for the production of several pints of the gas. This gas may also be obtained by introducing powdered charcoal into a retort and pouring over it concentrated sulphuric acid, until on shaking it, the mass appears moist. On heating, a constant stream of a mixture of two volumes sulphurous acid and one of carbonic acid gases is given off, which continues till the mass becomes dry.*

As this gas is heavier than air, when a mercurial trough is not at hand, the student may collect it in bottles, by the arrangement shown in Fig. 150. The bent tube passes loosely through the neck of the receiver, but is fixed to the gas bottle by means of plaster-of-paris and water.

Collected in bottles.

Fig 150.



531. Water takes up 33 times its bulk of this gas, it must therefore be collected in jars or bottles filled with mercury and over the mercurial trough.†

Absorbed by water.

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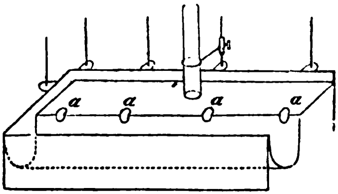
* Knezaurek in Baumgartner's *Zeitschrift*, ix.

† The apparatus for collecting this and other gases which are absorbed by water, is similar to that for collecting other gases. The trough may be made of wood, marble, soapstone, or, what is preferable, cast-iron, well varnishsd to prevent its rusting.

Mercurial trough.

Fig. 151 represents a convenient mercurial trough; which may be 17 inches long, 7 broad, and 5 deep. The mercury does not pass under the shelf, so that the body of the trough is only about half as broad below the shelf as above, and it is rounded at the bottom to save an unnecessary quantity of mercury. The four niches *a a a a*, at the edge of the shelf, are to receive the beaks of retorts, the jars being placed over them; the rods attached to two of the sides of the trough are intended to steady any tall jar left upon the shelf. Such a trough requires about 140 pounds of mercury, when a number of jars are used. Also see Fig. 105.

Fig. 151.



The jars for the mercurial trough should be at least one tenth of an inch in thickness, though not more than two inches in diameter; they ought also to be ground at the edges that they may be removed easily, when full of gas, on a flat glass plate rubbed over with a little gas lute, without losing any of their contents. The mercurial trough should be placed in a large sheet iron tray, to prevent the loss of mercury. Blotting paper is constantly required to remove any acid or water that may collect on the surface of the mercury, and after any acid gas has been prepared over it, the mer-

Exp. Remove a jar, filled with the gas, by means of a flat glass plate held firmly to it, or place the thumb or finger on the mouth of a small bottle or tube filled with the gas, and take it off under water. The gas will be absorbed and the water be forced up the vessel with violence. The acid property of the gas will also be evident if the water be coloured with purple cabbage.

Exp. The experiment may be varied by inverting the vessel over mercury, and passing a small quantity of water up through the mercury; the latter will rise, and the water will be seen to absorb many times its own bulk of the gas.

Bleaches. 532. Sulphurous acid has considerable bleaching properties. It reddens litmus paper, and then slowly bleaches it. Most vegetable colouring matters, such as those of the rose and violet, are speedily removed, without being first reddened. It is remarkable that the colouring principle is not destroyed; for it may be restored either by a stronger acid or by an alkali. Prepared by the combustion of sulphur, it is much used for bleaching cotton goods* and also for whitening silk and wool; in wine countries it is sometimes used to check vinous fermentation. It restores the colour of sirup of violets, which has been reddened by other acids.

Exp. A pleasing instance of its effect on colours, may be exhibited by holding a red rose over the blue flame of a common match, by which the colour will be discharged wherever the sulphurous acid comes in contact with it, so as to render it beautifully variegated, or entirely white. If it be then dipped into water, the redness, after a short time will be restored.

Noxious. 533. This gas has a suffocating nauseous odour, and an astringent taste; it extinguishes flame, and kills animals; it is exceedingly deleterious to vegetables, even in very minute quantity and proportion.†

Davy's analysis. 534. Davy proved that sulphurous acid gas contains exactly its own volume of oxygen,‡ and consequently the difference in the weights or specific gravity of these gases ($2.2117-1.1024=1.1093$), gives the weight of sulphur combined with the oxygen. The sulphur and oxygen are thus found to be in the ratio of 1.1093 to 1.1024 or 16.1 to 16. T.

Decomposition. 535. Sulphurous acid suffers no change at a red heat, but if mixed with hydrogen, and passed through a red-hot tube, water is formed and sulphur deposited; under the same circumstances, it is also decomposed by charcoal, by potassium and sodium, &c.

Converted into sulphuric acid. 536. Sulphurous acid is converted to the state of sulphuric acid by restoring oxygen to it.

A mixture of oxygen and sulphurous acid gases, both perfectly dry, and standing over mercury, is not diminished during some months; but if a small quantity of water be added, the mixture begins to diminish, and sulphuric acid is formed. Or if water impregnated with sulphurous acid be exposed to oxygen gas in a tube, the oxygen in 10 or 14 days is imbibed and sulphuric acid formed. The

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cury should always be washed with water, and dried with a towel and blotting paper. A red-hot poker held for a short time in the mercury enables this to be done more effectually; it is in this manner also, that mercury is most conveniently brought to a proper temperature when it is required to be heated for particular experiments.

The beak of the retort must be placed near the surface of the mercury, that the gas may have to overcome as little resistance as possible in rising through the heavy fluid; should this not be attended to, the retorts may be broken by the pressure from within. No gas should be collected till the atmospheric air has been all expelled from the retort. See Reid's *Elements of Prac. Chem.*

* *Quart. Jour. of Sci.* iv. 196.

† See Turner's *experiments on the effect of gases on vegetables*, Brewster's *Jour.* Jan. 1828.

‡ *Elements*, 273.

same gases in a state of mixture, by the action of electricity or by being driven through a red-hot porcelain tube, afford sulphuric acid. The proportions required for mutual saturation are two measures of sulphurous acid and one of oxygen gas.

Exp.

To a portion of water saturated with sulphurous acid gas add a little oxide of manganese, a substance that contains much oxygen loosely combined; the pungent smell of the water, and the other characteristics of sulphurous acid will soon disappear. H. 1. 385.

537. Sulphurous acid combines with metallic oxides, and forms salts which are called *sulphites*, which are decomposed by sulphuric acid, and then emit the characteristic odour of sulphurous acid.

Liquid acid.

538. Liquid sulphurous acid is obtained by transmitting the dry pure gas through a glass tube surrounded by a freezing mixture of snow and salt. It boils at 14°, and from the rapidity of its evaporation causes intense cold.*

Liquefaction of sulphurous acid gas.

539. Faraday, by producing sulphurous acid from mercury and concentrated sulphuric acid sealed up in a bent tube, obtained it in a liquid state, very limpid and fluid, and quite colourless. Its refractive power appeared to be nearly equal to that of water. It does not solidify at a temperature of 0° F. When a tube containing it is opened, it does not rush out as with an explosion, but a portion of the liquid evaporates rapidly, cooling another portion so much as to leave it in a liquid state under common barometric pressure. It rapidly dissipates, however, without appearing in visible fumes, but with a strong odour of sulphurous acid, leaving the tube perfectly dry. A piece of ice dropped into the fluid instantly made it boil from the heat communicated to it. The specific gravity of liquid sulphurous acid is about 1.42, at 45° F. it exerts a pressure of about two atmospheres.†

Sulphuric Acid.

			Composition.		
Form.	*Sp. Gr.* (*anhydrous*)	*Chem. Equiv.*	*Sulph.*	*Oxy.*	*Equiv.*
...	2.7629 air =1	By Vol. 100.	16.1 or 1 eq.	+24 or 3 eq.	=40.1
S+3O or S	40.10 Hyd.=1	" Wght. 40 1.			

Fuming acid of Nordhausen.

540. Sulphuric acid has been long known under the name of oil of vitriol, and is supposed to have been discovered by Basil Valentine in the 15th century. It is prepared in large quantities for the purposes of the arts. At Nordhausen, in Germany, the sulphate of oxide of iron (green vitriol) is decomposed by heat, and a dense oily liquid of a dark colour is obtained, which, from its emitting white fumes, is known as fuming sulphuric acid. It has a specific gravity of 1.896 or 1.90.‡

Usual process,

541. In the United States and most other places, sulphuric acid is manufactured from sulphur and nitrate of potassa.

The mixture is burned in a large room or chamber lined with lead and covered to the depth of several inches with water. The sulphur is converted into sulphurous acid during its combustion, and a portion of it into sulphuric acid by combining with some of the oxygen of the nitre, nitrous acid and binoxide of nitrogen being disengaged. The sulphurous acid combines with the nitrous acid and some watery vapour, forming a crystalline compound which is decomposed by

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* See Bussy's process in *Bost. Jour. of Philos.* ii. 359.

† *Phil. Trans.* 1823, p. 190. Sulphurous acid is employed in some diseases under the name of "Sulphur baths," for a description of which, see Dumas' *Traité*, vol. i. 152.

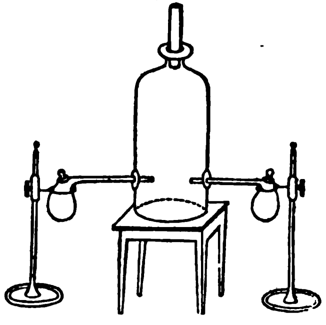
‡ For details see Turner 194, and *Amer. Jour Sci.* xx. 347.

the water at the bottom of the chamber, being converted into sulphuric acid, which remains in combination with the water, and binoxide of nitrogen gas, which is disengaged. All the binoxide rises in the chamber, and mixing with a fresh quantity of atmospheric air, combines with the oxygen and forms a dense ruddy vapour (nitrous acid), which immediately falls down in consequence of its great specific gravity, and meeting with more sulphurous acid and watery vapour, a crystalline compound is again formed, which is resolved as before into sulphuric acid and binoxide of nitrogen. In this manner, a small quantity of nitre is made to communicate or hand over, as it were, a large quantity of oxygen from the air to the sulphurous acid, and the same series of combinations and decompositions goes on till the water at the bottom of the chamber has become strongly acid. It is then boiled in leaden vessels to expel a part of the water, and the concentration finished in large glass retorts in a sand bath, or in platinum retorts placed over the open fire.

Theory illustrated.

542. The theory of the preparation of sulphuric acid may be illustrated very beautifully on the small scale by making sulphurous acid and nitrous acid meet together in a glass vessel, and as the experiment is intended solely for illustration, the sulphurous acid may be prepared by the decomposition of sulphuric acid.

Fig. 152.



Into one of the small retorts, (Fig 152,) which should be large enough to hold about three or four ounces of water when full,—put 400 grains of mercury and 600 grains of sulphuric acid, and into the other 80 or 90 grains of sugar. Heat the first retort by a chauffer, and when the sulphurous acid begins to come over, pour 300 grains of nitric acid over the sugar, previously diluted with an equal bulk of water, and heat the retort gently till the nitrous acid fumes begin to come over, which are formed by the sugar attracting oxygen from the nitric acid. When the gases meet in the large jar, (into which the retorts are fixed by being ground to the tubulures, or having their beaks passed through corks fitted to them,) a crystalline compound is soon deposited on the sides of the vessel in beautiful dendritical crystals, which often cover its whole surface. Remove the retorts when either the sulphurous or nitrous acid ceases to come over, and pour a little water into the vessel, a brisk effervescence will take place wherever it comes in contact with the crystalline compound, which is resolved into binoxide of nitrogen and sulphuric acid, the former producing ruddy coloured fumes as it comes into contact with the air, and the latter being retained in combination with the water. Reid.

Impurities.

543. Sulphuric acid obtained by the usual process is not pure, being contaminated by potassa and the oxide of lead, and sometimes iron, the first derived from the nitre, and the two latter from the leaden chamber. To separate them the acid should be distilled from a glass or platinum retort. The former may be safely used by putting into it some pieces of platinum leaf, which causes the acid to boil freely on applying heat, without danger of breaking the vessel. Arsenious acid, derived from arsenic in the sulphur used in the manufacture, has been lately detected in most of the oil of vitriol made in Germany, and from that source arsenic is introduced into preparations for which such acid is employed, as into phosphorus and hydrochloric acid. It is discovered by diluting with water and transmitting through the solution hydrosulphuric acid gas, which causes orpiment to be formed. The oil of vitriol may be purified from arsenious acid by adding a little hydrated peroxide of iron before distilling. T.

Arsenious acid.

Detected.

The oil of vitriol of commerce often contains sulphate of lead, which may be detected in the cold acid, by adding a few drops of hydrochloric acid. The precipitate is allowed to subside and the clear acid decanted.* Hayes's test for sulphate of lead.

544. Sulphuric acid of commerce is a limpid, colourless fluid, of a thick and oily consistence, having a specific gravity of 1.84; it is acrid and caustic, and even when largely diluted with water produces a very sour liquid. Properties.

545. It boils at 620° and freezes at — 15°, contracting at the same time considerably in its dimensions. But the temperature at which the diluted acid congeals is singularly modified by the quantity of water which it contains. At the specific gravity of 1.780 it freezes at 45°; but if the density be either increased or diminished, a greater cold is required for its congelation.† Its boiling point diminishes with its dilution. Boiling point.

546. It is acrid and caustic, and when diluted with water, produces a very sour liquid. When mixed suddenly with water, (66) considerable heat is produced. Four parts by weight, of concentrated sulphuric acid, and one of water, when mixed together, each at the temperature of 50° F. have their temperature raised to 300°. The greatest elevation of temperature, Ure finds to be occasioned by the sudden mixture of 73 parts by weight of strong sulphuric acid with 27 of water. Mixture with water.

547. It rapidly absorbs water from the atmosphere. Even a boiling temperature, when it is concentrated, does not prevent its taking up moisture from the air; hence it cannot be concentrated so well in an open as in a close vessel, on which account, retorts of glass or platinum, are used for the last stage of its concentration by the manufacturers. Imbibes moisture.

It chars animal and vegetable substances, and is apt to acquire a brown tinge from any small particles of straw, resin, or other matters that may accidentally have fallen into it.

548. The strength of sulphuric acid is best judged of by diluting a known weight of the acid moderately with water, and while warm, adding pure anhydrous carbonate of soda, until the solution is exactly neutral. Every 53.42 parts of the carbonate required to produce this effect, correspond to 40.1 parts of real sulphuric acid. For common purposes the strength of the acid may be estimated from its specific gravity.‡ Method of determining the strength of sulphuric acid.

549. The decomposition of sulphuric acid may be effected by passing it through a red-hot platinum tube, when it is resolved into sulphurous acid, oxygen and water. Analysis of sulphuric acid,

When heated with charcoal, sulphuric acid gives rise to the production of carbonic and sulphurous acids; with phosphorus it produces phosphoric and sulphurous acids; and, with sulphur, sulphurous acid is the only product. It is decomposed by several of the metals, which become oxidized, and evolve sulphurous acid, as shown in the production of this acid, by boiling sulphuric acid with mercury (530), tin, lead, &c.

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* Hayes in *Amer. Jour.* xvii. 195. † Keir, *Irish Phil. Trans.* iv. 88.

‡ For table of strength of this acid of different densities, see Appendix.

By galvanism. The liquid acid is also decomposed by platinum wires, communicating with the extremities of a galvanic pile.

Uses. 550. Sulphuric acid is largely consumed in a variety of manufactures. It is used by the makers of nitric, hydrochloric, citric, and tartaric acids; by bleachers, dyers, tin-plate makers, brass-founders, gilders, &c.

Tests. 551. Baryta in solution detects the presence of sulphuric acid, a white insoluble sulphate of baryta being precipitated. The precipitate heated with charcoal before the blow-pipe is decomposed; on moistening it with water and touching it with a solution of a salt of lead, the sulphur renders the lead black. This acid gives a copious white precipitate with soluble salts of lead.

Hyposulphurous Acid.

Composition.

Form.	*Sulph.*		*Oxy.*		*Equiv.*
$2S+2O$ or $\underline{\ddot{S}}$	32.2 or 2 eq.	+	16 or 2 eq.	=	48.2

How obtained. 552. Hyposulphurous acid may be formed by digesting sulphur in a solution of a sulphite (a compound of sulphurous acid and a salifiable base,) the two equivalents of oxygen in the sulphurous acid combining with an additional quantity of sulphur, and being thereby converted into two equivalents of hyposulphurous acid. It is not easy to procure this acid in a free state.

Peculiar relations. 553. It is distinguished by the peculiar relation it has to the oxide of silver, combining with it in preference to soda, which is easily separated from this acid by the oxide, the only instance where a metallic oxide can separate a fixed alkali from an acid, without the aid of some other affinity.

The solution of all the neutral hyposulphites dissolves recently precipitated chloride of silver in large quantity, and forms with it a liquid of an exceedingly sweet taste.

Hyposulphuric Acid.

Composition.

Form.	*Sulph.*		*Oxy.*		*Equiv.*
$2S+5O$ or $\underline{\overset{\cdot\,\cdot\,\cdot\,\cdot\,\cdot}{S}}$	32.2 or 2 eq.	+	40 or 5 eq.	=	72.2

Process. 554. This acid discovered by Welter and Gay-Lussac in 1819, is prepared by transmitting sulphurous acid through water in which finely powdered peroxide of manganese has been suspended, a portion of the oxygen of the oxide combining with some of the sulphurous acid and forming sulphuric acid, part of which unites with the remaining sulphurous acid, by which the hyposulphuric acid is produced. Both acids remain in combination with oxide of manganese, and by adding baryta it is precipitated, the sulphuric acid being also thrown down in combination with part of the baryta, while the hyposulphuric acid unites with the rest, and remains in solution. By cautiously adding sulphuric acid the baryta is removed, and the hyposulphuric acid remains in solution. R.

SECTION VI. *Phosphorus.*

Symb.	*Sp. Gr.*		*Chem. Equiv.*	
P.	4.3269	Air = 1	By Vol.	25
	62.80	Hyd. = 1	" Wght.	15.7

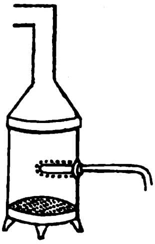
Name. 555. Phosphorus (φωσφόρος from φῶς *light* and φέρειν *to carry*), so called from its property of shining in the dark, was discovered about the year 1669 by Brandt, an alchemist of Hamburgh. It was originally prepared from urine; but Scheele afterwards described a method of obtaining it from bones, which is now generally practised.

556. The object of the process is to bring phosphoric acid in contact with charcoal at a strong red heat. The charcoal takes oxygen from the phosphoric acid; carbonic acid is disengaged, and phosphorus is set free.

Process. As the process for obtaining phosphorus is tedious and not unattended with danger, and as it can readily be obtained from the druggist, it will be sufficient to illustrate the principle on which it is prepared.

For this purpose 30 or 40 grains of a mixture of phosphoric acid, or of the superphosphate of lime,* with half its weight of charcoal may be put into a glass tube sealed at one end, about a foot in length and half an inch in diameter. The tube should be coated with a mixture of two parts of clay and one of sand, previously mixed with cut thread or flax, and then wrapped round with iron wire. The coating need not extend farther than an inch beyond the part to which the mixture reaches when it has been introduced, as this alone is to be exposed to heat. It is placed in a chauffer with a hole cut in the side, as shown in the figure, and a chimney placed over it to increase the heat; the tube should be gently inclined downwards, to carry off any watery vapour, and the end which is not coated had better be drawn out at the blowpipe when the mixture has been put in, till it is about a quarter or an eighth of an inch in diameter. A green glass tube is better than one of flint glass, as it is not so easily melted. A mixture of red hot cinders and charcoal gives the best fire for this experiment. When the heat has become sufficient, the phosphorus comes over, condensing along the sides of the tube, and a flame appears at the open end, similar to what is produced by the combustion of phosphorus. If the tube is broken off above the point where it is coated, after gas ceases to be disengaged, on blowing through it the phosphorus will take fire and burn with a vivid light. Reid.

Fig. 153.



Properties. 557. Pure phosphorus is transparent and almost colourless. It is so soft that it may be cut with a knife, and the cut surface has a waxy lustre. At the temperature of 108° it fuses, and at 550° is converted into vapour, which according to Dumas has a sp. gr. of 4.355.

Phosphorus is exceedingly inflammable. Exposed to the air at common temperatures, it undergoes slow combustion, emits a white vapour of a peculiar alliaceous odour, appears distinctly luminous in the dark, and is gradually consumed. On this account, phosphorus should always be kept under water.

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* Obtained by digesting calcined bones for a day or two with half their weight of strong sulphuric acid, with the addition of so much water as will give the consistence of a thin paste; sparingly soluble sulphate and a soluble superphosphate of lime are found. The latter is dissolved in warm water, and after filtration, evaporated.

Slow combustion.

The disappearance of oxygen which accompanies these changes is shown by putting a stick of phosphorus in a jar full of air, inverted over water. The volume of the gas gradually diminishes; and if the temperature of the air is at 60°, the whole of the oxygen will be withdrawn in the course of 12 or 24 hours. The residue is nitrogen gas, containing about 1-40th of its bulk of the vapour of phosphorus. It is remarkable that the slow combustion of phosphorus does not take place in pure oxygen, unless its temperature be about 80°. But if the oxygen be diluted with nitrogen, hydrogen, or carbonic acid gas, the oxidation occurs at 60°; and it takes place at temperatures still lower in a vessel of pure oxygen, rarefied by diminished pressure. Graham finds that minute quantities even, of some gases have a remarkable effect in preventing the slow combustion of phosphorus.*

Luminous in rarefied air.

558. If a stick of dry phosphorus be dusted over with powdered rosin or sulphur, and then introduced under the receiver of an air-pump, it will be found that, as soon as the exhaustion commences, the phosphorus will become luminous, which appearance increases as the rarefaction proceeds, until finally the phosphorus inflames.

Caution.

In all experiments with phosphorus, great care must be taken, as it is so easily kindled. It should be cut under water and be held by forceps.

A very slight degree of heat is sufficient to inflame phosphorus in the open air. Gentle pressure between the fingers, or a temperature not much above its point of fusion, kindles it readily.

According to Higgins, a temperature of 60° is sufficient to set it on fire, when properly dry.

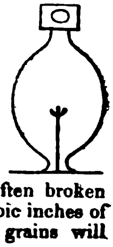
Exp.

It may be set on fire by friction. Rub a very small bit between two pieces of brown paper; the phosphorus will inflame, and will set the paper on fire also.

Combustion in oxygen.

559. Its combustion is far more rapid in oxygen gas, and the light proportionally more vivid.†

Fig. 154.



This may be done in a glass vessel of the annexed shape. (Fig 154.) It is filled with water after putting a cork into the opening at the top, placed on the shelf of a large pneumatic trough, in the same manner as a jar, and oxygen gas introduced by the lower aperture. When quite full, it is allowed to drain, removed on a flat plate of metal and placed over a small cup containing the phosphorus; sand being placed to the depth of half an inch where the jar is to rest. The cork is then taken out, and a thin plate of copper placed over the top after the phosphorus has been kindled by an iron wire; the copper plate allows part of the oxygen to escape freely when expanded by the heat. Corks should never be put in the mouths of the vessels, as they are generally set on fire; and if the expanded gas cannot easily escape, the apparatus will be blown to pieces. It is often broken also, when a large quantity of phosphorus is employed. 100 cubic inches of oxygen can combine with about 24 grains of phosphorus, but 8 or 10 grains will be sufficient for this experiment.

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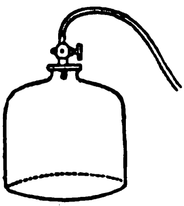
* See *Quart. Jour. of Sci.* N. S. vi. 83., and note to Turner's *Elements, Amer. Edit.* page 198.

† For a method of exhibiting this with splendour and collecting the products, see Hare's *compendium*, 103.

When a large jar is used it will be more convenient to exhaust the air, by means of the air-pump, connecting it with a brass plate well ground to the upper lip of the jar; (Fig. 155,) as the air is pumped out the water will rise; when the jar is filled, the stop-cock being closed, the connecting pipe may be detached. Or if the jars are not too large, the air may be drawn out by the mouth. It is not however, always necessary to fill a jar with water, as the gas from its weight, may be passed in by a pipe descending to the bottom and the atmospheric air be displaced, as described page 154.

Fig. 155.



Effect of light, &c.

560. When kept for a long time under water, especially if exposed to light, phosphorus acquires a thin coating of white matter, which according to Rose,* seems to be phosphorus in a peculiar mechanical state, which deprives it of its usual action upon light, and renders it opaque.

Solution in oil, &c.

561. Phosphorus is soluble in oils, and communicates to them the property of appearing luminous in the dark; alcohol and ether also dissolve it, but more sparingly.

Exp.

This may be shown by pouring a small quantity of either of these liquids, in which phosphorus has been dissolved, upon the surface of warm water in a dark room.

It is tasteless and insoluble in water, but proves poisonous when taken into the stomach.

Atom of of phosphorus.

562. The researches by Berzelius have shown that the oxygen in phosphorus and phosphoric acids is in the ratio of 3 to 5. It is hence inferred that the smallest molecule of phosphoric acid contains five atoms of oxygen. Also Berzelius finds that 31.4 parts of phosphorus require 40 of oxygen for forming phosphoric acid: if this acid consist of one atom of phosphorus and five atoms of oxygen, 31.4 will represent one atom of phosphorus; or if the acid contain two atoms to five, the atom of phosphorus will be half 31.4 or 15.7. It is doubtful which view is preferable, but we may continue to use 15.7 as its equivalent. T. 200.

Uses.

563. Phosphorus is largely consumed in the preparation of matches for obtaining instantaneous light.†

Oxide of Phosphorus.

Composition.

Form.	*Phos.*		*Oxy.*		*Equiv.*
$3P+O$ or P3O	47.1 or 3 eq.	+	8 or 1 eq.	=	55.1

Formation of oxide of phosphorus.

564. When a jet of oxygen gas is thrown upon phosphorus while in fusion under hot water, combustion ensues, phosphoric acid is formed, and a number of red particles collect, which have been considered as oxide of phosphorus. The red matter left when phosphorus is burned is probably of the same nature.

Exp.

Place a few grains of phosphorus in a deep glass, a champaign glass is the best, fill it up with hot water, and pass down upon the phosphorus a stream of oxygen gas, by means of a brass pipe (the common blow-pipe of jewellers made straight answers) attached to a flexible tube connected with a gasometer or bladder containing oxygen gas.

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[*] *Pog. Annal.* xxvii. 565.

[†] The matches are made by attaching phosphorus to the sulphur in which they are previously dipped, or by dipping them into a composition of phosphorus, chlorate of potassa, sulphuret of antimony and glue. The composition for what are known as "Loco foco" matches, is a paste made with about 4 parts of some earthy matter, as powdered chalk, 1 part phosphorus, and 1 glue, dissolved in water with the aid of heat; into this the matches, previously prepared with sulphur, are dipped. These matches ignite by slight friction.

Locofocos.

565. The oxide is of a red colour, without taste or odour, and insoluble in water. ether, alcohol, and oil. It is permanent in the air, even at 662° F., but takes fire at a low red heat. Heated to redness in a tube, phosphorus is expelled, and metaphosphoric acid remains. It takes fire in chlorine gas, and is rapidly oxidized by nitric acid. It does not appear to possess any alkaline character.[*] T. 200.

Hypophosphorous Acid.

Composition.

Form.	*Phos.*		*Oxy.*		*Equiv.*
$2P+O$ or P_2O	31.4 or 2 eq.	+	8 or 1 eq.	=	39.4

Hypophosphorous acid.

566. This acid was discovered in 1816 by Dulong.[†] When water acts upon the phosphuret of barium the elements of both enter into a new arrangement, giving rise to phosphuretted hydrogen, phosphoric acid, hypophosphorous acid, and baryta. The former escapes in the form of gas, and the two latter combine with the baryta. Hypophosphite of baryta being soluble, may consequently be separated by filtration from the phosphate of baryta, which is insoluble. On adding a sufficient quantity of sulphuric acid for precipitating the baryta, hypophosphorous acid is obtained in a free state, and on evaporating the solution, a viscid liquid remains, highly acid and even crystallizable, which is a *hydrate of hypophosphorous acid.*

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[*] *An. de Ch. et de Ph.* 1.83.

Verrier's method of obtaining pure oxide of phosphorus.

Verrier has recently proposed the following method of obtaining pure oxide of phosphorus, which, he is of opinion, has not been previously procured. Take a glass globe, capable of holding about two pints, the neck of which is about four inches long, and one inch wide; pour into this a little chloride of phosphorus, then introduce, of phosphorus, previously dried on paper, and cut into pieces of about eight grains each, enough to form a stratum of four fifths of an inch thick, at the bottom of the globe; add sufficient chloride of phosphorus to cover the phosphorus, and expose the whole to the air; eight or ten globes thus prepared are required to obtain thirty grains of oxide. In twentyfour hours, a thick white crust of phosphatic acid is formed at the surface of the solution, whilst below the stratum of phosphorus a yellow substance is seen which is a compound of phosphoric acid and oxide of phosphorus, called by Verrier *phosphate of oxide of phosphorus.*

In twentyfour hours after the appearance of the whitish matter, the chloride of phosphorus is poured off, to serve for another operation; the pieces of phosphorus are detached and *gradually* allowed to fall into cold water. The water becomes of a deep yellow colour from dissolving the phosphate; by decanting and filtering a limpid yellow liquid is obtained. By heating this solution, the phosphate decomposes at about 177° F. into phosphoric acid, and a yellow flocculent matter, which collects at the bottom, and is considered as hydrated phosphoric acid, nearly insoluble in water. This is washed upon a filter with hot water, removed from it while moist, to a porcelain capsule, and dried *in vacuo* over sulphuric acid. The oxide of phosphorus remains pure, in the form of small grains of a red colour, but when in fine powder, of canary yellow. Its composition according to Verrier is

Oxy. 11.35 Phos. 88.65

Properties.

It is insoluble in water, alcohol, and ether; it is denser than water. When removed from the vacuum it has neither taste nor smell, but is acidified by moist air or oxygen yielding a slight odour of phosphuretted hydrogen. It is not luminous in the dark.

Out of contact of the air it may be kept at a temperature of about 570° without decomposing, but becomes of a bright red colour. At a temperature a little below that of boiling mercury, it decomposes rapidly, phosphorus distils, and white phosphoric acid remains. Heated in the air it is unchanged, and burns only when it disengages phosphorus. Chlorine converts it into chloride of phosphorus and phosphoric acid. Nitric acid converts it into phosphoric acid.

Mixed with chlorate of potassa it gives a fulminating powder, which detonates sometimes during the mixture, and without pressure; it always explodes under slight pressure. The hydrate was inferred to contain 20.5 per cent. of water, its composition being very nearly oxide 1 eq. water 2. *Ann. de Chim. et de Phys.* July, 1837, and *Lond. and Edin. Phil. Mag.* Oct. 1838.

[†] *An. de Ch. et Ph.* ii.

Hypophosphorous acid is a powerful deoxidizing agent. It unites with alkaline bases; and it is remarkable that all its salts are soluble in water.

Phosphorous Acid.

Form.	Composition.				
	Phos.		*Oxy.*		*Equiv.*
$2P+3O$, $\underline{\overset{\cdots}{P}}$ or $P2O3$	31.4 or 2 eq.	+	24 or 3 eq.	=	55.4

Phosphorous acid obtained.

567. Phosphorous acid may be procured by subliming phosphorus through powdered bichloride of mercury contained in a glass tube; when a limpid liquid comes over, which is a compound of chlorine and phosphorus.[*] This substance and water mutually decompose each other: the hydrogen of water unites with the chlorine, and forms hydrochloric acid; while the oxygen attaches itself to the phosphorus, and thus phosphorous acid is produced. The solution is then evaporated to the consistence of sirup to expel the hydrochloric acid; and the residue, which is hydrate of phosphorous acid, becomes a crystalline solid on cooling. It is also generated during the slow oxidation of phosphorus in atmospheric air. The product attracts moisture from the air, and forms an oil-like liquid.

Properties.

568. It dissolves readily in water, has a sour taste, and smells somewhat like garlic. It unites with alkalies, and forms salts which are termed *phosphites*. The solution of phosphorous acid absorbs oxygen slowly from the air, and is converted into phosphoric acid. From its tendency to unite with an additional quantity of oxygen, it is a powerful deoxidizing agent; and hence, like sulphurous acid, precipitates mercury, silver, platinum, and gold from their saline combinations in the metallic form. Nitric acid converts it into phosphoric acid.

Phosphoric Acid.

Form.	Composition.				
	Phos.		*Oxy.*		*Equiv.*
$2P+5O$, $\underline{\overset{\cdot\because\cdot}{P},}$ or PO^5[†]	31.4 or 2 eq.	+	40 or 5 eq.	=	71.4

Phosphoric acid.

569. In 1827, Clarke of Aberdeen, showed that under the term *phosphoric acid*, had previously been confounded two distinct acids, one of which he proposed to distinguish by the name of *pyrophosphoric acid* (from πυρ *fire*,) to indicate that it is phosphoric acid modified by heat; and Graham has described another to which he has given the provisional name of metaphosphoric (from *μετα together with*), implying phosphoric acid and something besides. These acids contain phosphorus and oxygen in the same ratio, and have the same equivalent, so that they may be considered as isomeric bodies (page 36); but that difference in the arrangement of their elements on which their peculiarities may be presumed to depend, is very slight, since they are easily convertible into each other.[‡]

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[*] Davy's *Elements*, p. 288.

[†] But as it cannot exist uncombined, it is best denoted by $X^3 PO^5$, where X represents an equivalent of water, or any base. T. 203.

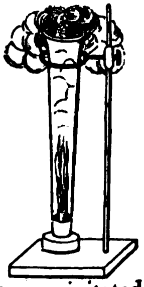
[‡] *Phil. Trans.* 1833, part ii., and *Phil. Mag.* 3d Series, iv. 401.

Chap. III.

570. Phosphoric acid may be obtained by oxidizing phosphorus by strong nitric acid; but great care is required as the action is often very violent, attended with a rapid evolution of great quantities of binoxide of nitrogen.

Exp. Place a few fragments of phosphorus in a deep and strong glass vessel, of the form represented in the figure. (Fig. 156.) Pour upon it, from a vessel attached to the end of a long stick, an ounce or more of nitric acid recently prepared from nitre and sulphuric acid. If the acid is very strong and warm, violent and dangerous explosion often occurs, and the acid, fragments of phosphorus and of glass are thrown to a considerable distance. A platinum vessel is preferable, and should be firmly secured to the table.

Fig. 156.



Process. 571. Phosphoric acid may be prepared at a much cheaper rate from bones. For this purpose, superphosphate of lime, obtained in the way already described, (556) should be boiled for a few minutes with excess of carbonate of ammonia. The lime is thus precipitated as a phosphate, and the solution contains phosphate, together with a little sulphate of ammonia. The liquid, after filtration, is evaporated to dryness, and then ignited in a platinum crucible, by which means the ammonia and sulphuric acid are expelled.

Properties. 572. Phosphoric acid is colourless, intensely sour, reddens litmus, and neutralizes alkalies. It is concentrated by evaporation at 300° F., and becomes dark, and thick as treacle when cold. It consists of 71.4 parts or 1 equiv. phosphoric acid and 27 parts or 3 equiv. water.

Unites with bases. 573. Phosphoric acid is remarkable for its tendency to unite with alkaline bases, in such proportions that the oxygen of the base and of the acid is as 3 to 5; or, in other words, it is prone to form subsalts, in which one equivalent of acid is combined with three equivalents of base. It manifests the same character in regard to water, and ceases to be phosphoric acid unless three equivalents of water to one of acid are present; it even appears that the water acts the part of a base, hence called *basic* water, and that the aqueous solution is not a mere solution of phosphoric acid, but of triphosphate of water, a sort of salt composed of one equivalent of acid and three equivalents of water. Part of this basic water enters along with soda into the constitution of two of the phosphates of soda, the water and soda together forming the three equivalents of base required by one equivalent of the acid. T. 202.

Test. 574. A certain test between phosphoric and arsenious acids is, that the former is neither changed in colour nor precipitated when a stream of hydrosulphuric acid gas is transmitted through it; while the latter, with the required precautions, first acquires a yellow tint, and then yields a yellow precipitate.

Pyrophosphoric acid. 575. *Pyrophosphoric Acid.*—This acid is formed by exposing concentrated phosphoric acid for some time to a heat of 415°. Its general characters resemble those of phosphoric acid; it is remarkable for its tendency to unite with two equivalents of a base.

Metaphosphoric acid. 576. *Metaphosphoric Acid,* $HO.P^2O^5$, is obtained by burning phosphorus in dry air or oxygen gas, or heating to redness a concentrated solution of phosphoric or pyrophosphoric acids.

Peculiarity. 577. The peculiarity of this acid is to combine with one equivalent of a base. On exposing the anhydrous acid to the air it rapidly deliquesces, and at the same time acquires its basic water, which can only be replaced by an equivalent quantity of soda or some other alkaline base. The pure hydrated acid is of itself very fusible, and on cooling concretes into a transparent brittle solid, being known under the name of *glacial phosphoric acid*, which is highly deliquescent, and can hence only be preserved in its glassy state in bottles carefully closed. This acid when free, occasions precipitates in solutions of the salts of baryta, and most of the earths and metallic oxides, and forms an insoluble compound with albumen.

Glacial acid.

SECTION VII. *Boron.*

Symb. B. *Equiv.* 10.9 *eq. vol.* = 100

Boron. 578. Boron was discovered by Davy, by the action of Voltaic electricity upon boracic acid, hence its name. It was also obtained by Gay-Lussac and Thenard in 1808,* by heating boracic acid with potassium, the boracic acid being deprived of its oxygen and the boron set free. The easiest method, according to Berzelius, is to decompose borofluoride of potassium or sodium by means of potassium.†

Properties. 579. Boron is a dark olive-coloured substance, which has neither taste nor smell, and is a non-conductor of electricity. It is insoluble in water, alcohol, ether and oils. It does not decompose water. It bears intense heat in close vessels, without fusing or undergoing any other change except a slight increase of density. Its specific gravity is about twice as great as that of water. It may be exposed to the atmosphere at common temperatures without change; but if heated to 600°, it suddenly takes fire, oxygen gas disappears, and boracic acid is generated. It also passes into boracic acid when heated with nitric acid, or with any substance that yields oxygen with facility.

Union with Oxygen. 580. According to the experiments of Davy and Berzelius, boron in burning unites with 200 per cent. of oxygen; and the latter, from the composition of borax, estimates the oxygen in boracic acid at 68.8 per cent.

Boracic Acid.

Symb. $B+3O$, $\dddot{B}$ or BO^3 *Equiv.* 34.9

Boracic acid. 581. This is the only known compound of boron and oxygen. It is found in the hot springs of Lipari, and in those of Sasso in the Florentine territory. It is a constituent of several minerals, as the datholite and boracite. It occurs much more abundantly under the form of *borax*, a native compound of boracic acid and soda.

Process. 582. It is prepared for chemical purposes by adding sulphuric acid to a solution of purified borax in about four times its weight of boil-

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* See the original memoirs in the *Ann. de Chim. et de Phys.* xxvi. 66, 113, and an abstract in the *Quart. Jour.* xviii. 149.

† *Ann. Philos.* xxvi. 128.

ing water, till the liquid acquires a distinct acid reaction. The sulphuric acid unites with the soda; and the boracic acid is deposited, when the solution cools, in a confused group of shining scaly crystals. It is then thrown on a filter, washed with cold water to separate the adhering sulphate of soda and sulphuric acid, and still further purified by solution in boiling water and re-crystallization. It is apt to retain a little sulphuric acid; and on this account, when required to be absolutely pure, it should be fused in a platinum crucible, dissolved in hot water and crystallized.

Properties. 583. Boracic acid in this state is a hydrate, which contains 43.62 per cent. of water, being a ratio of 34.9 parts or one equivalent of the anhydrous acid to 27 parts or three eq. of water. This hydrate dissolves in 25.7 times its weight of water at 60°, and in 3 times at 212°. Boiling alcohol dissolves it freely, and the solution, when set on fire, burns with a beautiful green flame; a test which affords the surest indication of the presence of boracic acid. Its specific gravity is 1.479. It has no odour, and its taste is rather bitter than acid. It reddens litmus paper feebly, and effervesces with alkaline carbonates. Its acid properties are weak, and the borates, when in solution, are decomposed by the stronger acids.

Effect of heat. 584. When exposed to a gradually increasing heat in a platinum crucible, the water of crystallization is expelled, and a fused mass remains, which, on cooling, forms a hard, colourless, transparent glass, which is anhydrous boracic acid. If the water of crystallization be driven off by the sudden application of a strong heat, a large quantity of boracic acid is carried away during the rapid escape of watery vapour. Vitrified boracic acid should be preserved in well-stopped vessels; for if exposed to the air, it absorbs water, and gradually loses its transparency. Its specific gravity is 1.803. It is exceedingly fusible, and communicates this property to the substances with which it unites. For this reason borax is often used as a flux.

SECTION VIII. *Silicon.*

Symb. Si. *Equiv.* 22.5

Discovery. 585. It was shown by Davy that silica is a compound of a combustible body and oxygen, to which the name *silicium* was given, but which is now termed *silicon*. Silicon was obtained by Berzelius in

How obtained. 1824, by the action of potassium on fluosilicic acid gas; it may be more conveniently prepared from the double fluoride of silicon and potassium, or sodium, heated in a glass tube with potassium, which unites to the fluorine and the silicon is separated, united with a little hydrogen. It is purified by a red heat and digestion in dilute hydrofluoric acid.*

Properties. 586. Silicon has a dark brown colour, but no metallic lustre. It is a non-conductor of electricity.

Before ignition it is not oxidized or dissolved by sulphuric, nitric, or nitro-hydrochloric acids, but is soluble in hydrofluoric acid, and in a hot concentrated solution of caustic potassa. It undergoes partial combustion in air and oxygen gas.

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* *Ann. Philos.* xxvi. 116.

After combustion on its surface the silica is removed, by hydrofluoric acid, and the silicon within is insoluble. A difference attributed by Berzelius to a difference in the aggregation of the particles.*

Oxidation of.

587. Silicon is not changed by ignition with chlorate of potassa. In nitre it does not deflagrate until the temperature is raised so high that the acid is decomposed. It burns vividly when brought into contact with carbonate of potassa or soda, and the combustion ensues at a temperature considerably below that of redness. It explodes in consequence of a copious evolution of hydrogen gas, when it is dropped upon the fused hydrate of potassa, soda, or baryta.

Equivalent.

588. Berzelius ascertained, by oxidizing a known weight of silicon, that 100 parts of silicic acid are composed of 48.4 of silicon and 51.6 of oxygen. Now if silicic acid, as Thomson supposes, be composed of single atoms of its elements, then the equivalent of silicon will be 7.5; but if, as Berzelius believes, the smallest molecule of that acid contain three atoms of oxygen united with one atom of silicon, the equivalent of silicon would be 22.5. The latter view is supported by very strong analogies. T.

Silicic Acid—Silica.

Symb.	*Equiv.*
$Si+3O$, $\dddot{Si}$, or $SiO3$	46.5

Abundant in nature.

589. Silica or siliceous earth is an abundant natural product, constituting a principal ingredient of extensive mountain masses, of sand, and of several minerals as quartz, calcedony, opal, &c. It is an important part of fertile soils, rendering them porous and open to the transmission of water. It abounds in the natural hot springs of Iceland and of the Azores,† and is probably an universal ingredient in thermal waters. It exists in the epidermis of most monocotyledonous plants.‡

Obtained pure.

590. The purest form of silica is rock crystal, from which it may be procured of sufficient purity for most purposes, by ignition, quenching in cold water and reduction to powder.§

Properties.

591. Silica is white; its sp. gr. is 2.69; it requires a very high temperature for fusion. In its ordinary state it is insoluble in water; but if presented to water while in the nascent state it is dissolved in large quantities.‖

Acid,

592. Silica has no action on test paper, but in its chemical relations it exhibits the properties of an acid, and displaces carbonic acid by the aid of heat from the alkalies, hence it has been called *silicic acid.*

Action of heat.

593. On gently evaporating its solution in water, a bulky gelatinous hydrate separates, which is partially decomposed by a very moderate temperature, but it does not part with all its water except at a red heat.

Liquor silicum.

594. On igniting one part of silicic acid with three of carbonate of potassa, a vitreous mass is formed, which is deliquescent, and

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* Berzelius, *Traité de Chem.* 1,370.

† See Webster's *Azores.*

‡ See Daubeny's *Report on Waters, in Rep. Brit. Assoc.* v.

§ For minute details see Henry's *Chem.* i. 643.

‖ Berzelius.

may be dissolved completely in water. This solution was formerly called *liquor silicum*; it has an alkaline reaction, and absorbs carbonic acid on exposure to the atmosphere by which it is partially decomposed.

Glass. 595. With one part of alkali and three of silicic acid the well known compound *glass* is formed. Every kind of ordinary glass is a silicate, and its varieties are owing to differences in the proportion of the constituents, to the nature of the alkali, or to the presence of foreign matters. *Bottle glass* is obtained from common sand, which contains iron, and the most common kind of kelp or pearlashes. Varieties. *Crown glass* for windows is made of a purer alkali and sand which is free from iron. *Plate glass* for looking-glasses, is composed of sand and alkali in their purest state; and in the formation of *Flint glass*, besides these pure ingredients, a considerable quantity of litharge or red lead is employed.[*] A small portion of peroxide of manganese is also used, in order to oxidize carbonaceous matters contained in the materials; and nitre with the same intention.[†]

Annealing. 596. Glass vessels must be cooled very slowly, or *annealed*, otherwise they are very brittle. When properly prepared, glass is acted upon by few chemical agents.[‡] Hydrofluoric acid, however, attacks the silica.[§] The metallic bases of the alkalies appear to decompose it; and Davy found that oxide of lead in fine glass, is acted upon by hydrochloric acid at a high temperature, chloride of lead and water being formed.

Section IX. *Selenium.*

Symb.	*Sp. Gr.*	*Equiv.*
Se	4.3	39.6

597. Selenium was discovered in 1818 by Berzelius in the sulphur obtained by sublimation from the iron pyrites of Fahlun in Sweden. It exists as a sulphuret among the volcanic products of the Lipari islands; and in other places, combined with metals.

Sources of selenium, In the chambers for manufacturing sulphuric acid, a reddish mass

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[*] For many chemical processes glass vessels free from lead should be employed. Those made of German potash glass, or hard white glass free from lead, can now be obtained of any required form or size, from Richard Griffin & Co. Glasgow, Scotland, and I have found them exceedingly durable and well adapted to all required purposes. W.

[†] The art of colouring glass and of making artificial gems is of an old date, and effected by metallic oxides. The metals employed as colouring materials are 1. Gold. The purple of cassius imparts a fine ruby tint. 2. Silver, oxide or phosphate of silver gives a yellow colour. 3. Iron-oxides, produce green, yellow, and brown. 4. Copper-oxides, green; with a small proportion of tartar, the oxides produce a red. 5. Antimony, gives a rich yellow. 6. Manganese, the black oxide in large quantity gives a black, in smaller quantities various shades of purple. 7. Cobalt, blue. 8. Chrome, greens and reds, according to the degree of oxidation. On this subject see Neri *Art de la Verrerie*, *Ann. de Chim. et Phys.* xiv. 57. Aikin's *Dict'y. Art. Glass.* Dumas *Traité de Chim.* II. 531.

White enamel is merely glass rendered more or less opaque by oxide of tin; it forms the basis of the coloured enamels, which are tinged with the metallic oxides.

[‡] Turner found that steam under high pressure becomes a rapid solvent of alkaline silicates. *Geol. Trans. Lond.* ii. 95.

[§] For a method of exposing siliceous substances to hydrofluric acid see *Lond. and Ed. Philos. Mag.* xiii. 473.

is deposited, which is principally sulphur. This substance, in burning, gave out an odour, which induced Berzelius to suspect that it contained tellurium, but on a minute examination he discovered, instead of that metal, a body with entirely new properties, to which he has given the name of *Selenium*, from Σελήνη the moon.

Extraction of.

598. For the extraction of selenium from the native sulphuret, Magnus proposes to mix it with eight times its weight of peroxide of manganese, and to expose the mixture to a low red heat in a glass retort, the beak of which dips into water. The sulphur, oxidized at the expense of the manganese, escapes in the form of sulphurous acid; while the selenium either sublimes as such or in the state of selenious acid. Should any of the latter be carried over into the water, it would there be reduced by the sulphurous acid.

Properties.

599. The colour of Selenium varies a good deal. When rapidly cooled, its surface has a dark brown hue, and its fracture the colour of lead. Its powder has a deep red colour, but it sticks together when pounded, and then assumes a gray colour and a smooth surface. Its specific gravity is between 4.3 and 4.32. It softens at 212° F., and completely fuses at a few degrees higher. While cooling, it has a considerable degree of ductility, and may be kneaded between the fingers, and drawn out into fine threads, which have a strong metallic lustre, and are red by transmitted light. When slowly cooled it assumes a granulated fracture, and is extremely like a piece of cobalt. It boils at about 650°, its vapour has a deep yellow colour, and condenses either into opaque metallic drops, or, when a retort with a large neck is used, into flowers of a fine cinnabar colour.

Tinges flame.

600. When heated before the blow-pipe, it tinges the flame of a fine azure blue, and exhales so strong a smell of horse-radish, that a fragment, not exceeding $\frac{1}{50}$ of a grain, is sufficient to fill the air of a large apartment.

Equivalent.

601. Berzelius at first regarded it as a metal; but, since it is an imperfect conductor of heat and electricity, it more properly belongs to the class of the simple non-metallic bodies. He has shown that selenic acid is composed of 24 parts of oxygen and 39.6 of selenium. This substance, also, has three grades of oxidation, the oxygen in the two last of which is in the ratio of 2 to 3; and the highest grade, selenic acid, has in all its chemical relations a singularly close analogy to sulphuric acid. From these facts it is inferred that selenic acid is composed of one atom of selenium and three atoms of oxygen.

Oxide of Selenium.

Composition.

Form.	*Selen.*		*Oxy.*	*Equiv.*
$Se+O$	39.6 or 1 eq.	+	8 or 1 eq.	=47.6

Oxide of

602. This compound is formed by heating selenium in a limited quantity of atmospheric air, and by washing the product to separate selenious acid, which is generated at the same time. It is a colourless gas, very sparingly soluble in water, and is the cause of the peculiar odour which is emitted during the oxidation of selenium.

Selenious Acid.

Form.	*Selen.*	*Oxy.*
$Se+2O$	39.6	+16 or 2 eq.=55.6

Selenious acid.

603. This acid is prepared by digesting selenium in nitric or nitro-hydrochloric acid till it is completely dissolved. On evaporating the solution to dryness, a white residue is left, which is selenious acid. By increase of temperature, the acid itself sublimes, and condenses again unchanged into long four-sided needles. It attracts moisture from the air, and dissolves in alcohol and water. It has distinct acid properties, and its salts are called *selenites.*

Decomposed.

604. Selenious acid is readily decomposed by all substances which have a strong affinity for oxygen.

Selenic Acid.

$Se+3O$	39.6	+24 or 3 eq.=63.6

Selenic acid.

605. This acid is prepared by fusing nitrate of potassa or soda with selenium, a metallic seleniuret, or with selenious acid or any of its salts.*

Properties.

606. Selenic acid is a colourless liquid, which may be heated to 536° without appreciable decomposition; but above that point decomposition commences, and it becomes rapid at 554°, giving rise to disengagement of oxygen and selenious acid. When concentrated by a temperature of 329° its specific gravity is 2.524; at 512° it is 2.60, and at 545° it is 2.625, but a little selenious acid is then present.

Action upon metals.

Selenic acid has a powerful affinity for water, and emits as much heat in uniting with it as sulphuric acid does. Like this acid it is not decomposed by hydrosulphuric acid, and hence this gas may be employed for decomposing seleniate of the oxides of lead or copper. Selenic acid dissolves zinc and iron with disengagement of hydrogen gas, and copper with formation of selenious acid. It dissolves gold also, but not platinum. Sulphurous acid has no action on selenic acid, whereas selenious acid is easily reduced by it. Consequently, when it is wished to precipitate selenium from selenic acid, it must be boiled with hydrochloric acid before sulphurous acid is added.

Selenic and sulphuric acids are not only analogous in composition and in many of their properties, but the similarity runs through their compounds with alkaline substances, their salts resembling each other in chemical properties, constitution, and form. T.

SECTION X. *Chlorine.*

Symb.	*Sp. Gr.*	*Chem. Equiv.*
Cl	2.4700 Air = 1	By Vol. 100
	35.42 Hyd. = 1	" Wght. 35.42

Time of discovery. Synonyms.

607. Chlorine was discovered by Scheele in 1774; it was called by him *dephlogisticated marine acid.* The term *oxy-muriatic* acid was afterwards applied to it by the French chemists. From its colour the name by which it is now known, was given to this gas by Davy, from the Greek χλωρος green.

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* For a description of the process, see Turner's *Elements* 6th ed. p. 209.

608. Chlorine gas may be formed by either of the following processes:

Method of obtaining chlorine.

The most convenient method of preparing it is by mixing concentrated hydrochloric acid, contained in a glass flask or tubulated retort, with half its weight of finely powdered peroxide of manganese. Effervescence, owing to the escape of chlorine, takes place even in the cold; but the gas is evolved much more freely by the application of a moderate heat. It should be collected in inverted glass bottles filled with warm water; and when the water is wholly displaced by the gas, the bottles should be closed with a well ground glass stopper. As some hydrochloric acid gas commonly passes over with it, the chlorine should not be considered quite pure, till after being transmitted through water.

Theory.

609. The theory of this process will be readily understood by first viewing the elements which act on each other, namely :—

Mang.	27.7 or 1 eq.	Mn	Chlor.	70.84 or 2 eq.	$2Cl$
Oxy.	16 2 eq.	$2O$	Hyd.	2 or 2 eq.	$2H$
Perox. of mang.	43.7 or 1 eq.	$Mn+2O$	Hydroch. ac.	72.84 or 2 eq.	$2(H+Cl)$;

and then inspecting the products derived from them, namely,

Mang.	27.7	Hyd.	2	Chlor. 35.42 or 1 eq.
Chlor.	35.42	Oxy.	16	
Chloride of mang.	63.12	Water	18	

In symbols

$$Mn+2O, \text{ and } 2(H+Cl), \text{ yield } Mn+Cl, 2(H+O), \text{ and } Cl.$$

The affinities which determine these changes are the mutual attraction of oxygen and hydrogen, and of chlorine and manganese.

Cheaper process.

610. When it is an object to prepare chlorine at the cheapest rate, as for the purposes of manufacture, the preceding process is modified in the following manner :—

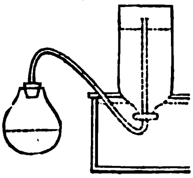
Three parts of sea-salt are intimately mixed with one of peroxide of manganese, and to this mixture two parts of sulphuric acid, diluted with an equal weight of water, are added. By the action of sulphuric acid on sea-salt, hydrochloric acid is disengaged, which reacts as in the former case upon the peroxide of manganese; so that, instead of adding hydrochloric acid directly to the manganese, the materials for forming it are employed. In this process, however, the sulphates of soda and protoxide of manganese are generated, instead of chloride of manganese.

Thus the materials which act on each other are MnO^2, $NaCl$ and $2SO^3$; and the products MnO, SO^3, NaO, SO^3 and Cl.

Method of collecting.

611. The gas should be received, when it is intended to be kept, in bottles filled with, and inverted in, water of the temperature of 80° or 90° F., and provided with accurately ground stoppers. It will be found also much to diminish the loss of gas by absorption, if it be made to issue from a gas bottle, the tube of which is sufficiently long to reach nearly to the bottom of the inverted receiving bottle, as in Fig. 157. The stopper must be introduced under water, while the bottle remains quite full of the gas and inverted, and no water must be left in the bottle, along with the gas.

Fig. 157.



Cold recently boiled water, at the common pressure, absorbs twice its volume of chlorine, and yields it again when heated.

Properties.

612. Chlorine is an elastic, gaseous fluid, it has a pungent disagreeable odour, and is highly injurious when respired even largely

diluted with atmospheric air.* When the hand is immersed in the gas a distinct sensation of heat is perceived. Its colour is greenish yellow.

Weight. According to Davy 100 cubic inches of dry chlorine, at 30 Bar. and 60° F. weigh between 76. and 77 grains. Gay-Lussac and Thenard found the density of pure and dry chlorine to be 2.47, which gives 76.5988 grains as the weight of 100 cubic inches at 60° F. and 30 Bar.

Destroys vegetable colours. 613. Chlorine gas, in its ordinary state, destroys all vegetable colours. This may be shown by passing into the gas confined by water, a piece of paper stained with litmus, the colour of which will immediately disappear. Hence the application of this gas to the purpose of bleaching, its power of effecting which may be shown by confining, in the gas, a pattern of unbleached calico, which has been previously boiled in a weak solution of caustic potassa, and then washed in water, but not dried. Chlorine gas, however, which has been carefully dried by solid chloride of calcium, and into which perfectly dry litmus paper is introduced, produces no change of colour in the litmus, a sufficient proof that its bleaching power depends on the presence and decomposition of water.

Bleaching property illustrated. 614. The bleaching property may be shown by water impregnated with the gas.

Exp. For this purpose fill a small bottle with cold water, and invert it on the shelf of the pneumatic trough, pass up chlorine until about one half the water is displaced from the bottle; close its mouth with the thumb under water—agitate the water and gas together—invert the bottle in a basin of cold water and remove the thumb. Water will rush in to supply the place of that absorbed; more gas may be then passed up and the process repeated three or four times. Strips of calico immersed in this solution will soon be bleached.

615. Dry chlorine, is not condensable by a cold of —40° F.; but either the moist gas, or a solution of chlorine in water, crystallizes at 32°. The crystals may be obtained by introducing into a clean bottle of the gas, a little water, and exposing the bottle for a few days to a temperature at or below freezing, in a dark place. A solid compound of chlorine and water is formed, which, in a day or two, sublimes and shoots into delicate prismatic needles, extending from half an inch to two inches into the atmosphere of the bottle.

Hydrate of chlorine. These crystals are composed, according to Faraday, of 35.42 or 1 atom of chlorine + 90 or 10 atoms water.

Effect of light. 616. Light does not act on dry chlorine; but if water be present, the chlorine decomposes that liquid, unites with the hydrogen to form hydrochloric acid, and oxygen gas is set at liberty. This change takes place quickly in sunshine, more slowly in diffused daylight, and not at all when light is wholly excluded. Hence the necessity of keeping moist chlorine gas, or its solution, in a dark place.

Supporter of combustion. Chlorine unites with some substances with evolution of heat and light, and is hence termed a supporter of combustion. If a lighted taper be plunged into chlorine gas, it burns for a short time with a

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* In case chlorine should escape into the apartment and be inhaled, relief will be found by opening a bottle of aq. ammonia and breathing over it. Breathing the vapour of spirits of wine or swallowing lumps of sugar steeped in alcohol, is said to be effectual.

small red flame, and emits a large quantity of smoke. Phosphorus takes fire in it spontaneously, and burns with a pale white light. Several of the metals, such as tin, copper, arsenic, antimony, and zinc, when introduced into chlorine in the state of powder or in fine leaves, are suddenly inflamed.* In all these cases the combustible substances unite with chlorine.

Combustion of metals, Exp. 1.

Fill a narrow jar 18 or 20 inches in length with chlorine, and sprinkle into it powdered antimony; a beautiful shower of the ignited metal will be perceived until the jar becomes filled with dense white fumes, which should as far as possible be prevented from escaping into the room.

Fig. 158.

Of mercury. Exp. 2.

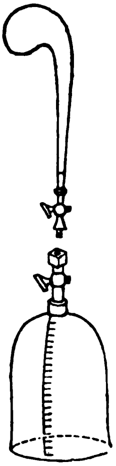
Put some mercury into a copper cup, attached to a thin plate of copper, (Fig. 158,) and rubbed over with a little gas-lute to prevent the metals from combining, and place it in a bottle of the gas, after heating it in the flame of a spirit lamp. It will take fire and combine with the chlorine.

Exp.

The most elegant way of making these experiments consists in introducing the phosphorus or metallic leaves into a retort furnished with a stop-cock, and exhausted upon the air-pump; (Fig. 159.) it is then screwed into the cap of an air jar of chlorine also furnished with a stop-cock, and standing over water in the pneumatic trough. Upon opening the cocks the gas rushes from the jar into the retort, and the phosphorus or leaves immediately burn. A small quantity only of the metals should be used, as the heat is sudden and often sufficient to crack the retort.

As retorts are very liable to break while exhausting, it is advisable to cover them with a cloth during the process. B. 139.

Fig. 159.



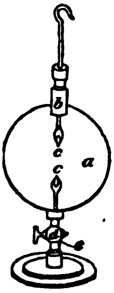
Union with hydrogen.

617. Chlorine has a very powerful attraction for hydrogen; and many of the chemical phenomena, to which chlorine gives rise, are owing to this property. A striking example is its power of decomposing water by the action of light, or at a red heat; and most compound substances, of which hydrogen is an element, are deprived by it of that principle. For the same reason, when chlorine, water, and some other body which has a strong affinity for oxygen, are presented to one another, water is usually resolved into its elements, its hydrogen attaching itself to the chlorine, and its oxygen to the other body. Hence it happens that chlorine is, indirectly, one of the most powerful oxidizing agents which we possess.

Unaltered in high temperatures.

618. It is not altered by exposure to very high temperatures. By means of the apparatus, (Fig. 160,) Davy exposed it to the continued action of charcoal intensely ignited by voltaic electricity, without the smallest change in its properties.

Fig. 160.



Exp.

A glass globe *a*, of about four inches diameter, has at its upper part a sliding wire passing air-tight through a ground collar *b*, to the lower end of which is attached a piece of well burned charcoal *c*: at the bottom is a stop-cock supporting a pair of brass pincers, in which is another pointed piece of charcoal *c*; the globe is exhausted upon the air-pump, filled with chlorine, and the stop-cock *d* and sliding wire *e* attached to the extremities of the Voltaic apparatus; the charcoal points are then brought into contact by pushing down the upper wire, and they are thus retained as long as necessary in intense ignition. B.

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* This is seen to most advantage when a very tall narrow jar is employed.

Effect of pressure. 619. When chlorine is suddenly and considerably condensed by mechanical pressure, not only heat is evolved, as from all other gases, but it emits a weak violet coloured light also.

Liquefaction of chlorine. Under the pressure of about four atmospheres Faraday discovered that chlorine is a limpid liquid of a bright yellow colour, which does not freeze at the temperature of zero, and which assumes the gaseous form with the appearance of ebullition when the pressure is removed.

Used in fumigation. 620. Chlorine is useful for the purposes of fumigation, in destroying the volatile principles given off by putrefying animal matter and contagious effluvia. A peculiar compound of chlorine and soda, the nature of which will be considered in the section on ~~sodium,~~ Salts has been lately introduced for this purpose by Labarraque.

Recognised. 621. Chlorine is in general easily recognised by its colour and odour. Chemically it may be detected by its bleaching property, added to the circumstance that a solution of nitrate of oxide of silver occasions in it a dense white precipitate (a compound of chlorine and metallic silver,) which becomes dark on exposure to light.

Exp. Into a weak solution of common lunar caustic, drop a small quantity of the water impregnated with chlorine.

Those compounds of chlorine, which are not acid, are termed *chlorides* or *chlorurets.*

Hydrogen and Chlorine—Hydrochloric Acid.

			Composition.				
Form.	*Sp. Gr.*		*Chlor.*		*Hyd.*		*Equiv.*
$H+Cl$	1.2694 Air = 1						By Vol. 200
	18.21 Hyd. = 1		35.42	+	1	=	" Wgt. 36.42

Muriatic acid gas. 622. When equal volumes of hydrogen and chlorine gases are mixed and exposed to light, they combine and produce a sour compound commonly called *muriatic acid gas;* or in conformity to more modern nomenclature *hydrochloric acid gas.*

623. Chlorine and hydrogen gases act with considerable energy upon each other, and with different phenomena accordingly as the experiment is conducted.

Explosion of chlorine and hydrogen. If a phial be entirely filled with a mixture of hydrogen and chlorine gases in equal proportions, and a well ground stopper be introduced, no action takes place, provided light be carefully and completely excluded, even by standing some time; but on applying a lighted taper, the gases immediately explode.

Into a small but strong vessel, guarded from the light, introduce equal volumes of the two gases, and inflame the mixture by the electric spark, hydrochloric acid gas results. The apparatus shown at Fig. 133, may be used for the purpose.

Exp. The vessel should be previously exhausted by the air pump,* and then filled with the mixed gases. An electric spark may now be passed through the mixture, when a detonation will ensue, to avoid any injury from which, the vessel should be wrapped in several folds of cloth. If the cock, attached to the vessel, be opened under mercury in about a quarter of an hour, very little of that fluid will enter, proving that the volume of gas after the experiment is scarcely diminished; that it is diminished at all, is owing to a small portion of air being

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* The foot *a* being unscrewed, and the end of the stop-cock connected with the pump plate.

mingled with the other gases: and it was found by Davy that the more perfectly this is excluded, the less is the amount of the contraction of volume. If the cock be now opened under water, and left there for a few minutes, the water will be found to have ascended and entirely filled the vessel.

Effect of light

624. If a phial containing the mixed gases be exposed to the sun's rays a detonation will ensue, which will probably drive out the stopper. But if this should not happen the stopper may be removed under water, which will ascend and completely fill the phial as in the former experiment.

Exp.

The agency of light may be beautifully shewn by filling a tube about half an inch diameter, and 12 inches long, with the mixed gases, and alternately shading it with an opaque cover, and exposing it to the sun's rays. The moment the tube is exposed even to the diffused light of day, a cloudiness will appear within it, and the water will ascend more or less rapidly according to the intensity of the light. The effect even of a passing cloud is distinctly seen in retarding the rapidity of the combination, which is very striking in the full solar light.*

625. The intense light issuing from charcoal points connected with a powerful galvanic battery is as effectual as solar light in acting on hydrogen and chlorine gases; showing a curious analogy between electric and solar light; for ordinary artificial light does not accelerate the combination.†

Hydrochloric acid gas.

626. Hydrochloric acid gas differs essentially from either of its components, and especially in being instantly absorbed by water. To preserve it, therefore, in a gaseous state, it is necessary to confine it by quicksilver.

Liquid.

627. It was generated by Faraday in close tubes, from hydrochlorate of ammonia and sulphuric acid, in a liquid state, and its refractive power was found inferior to that of water. The pressure of its vapour at 50° F. was equal to about 40 atmospheres.

Process for obtaining.

628. To obtain hydrochloric acid gas in sufficient quantity for the exhibition of its properties, the direct combination of chlorine and hydrogen gases is not an eligible process. It may be procured much more conveniently by the action of sulphuric acid on sea-salt.

Let the tubulated gas bottle, (Fig. 87, *a*,) be about one fourth or one third, filled with well dried sea-salt, in lumps, not in powder. To this adapt the acid holder, *b*, filled with concentrated sulphuric acid; and let the aperture of the bent pipe *c*, terminate under a jar filled with, and inverted in quicksilver. Open the communication between the acid and the salt, by turning the cock, *d*; and immediately on the contact of these two bodies, an immense quantity of hydrochloric acid gas will be disengaged. A common or tubulated gas-bottle, or tubulated retort will answer sufficiently well for procuring the gas. The first portions that come over, may be allowed to escape under a chimney; because they are contaminated by the admixture of common air present in the bottle. The subsequent portions may be preserved for use.

Theory.

629. This gas was first obtained pure by Priestley, but its composition was discovered by Scheele, and has since been most ably investigated by Davy. Sea-salt was formerly supposed to be a compound of hydrochloric acid and soda; and, on this supposition, the

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Caution.

* It had been supposed that the direct beams of the sun were necessary to explode a mixture of chlorine and hydrogen gases; but Silliman has related the accidental explosion of a mixture of the gases, in the quantity that filled a Florence oil flask, not only when no direct solar light fell upon it, but when the diffuse light of day was rendered more feeble than common by a thick snow-storm.* This fact furnishes a caution against mixing the two gases in considerable quantities.

† Brande, *Phil. Trans.* 1820.

* See *Amer. Jour. of Sci.* iii. 342.

soda was believed merely to quit the hydrochloric and unite with sulphuric acid. But the researches of Gay-Lussac, Thenard, and Davy proved that it consists of chlorine and sodium combined in the ratio of their equivalents. The nature of its action with sulphuric acid will be understood by comparing the elements concerned in the change before and after it has occurred :—

Hydrous Sulp. Acid.			Chloride of Sodium.		Sulp. of Soda.			Hydrochloric Acid.	
Real acid		40.1	Chlor.	35.45	Acid		40.1	Chlor.	35.42
Water	Hyd.	1	Sodium	23.3	Soda	Sod.	23.3	Hyd.	1
	Oxy.	8				Oxy.	8		

Or in symbols,

$$(S+3O)+(H+O), \text{ and } Na+Cl, \text{ yield } (Na+O)+(S+3O), \text{ and } H+Cl.$$

Thus it appears that single equivalents of water, sulphuric acid, and chloride of sodium, yield sulphate of soda and hydrochloric acid. The water of the sulphuric acid is essential; so much so, indeed, that chloride of sodium is not decomposed at all by anhydrous sulphuric acid.

Properties. 630. It has a very pungent smell; and is sufficiently caustic to blister the skin, when applied to it for some time. When brought into contact with common air, it occasions a white cloud, owing to its union with the aqueous vapour, which is always present in the atmosphere. It is heavier than common air.

Extinguishes flame. 631. It extinguishes a lighted candle. Before the flame goes out, the upper part of it assumes a greenish hue. .A white vapour also surrounds the extinguished wick, owing to the combination of water, produced by the combustion of the candle, with the acid gas.

Absorbed by water, 632. Hydrochloric acid gas is greedily absorbed by water, which at 40° F. Davy found to take up about 480 times its bulk, forming a solution of specific gravity 1.2109.*

Exp. Fill a narrow jar, or tube closed at one end, with the acid gas, over mercury, and through the latter pass up a few drops of water; the gas will be rapidly absorbed, and the mercury will rise in the vessel.

The acid property of the solution may be shown as follows :—

Exp. Take a long tube filled with the gas at the mercurial trough, close it with the thumb or finger, transfer it to a basin of water coloured blue by an infusion of cabbage, and remove the finger under the surface of the water; the gas is immediately condensed, the coloured water is forced up the tube by atmospheric pressure, and reddened at the same time by the acid gas.

Exp. Into a similar vessel filled with the gas introduce a piece of ice; it will be liquefied, almost as rapidly as if touched with a red-hot iron, and the gas will be absorbed.

The quantity of real acid contained in solutions of different densities may be determined by ascertaining the quantity of pure marble dissolved by a given weight of each. Every 50.6 grains of marble correspond to 36.42 of real acid.

Analysis. 633. When a mixture of oxygen and hydrochloric acid gases is either electrified or transmitted through a red-hot porcelain tube, the oxygen unites with the hydrogen of the acid, and the chlorine of the latter is set at liberty. A similar mixture Henry found to be also decomposed by being exposed, at a temperature of 250° F. to

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* *Elements*, p. 252. For table of specific gravity of acid of different strengths, see Appendix.

contact with the platinum sponge. Water is formed and the disengaged chlorine acts on the mercury used to confine the gas.* H. 1. 263.

Liquid hydrochloric acid, how obtained.

634. It is in the state of watery combination that hydrochloric acid is kept for chemical purposes, and all the processes for preparing the liquid acid have for their object the disengagement of the acid gas, and its absorption by water.

For saturating water with this gas we commonly employ Woulfe's apparatus.†

The retort being furnished with the bent tube, *a*, Fig. 161, and placed in a sand bath, the junctures should be carefully luted, and the acid should be added to the salt in the retort at intervals. The water employed may amount to half the weight of the salt, and may be equally distributed between the bottles. These it

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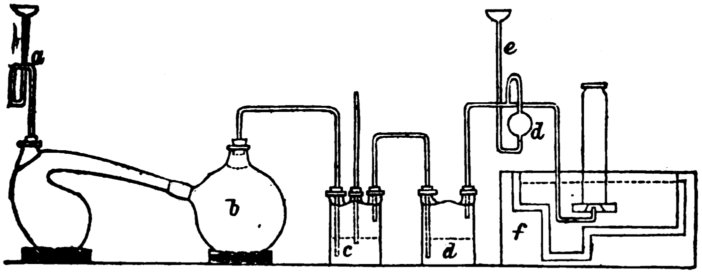
* *Phil. Trans.* 1824.

Woulfe's apparatus.

† In several instances, the substance raised by distillation is partly a condensable liquid, and partly a gas, which is not condensed, till it is brought into contact with water. To effect this double purpose, a series of receivers, termed *Woulfe's apparatus*, is employed. The first receiver (*a*, Fig. 161) has a right-angled glass tube, open at both ends, fixed into its tubulure; and the other extremity of the tube is made to terminate beneath the surface of distilled water, contained, as high as the horizontal dotted line, in the three-necked bottle *c*. From another neck of this bottle, a second pipe proceeds, which ends, like the first, under water, contained in a second bottle *d*. To the central neck, a straight tube open at both ends, is fixed, so that its lower end may be a little beneath the surface of the liquid. Of these bottles any number may be employed that is thought necessary.

Fig. 161.



The materials being introduced into the retort, the arrangement completed, and the joints secured, the distillation is begun. The condensable vapour collects in a liquid form in the balloon *b*, while the evolved gas passes through the bent pipe, beneath the surface of the water in *c*, which continues to absorb it till saturated. When the water of the first bottle can absorb no more, the gas passes, uncondensed, through the second right-angled tube, into the water of the second bottle, which, in its turn, becomes saturated. Any gas that may be produced, which is not absorbable by water, escapes through the bent tube *e*, and may be collected, if necessary.

Supposing the bottles to be destitute of the middle necks, and, consequently, without the perpendicular tubes, the process would be liable to be interrupted by an accident: for if, in consequence of a diminished temperature, an absorption or condensation of gas should take place in the retort, and, of course, in the balloon *b*, it must necessarily ensue that the water of the bottles *c* and *d* would be forced, by the pressure of the atmosphere into the balloon, and possibly into the retort; but with the addition of the central tubes, a sufficient quantity of air rushes through them to supply any accidental vacuum. This inconvenience, however, is still more conveniently obviated by Welther's tube of safety, *e*, which supersedes the expediency of three-necked bottles. The apparatus being adjusted, as shown by the figure, a small quantity of water is poured into the funnel, so as to about half fill the ball *d*. When any absorption happens, the fluid rises in the ball, till none remains in the tube, when a quantity of air immediately rushes in. On the other hand, no gas can escape, because any pressure from within is instantly followed by the formation of a high column of liquid in the perpendicular part, which resists the egress of gas.—A convenient apparatus for this and similar purposes is described in Brewster's *Edin. Jour.* viii. p. 3.

Chap. III. is better to surround with cold water, or, still preferably, with ice or snow; because the condensation of the gas evolves considerable heat, which prevents the water from attaining its full impregnation. When the whole of the sulphuric acid has been added, and the gas no longer issues, let a fire be lighted in the furnace beneath the sand bath, removing the bent tube *a*, and substituting a well ground glass stopper. This will renew the production of gas; and the temperature must be preserved, as long as gas continues to be evolved. At this period it is necessary to keep the luting which connects the retort and receiver, perfectly cool.* Towards the close of the process, a dark coloured liquid is condensed in the first receiver, consisting of a mixture of sulphuric and hydrochloric acids. When nothing more comes over, the operation may be suspended, and the liquid in the two receivers must be preserved in bottles with ground stoppers. It consists of liquid hydrochloric acid. H. 272.

635. When hydrochloric acid is thus dissolved in water, it forms the *liquid muriatic acid*, or *spirit of salt*. When pure it is perfectly colourless, but it is generally impure. Its usual impurities are nitric acid, sulphuric acid, and oxide of iron. The presence of nitric acid may be inferred if the hydrochloric acid has the property of dissolving gold-leaf. Iron may be detected by ferrocyanuret of potassium, and sulphuric acid by chloride of barium, the suspected hydrochloric acid being previously diluted with three or four parts of water. The presence of nitric acid is provided against by igniting the sea-salt, in order to decompose any nitre which it may contain. The other impurities may be avoided by employing Woulfe's apparatus.

Impurities.

636. Liquid hydrochloric acid emits white suffocating fumes, consisting of hydrochloric acid gas, which become visible by contact with the moisture of the air (630). When heated in a retort, the gas is disengaged, and may be collected. It is not decomposed by the contact of charcoal, or other combustible bodies. When diluted with water, an elevation of temperature is produced, less remarkable, however, than that occasioned by diluting sulphuric acid (66); and when the mixture has cooled to its former temperature, a diminution of volume is found to have ensued.

Properties of the liquid acid.

Combines with alkalies.

637. Hydrochloric acid combines readily with alkalies, and with most of the oxides both in their pure and carbonated state.† H. i. 272.

Aqua regia.

A mixture of nitric and hydrochloric acids, in the ratio of one measure of the former to two of the latter, has long been known under the name of *aqua regia*, as a solvent for gold and platinum. When these acids are mixed together, the solution instantly becomes yellow; and on heating the mixture, pure chlorine is evolved, and the colour of the solution deepens. On continuing the heat, chlorine and nitrous acid vapors are disengaged. At length the evolution of chlorine ceases, and the residual liquid is found to be a solution of hydrochloric and nitrous acids, which is incapable of dissolving gold. The explanation of these facts is, that nitric and hydrochloric acids decompose one another, giving rise to the production of water and nitrous acid, and the separation of chlorine; while hydrochloric and nitrous acids may be heated together without mutual decompo-

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* The clay and sand lute is the best for this juncture.

† For a full account of the opinions which have been maintained concerning the nature of chlorine and hydrochloric acid, the reader is referred to the controversy between Murray and J. Davy, in the 34th vol. of *Nicholson's Jour.*; to Davy's paper in the *Phil. Trans.* for 1818, p. 169; to the 8th vol. of *Trans. Roy. Soc. Edin.*; the *Ann. of Philos.* xii. 379 and xiii. 26, 285; and to a paper by Phillips, in the new series of that work, vol. i. p. 27, on the action of chlorides on water.

sition. It is hence inferred that the power of nitro-hydrochloric acid in dissolving gold is owing to the chlorine which is liberated.*

Hydrochloric acid distinguished.

638. Hydrochloric acid is distinguished by its odour, volatility, and strong acid properties. With nitrate of oxide of silver it yields the same precipitate as chlorine; but there is no difficulty in distinguishing between them; for the bleaching property of the former is a sure ground of distinction.

Composition.

639. The experiments of Davy, and Gay-Lussac and Thenard concur in proving that hydrogen and chlorine gases unite in equal volumes, and that the hydrochloric acid, which is the sole and constant product, occupies the same space as the gases from which it is formed. From these facts the composition of hydrochloric acid is easily inferred. For, as

50 cubic inches of chlorine weigh . .	38.2994 grains.
50 " hydrogen , ,	1.0683 "
100 cubic inches of hydrochloric acid gas must weigh	39.3677

These numbers are nearly in the ratio of 1 to 35.42, being that of single eq. of chlorine and hydrogen. Hence its eq. is as already stated.

Compounds of Chlorine and Oxygen.

Leading character.

640. The leading character of these compounds is derived from the circumstance that chlorine and oxygen, the attraction of which for most elementary substances is so energetic, have but a feeble affinity for each other.

They cannot be made to combine directly, and very slight causes effect their separation.

Two volumes of chlorine, as also two of hydrogen and of nitrogen correspond to one equivalent or atom.†

Hypochlorous Acid.

			Composition.		
Form.	*Sp. Gr.*		*Chlor.*	*Oxy.*	*Chem. Equiv.*
$Cl+O$, $\dot{C}l$, or ClO	3.0212	By Wght.	35.42 =	8	43.42
		" Vol.	2 =	1	

Discovery.

641. This gas was discovered in 1811 by Davy and described under the name of *Euchlorine.*‡ Until recently it has been considered to be the protoxide of chlorine.

Process.

642. It is obtained by the action of hydrochloric acid on chlorate of potassa.

Twelve parts of acid diluted with an equal weight of water may be poured upon five parts of the salt (50 or 100 grains will be sufficient); a very gentle heat is to be applied by a small spirit lamp, and the gas may be collected over mercury.

643. This gas is generally, if not always, best made in a tube retort, formed from a piece of plain glass tube, about half an inch in diameter, two or three

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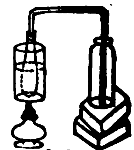
* Davy in *Quart. Jour.* vol. 1.

† Berzelius considers the atoms of all elements as possessing the same vo'ume, and regards the compounds of chlorine and oxygen as composed of two equiv. of chlorine and one, four, five and seven of oxygen.

‡ *Philos. Trans.*

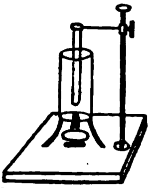
Fig. 162.



inches in length, according to circumstances, and closed at one end. (Fig. 162.) The mouth should be fitted with a good perforated cork, having a small tube fixed into it, which, after proceeding about an inch upwards from the cork, is to turn off nearly at right angles for about three inches, and then return to its first direction for about the eighth of an inch. This piece of tube is the neck of the retort, whilst the wide short piece is the body; the latter having received its charge, the cork is to be put in and made tight by cement, when the distillation may be proceeded with, and the gas evolved and collected. F.

Caution. Great care should be taken in preparing this gas, as it explodes violently when exposed to a moderate heat, though nothing is mixed with it; when the spirit lamp is used, it should be held immediately below the retort, so as not to play on its sides, and the gas should then come slowly away, producing a very moderate effervescence.*

Fig. 163.



644. When the object is merely to notice a few of the properties of the gas, it may be obtained from materials placed in a glass tube, 15 or 16 inches in length and about an inch in diameter, surrounded by water and heated, as in the Fig. 163.

Theory. 645. The production of this gas is explicable by the fact, that hydrochloric and chloric acids mutually decompose each other. When hydrochloric acid and chlorate of potassa are mixed together, more or less of the potassa is separated by the hydrochloric acid from the chloric acid, and the latter being set at liberty, reacts on free hydrochloric acid. The result depends upon the relative quantities of the materials. If hydrochloric acid be in excess, the chloric acid undergoes complete decomposition. For each eq. of chloric acid, five eq. of hydrochloric acid are decomposed: the five eq. of oxygen contained in the former, unite with the hydrogen of the latter, producing five eq. of water; while the chlorine of both acids is disengaged. If, on the contrary, chlorate of potassa be in excess, the chloric acid is deprived of part of its oxygen only; the products are water and the euchlorine of Davy.

646. The chloric and hydrochloric acids react on each other in the ratio of one eq. to two, or, what is the same thing, in that of four eq. to eight eq.; thus

$$\begin{array}{rcl} 4\ (Cl+5O) & & 8\ (H+O) \\ & \text{yield} & \\ \text{and } 8\ (H+Cl) & & 12\ (Cl+O) \end{array}$$

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* In reference to the distillation of this gas, and of all other explosive substances, the student should be aware of the caution required to prevent accidents, in case explosion should occur. Whenever such an effect is probable, the vessel should be surrounded with tow or cloth, that if it break, the fragments may be retained; and during distillation the side of the apparatus, or that part which is guarded by the tow, is to be turned towards the eyes, that they at least may be out of danger. It is not easy to wrap tow regularly and tightly round a clean glass tube, from its tendency to slip over the surface; but the difficulty is easily obviated, by rubbing the outside of the tube with soft cement, or a very little turpentine with a piece of tow or cloth, so as to render it slightly adhesive to the fingers. Faraday p. 409.

Silliman prefers placing the materials for producing the gas in a small glass flask furnished with a tube bent twice at right angles, and passing to the bottom of any clean dry phial, flask, or tube, rather deep with a narrow neck, a gentle heat, applied beneath the flask, soon disengages the euchlorine gas, which, by its great weight, displaces the common air from the recipient, and takes its place. By using tongs, properly curved, so as to embrace the phials or tubes filled with the gas, the operator may perform all the necessary experiments, without danger of causing an explosion by the warmth of the hand. *Amer. Jour.* vi. 165.

The gas thus obtained, is not a distinct compound, but a mixture of chlorine and chlorous acid. T. 218.

Process for the pure acid.

647. The process for obtaining the pure acid, is to pour into bottles filled with chlorine gas, peroxide of mercury in fine powder, and mixed with twice its weight of distilled water; by brisk agitation the chlorine is rapidly and completely absorbed, if a slight excess of the peroxide be used. By this process one portion of the peroxide of mercury, HgO^2, is decomposed, both its constituents combining with chlorine; the mercury forming corrosive sublimate $HgCl^2$, and the oxygen hypochlorous acid. The latter remains in solution in the water; while the former, by combining with undecomposed peroxide of mercury, forms the sparingly soluble oxychloride of mercury, which is separated by filtration. The hypochlorous acid being volatile, is obtained pure by distillation; the temperature being kept below 212° as the acid decomposes at that heat. The process is best performed under reduced pressure.

Properties.

648. As thus obtained, hypochlorous acid is a transparent liquid of a slightly yellow colour; when concentrated, with a strong penetrating odour, similar to that of chlorine. It acts powerfully upon the skin, and bleaches.

It is easily decomposed, chlorine being evolved and chloric acid produced; a change effected by light and instantly by the direct rays of the sun. It is also decomposed by angular bodies, as by pounded glass.

Oxidizes.

649. It is one of the most powerful oxidizing agents; its action, however, is various and is principally observed in relation to the simple non-metallic elements. Its action on the more perfect metals is slight, with the exception of iron and silver, which in a state of minute division instantly decompose it.

Another process.

650. Hypochlorous acid has also been obtained in the gaseous form, by introducing a small quantity of its concentrated solution into a bell glass over mercury and adding fragments of dry nitrate of lime. The latter unites with the water and the acid gas escapes. The gas is of a yellowish green colour; it unites rapidly with water which absorbs at least 100 times its volume.

Specific gravity, &c.

651. It detonates by a slight increase of temperature, and oxygen and chlorine are the results; 100 measures produce 100 of chlorine and 50 of oxygen.* From these data its sp. gr. is 3.0212; its eq. 43.42; eq. vol. = 100; symb. $Cl+O$, Cl, or ClO. (T.)

Chlorous Acid.

Composition.

Symb.	*Sp. Gr.*	*Chl.*	*Oxy.*	*Equiv.*	*Equiv. Vol.*
$Cl+4O$, $\overset{\cdot\cdot\cdot\cdot}{Cl}$ or ClO^4	2.3374	By Wght. 35.42	32	67.42	= 200
		" Vol. 2	4		

652. This compound was discovered by Davy in 1815, and soon after by Count Stadion of Vienna. It has heretofore been described as the *peroxide of chlorine*, but having been found to possess acid properties, and to form definite compounds with alkaline bases, it

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* Balard *Ann. de Chim. et de Phys.* lvii. 225.

must now be called *chlorous acid.* It is formed by the action of sulphuric acid on the chlorate of potassa.

Method of obtaining.

To procure it, 50 or 60 grains of the powdered chlorate of potassa, are to be mixed with a small quantity of concentrated sulphuric acid. When thoroughly incorporated, a solid mass will result, of a bright orange colour. This is to be introduced into a very small retort of glass, or a bent tube, which is to be exposed to the heat of water gradually warmed, but prevented from attaining the boiling point, by an admixture of spirit of wine.

Theory.

653. In this process the sulphuric acid decomposes some of the chlorate of potassa, and sets chloric acid at liberty. The chloric acid at the moment of separation, resolves itself into chlorous acid and oxygen; the last of which, instead of escaping as free oxygen gas, goes over to the acid of some undecomposed chlorate of potassa, and converts it into perchloric acid. The products are bisulphate and perchlorate of potassa, and chlorous acid. It is probable that every three eq. of chloric acid yield one eq. of perchloric and two eq. of chlorous acid. T.

Salts of,

654. This acid readily unites with the alkalies and alkaline earths, and the union is effected by transmitting the gas into the alkaline solutions. The salts are soluble in water and bleach.

Decomposed by phosphorus and heat.

655. It is decomposed, at common temperatures, by phosphorus, which occasions an explosion when introduced into it. It explodes violently at 212°, and great care is necessary in operating with it.

Chloric Acid.

Form.		Composition. *Chlor.*	*Oxy.*	*Equiv.*
$Cl+5O$, $\overset{.....}{Cl}$, or ClO^5	By Wght.	35.42	40	75.42
	" Vol.	2	5	

656. When a current of chlorine gas is passed into a strong solution of pure potassa, part of the alkali is decomposed and chloride of potassium and hypochlorite of potassa are generated. On bringing the solution to the boiling point, the latter salt is decomposed. The changes are complicated; from experiments* nine eq. of hypochlorite of potassa produce one eq. of chlorate of potassa, eight eq. of chloride of potassium, and twelve eq. of oxygen: or thus

Process.

$$9\,(KO+ClO) \text{ yield } (KO+ClO^5),\ 8KCl \text{ and } 12O$$

657. When weak sulphuric acid is added to a dilute solution of chlorate of baryta, exactly sufficient for combining with the baryta, sulphate of baryta subsides, and pure chloric acid remains in the liquid.

Properties.

658. This acid was first obtained by Gay-Lussac. It reddens vegetable blue colours, has a sour taste, and forms neutral salts, called *chlorates* (formerly *hyperoxymuriates.*) It has no bleaching properties, nor does it afford a precipitate with solution of nitrate of oxide of silver.

Decomposed.

659. Chloric acid is easily decomposed by oxidizing agents; and it is easily known by forming a salt with potassa, which crystallizes

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* Of Morin, Soubeirain, and Balard.

in tables and has a pearly lustre, deflagrates on burning coals, and yields chlorous acid by the action of concentrated sulphuric acid.

Perchloric Acid.

		Composition.		
Form.		*Chl.*	*Oxy.*	*Equiv.*
$\mathrm{Cl}+7\mathrm{O}$, $\overset{\cdot\cdot\cdot\cdot\cdot\cdot\cdot}{\mathrm{Cl}}$ or ClO_7	By Wght.	35.42 .	56	91.42
	" Vol.	2	7	

Process. 660. The saline matter which remains in the retort after forming chlorous acid, is a mixture of perchlorate and bisulphate of potassa, and by washing it with cold water, the bisulphate is dissolved and the perchlorate is left. This acid may be prepared from the salt by mixing it in a retort with half its weight of sulphuric acid, diluted with one third water, and applying heat to the mixture. At the temperature of about 284° F. white vapours rise, which condense as a colourless liquid in the receiver. This is a solution of perchloric acid.

Composition. Stadion, its discoverer, found it to be a compound of 1 eq. chlorine + 7 eq. oxygen, and his analysis has been confirmed by Gay-Lussac and others.

Properties. 661. When concentrated it has a density of 1.65 in which state it emits vapour on exposure to the air, absorbs moisture, and boils at 392°. It hisses when thrown into water like a red-hot iron when quenched.

662. It forms a salt with potassa, requiring 65 times its weight of water at 60° for solution. The perchlorate of potassa is distinguished from the chlorate by not acquiring a yellow tint on the addition of hydrochloric acid.

Quadrochloride of Nitrogen—Chloride of Nitrogen.

Sp. Gr. 1.653.

Properties. 663. Quadrochloride of nitrogen, discovered in 1811 by Dulong,* is one of the most explosive compounds yet known, having been the cause of serious accidents both to its discoverer and to Davy.† It does not congeal in the intense cold produced by a mixture of snow and salt. It may be distilled at 160°; but at a temperature between 200 and 212° it explodes. Its mere contact with some substances of a combustible nature causes detonation even at common temperatures. This result ensues particularly with oils, both volatile and fixed. The products of the explosion are chlorine and nitrogen.‡

Process. 664. It is prepared by inverting a jar or wide-mouthed bottle, (capable of containing about 12 or 14 ounces) full of chlorine, over a dilute solution of the hydrochlorate of ammonia, (sal ammoniac) made by dissolving an ounce of the salt in 10 or 12 ounces of water; the bottle is placed on a very strong shallow leaden cup, which rests on a deep plate containing the solution previously heated to the temperature of 90°. One portion of the chlorine takes the hydrogen of the ammonia,§ forming hydrochloric acid, and the other, combining with the nitrogen, is converted into the quadrochloride, which collects in the form of an oil on the surface of the liquid, and drops through it into the leaden cup: an additional quantity of the solution must be ready to fill up the plate as the absorption of the chlorine proceeds.

Caution. 665. Great care must be taken not to shake the bottle, and any

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* *Ann. de Ch.* lxxxvi.

† *Phil. Trans.* 1813.

‡ Nicholson's *Jour.* xxxiv.

§ Ammonia consists of hydrogen and nitrogen.

greasy or oily matter adhering to it must be removed by washing it with a dilute solution of potassa before it is filled with chlorine. When the oil has fallen into the leaden cup, the bottle is carefully moved from the cup to the plate, and the leaden cup taken cautiously away.

The liquid remaining above the quadrochloride in the cup is withdrawn by dipping small pieces of filtering paper into it. The oily looking globules may be conveniently removed by drawing them into a small and perfectly clean glass syringe, made of a glass tube drawn to a pointed orifice, and having a copper wire with a piece of clean tow wrapped round it for a piston, (Fig. 164); in this way a globule may be drawn into the tube, and transferred to any other vessel.

Fig. 164.

Precautions in experimenting with. 666. In making these experiments, a small globule of the compound, about the size of a mustard-seed, should be cautiously transferred to a clean porcelain basin, half filled with water. The basin should be covered with a wire safeguard. A very small piece of phosphorus, fixed to the end of a long rod with the extremity dipped in oil, may be then brought into contact with the globule, which instantly explodes, dispersing the water and breaking the basin. The same compound may be obtained by suspending a fragment of sal ammoniac in a solution of hypochlorous acid. T.

Analysis. 667. Davy analyzed this compound by means of mercury, which unites with chlorine, and liberates the nitrogen. He inferred from his analysis that its elements are united in the proportion of four measures of chlorine to one of nitrogen; and it hence follows that, by weight, it consists of four equivalents of chlorine, and one equivalent of nitrogen. Its odour is extremely penetrating and almost insupportable, affecting the eyes very much on leaning over it even for a second or two. It is very volatile.

Perchloride of Carbon.

Symb.	*Equiv.*
$2C+3Cl$, or C^2Cl^3.	118.5

Discovery. 668. The discovery of this compound is due to Faraday. When olefiant gas (a compound of carbon and hydrogen) is mixed with chlorine, combination takes place between them, and an oil-like liquid is generated, which consists of chlorine, carbon and hydrogen. On exposing this liquid in a vessel full of chlorine gas to the direct solar rays, the chlorine acts upon and decomposes the liquid, hydrochloric acid is set free, and the carbon, at the moment of separation, unites with the chlorine.*

Properties. 669. Perchloride of carbon is solid at common temperatures, has an aromatic odour approaching to that of camphor, is a non-conductor of electricity, and refracts light very powerfully. Its specific gravity is exactly double that of water. It fuses at 320°, and after fusion it is colourless and very transparent. It boils at 360°.

Perchloride of carbon burns with a red light when held in the flame of a spirit-lamp, giving out acid vapours and smoke.†

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* *Phil. Trans.* 1821.

† *Protochloride of Carbon.* *Symb.* $C+Cl$, or CCl. *Equiv.* 41.54. Discovered by Faraday in decomposing perchloride of carbon. It is liquid, colourless, and boils

Sect. X.
Nature of chlorine.

670. Chlorine was long regarded as a compound of muriatic acid and oxygen, an opinion ably defended by Murray; the phenomena which it presents are all explicable on this supposition, though the view proposed by Davy, Gay-Lussac and Thenard, of its elementary nature, is considered more in accordance with actual experiment, and now generally adopted.*

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at 170°. Its density is 1.5526. Does not congeal at 0° F. Analogous to perchloride of carbon in its chemical relations.

Dichloride of Carbon. *Symb*. $2C+Cl$, or C^2Cl. *Eq*. 47.66. Obtained during the distillation of nitric acid from crude nitre and sulphate of iron, in soft, adhesive fibres of a white colour and peculiar odour. Boils between 350°, and 450°, sublimes at 250. Soluble in hot oil of turpentine or alcohol. Burns with a red flame.

Dichloride of Sulphur. *Symb*. $2S+Cl$, or S^2Cl. Density 1.687. Discovered by Thomson.* Prepared by passing chlorine over flowers of sulphur. Liquid, volatile below 200°, boils at 280°. Emits acrid fumes. Consists of 35.42 parts or 1 eq. chlorine, and 32.2 parts or 2 eq. sulphur.†

Perchloride of Phosphorus. *Symb*. $2P+5Cl$, or P^2Cl^5 *Equiv*. 208.5. There are two definite compounds of chlorine and phosphorus. the nature of which was first satisfactorily explained by Davy.‡ When phosphorus is introduced into a jar of dry chlorine, it inflames, and on the inside of the vessel a white matter collects, which is *perchloride of phosphorus*. It is very volatile, a temperature much below 212° being sufficient to convert it into vapour. Under pressure it may be fused, and it yields transparent prismatic crystals in cooling.

Sesquichloride of Phosphorus, *Symb*. $2P+3Cl$, or P^2Cl^3; *Equiv*. 137.66, may be made by heating the perchloride with phosphorus, or by passing the vapour of phosphorus over corrosive sublimate contained in a glass tube. It is a clear liquid like water, of specific gravity 1.45; emits acid fumes when exposed to the air, owing to the decomposition of watery vapour; but when pure it does not redden dry litmus paper. It appears to consist of 31.4 parts or two equivalents of phosphorus, and 106.26 parts or 3 eq. of chlorine.

Chlorocarbonic Acid Gas. *Symb*. $CO+Cl$, or CO,Cl *Equiv*. 49.54. This compound was discovered in 1812 by Dr Davy, who described it in the *Philos*. *Trans*. under the name of *phosgene gas*. (From φως light, and γεννειν to produce.) It is made by exposing a mixture of equal measures of dry chlorine and carbonic oxide gases to sunshine, when rapid but silent combination ensues, and they contract to one half their volume. Diffused daylight also effects their union slowly; but they do not combine at all when the mixture is wholly excluded from light.

Chlorocarbonic acid gas is colourless, has a strong odour, and reddens dry litmus paper. It possesses the characteristic property of acids. It is decomposed by contact with water. 100 cubic inches weigh 106.7633 grains. Its specific gravity is 3.4427, and it consists of 35.42 parts or one equivalent of chlorine, and 14.12 parts or one equivalent of carbonic oxide.

Terchloride of Boron. *Symb* $B+3Cl$, or BCl_3. *Equiv*. 117.16; *eq. vol*. = 200. Berzelius found that if boron, previously heated, was exposed in a glass tube to a current of dry chlorine, and gently heated as soon as the atmospheric air was expelled, a colourless gas was obtained, which could be collected over mercury. It may also be generated by the action of dry chlorine on a mixture of charcoal and boracic acid heated to redness in a porcelain tube. It is absorbed by water. Its sp. gr. is 4.0805.

Terchloride of Silicon. *Symb* $Si+3Cl$, or $SiCl^3$; *Equiv*. 128.76, is obtained by heating silicon in a current of chlorine gas. It is a limpid, volatile fluid, boiling at 124° and not solid at zero. Its odour is suffocating.

Oersted obtained it by mixing about equal parts of hydrated silicic acid and starch into a paste with oil, heating the mass in a covered crucible so as to char the starch, introducing the mixture in fragments into a porcelain tube, and then transmitting through it a current of dry chlorine while the tube is kept at a red heat. The chlorine unites with silicon, and the charcoal and oxygen combine. The volatile chloride is then agitated with mercury to separate the free chlorine, and purified by distillation.

Chloronitrous Gas. When fused chloride of sodium, potassium, or calcium, in powder, is treated with as much strong nitric acid as is sufficient to wet it, mutual decomposition ensues, and a new gas, composed of chlorine and binoxide of nitrogen, is generated. It was discovered by E. Davy, who describes it as of a pale reddish yellow colour, of an odour similar to that of chlorine, and as having bleaching properties.

* For an account of the changes of opinion concerning the nature of chlorine, see Turner. 226.

In referring to chemical works published before the present views were entertained,

* Nicholson's *Jour*. vol. vi. † Rose—*Pog. Ann*. xxi. 431. ‡ *Elements*, p. 290.

SECTION XI. *Iodine.*

Symb.	*Sp. Gr.*	*Chem. Equiv.*
I.	8.7020 Air = 1	By Vol. 100
	126.30 Hyd. = 1	" Wght. 126.3

Discovery of iodine.

671. Iodine was discovered accidentally by Courtois, a manufacturer of saltpetre at Paris, in 1812. In the process for procuring soda from the ashes of sea-weeds, he found that his metallic vessels were much corroded, and in searching for the cause, he made the discovery of iodine. Its real nature was soon after determined by Gay-Lussac and Davy, each of whom proved that it is a simple non-metallic substance, exceedingly analogous to chlorine.*

Occurs in nature.

672. Iodine is frequently met with in nature in combination with potassium or sodium. Under this form it occurs in many salt and other mineral springs, both in Europe and America.† It has been detected in the water of the Mediterranean, in the oyster and some other marine molluscous animals, in sponges, and in most kinds of sea-weed. In some of these productions, such as the *Fucus serratus* and *Fucus digitatus*, it exists ready formed, and according to Fyfe‡ may be separated by the action of water; but in others it can be detected only after incineration. Marine animals and plants doubtless derive from the sea the iodine which they contain. Vauquelin found it also in the mineral kingdom, in combination with silver.§

Process for obtaining iodine,

673. Iodine is procured from the impure carbonate of soda, called kelp,|| which is prepared in large quantity on the northern shores of Scotland, by incinerating sea-weeds. The kelp is employed by soap-makers, for the preparation of carbonate of soda; and the dark residual liquor, remaining after that salt has crystallized, contains a considerable quantity of iodine, combined with sodium or potassium. By adding a sufficient quantity of sulphuric acid, hydriodic acid is first generated, and then decomposed.

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the following memoranda will enable the student to translate the language formerly employed into the present nomenclature.

According to the old doctrine.	*According to Davy.*
1. Chlorine is a compound of muriatic acid 28 + Oxygen 8 = 36.*	1. Chlorine is an element.
2. Muriatic acid gas consists of 28 real acid + 9 water = 37.	2. Muriatic acid gas is the real acid, and contains no water, consisting of chlorine 36 + hydrogen 1 = 37.
3. Muriatic acid gas, acting on oxides, gives out its combined water, the real acid 28 combining with the oxide.	3. Muriatic acid gas acting on oxides is decomposed, its hydrogen uniting with the oxygen of the oxide, and producing the water which is detached, while a compound of chlorine and the metal is left. Reid's *Text Book.*

* The original papers on this subject are in the *Ann. de Chim.* vols. lxxxviii., xc. and xci., and in the *Philos. Trans.* for 1814 and 1815.

† On iodine in the waters of Saratoga, see *Amer. Jour.* xvi. 242.

‡ *Edin. Philos. Jour.* 1. 254.

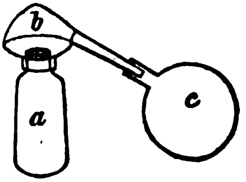
§ *An. de Ch. et de Ph.* xxix.

|| For a method of determining the proportions of iodine in kelp, &c. see *Jour. de Chem. Med.* Aug. 1838, and *Lond. and Edin. Phil. Mag.* xiii. 466.

* The numbers given by Reid are retained, but can readily be made to correspond with the more correct numbers of Turner.

Illustrated,

Fig. 165.



Lixiviate* powdered kelp with cold water. Evaporate the lixivium till a pellicle forms, and set aside to crystallize. Evaporate the mother liquor to dryness, and pour upon the mass half its weight of sulphuric acid. Apply a gentle heat to this mixture in the flask *a* of the *alembic* shown in Fig. 165, of which the head or capital *b*, has a tube issuing from it, and descending into the receiver *c*. Fumes of a violet colour arise and condense in the form of opaque crystals, having a metallic lustre, which are to be washed out of the head of the alembic with a small quantity of water, and quickly dried upon bibulous paper.

Another. 674. A more convenient process is to employ a moderate excess of sulphuric acid, and then add to the mixture some peroxide of manganese, which acts on hydriodic in the same way as on hydrochloric acid (608). Another method, proposed by Soubeirain, is by adding to the ley from kelp a solution made with the sulphates of protoxides of copper and iron in the ratio of 1 of the former to $2\frac{1}{4}$ of the latter, as long as a white precipitate appears. The diniodide of copper is thus thrown down; and it may be decomposed either by peroxide of manganese alone, or by manganese and sulphuric acid. By means of the former, the iodine passes over quite dry; but a strong heat is requisite.

675. As the liquid directed to be used (673) may not be easily procured, the method of preparing iodine may be shown, by mixing a little pure hydriodic acid with the peroxide of manganese in a small tube or glass retort.

Properties. 676. Iodine is a solid at the ordinary temperature of the atmosphere. It is often in scales resembling those of micaceous iron ore; sometimes in large and brilliant rhomboidal plates, the primitive form of which is a rhombic octohedron. Its colour is bluish black; its lustre metallic; it is soft and friable, and a non-conductor of electricity. It produces a yellow stain upon the skin. Its smell resembles that of diluted chlorine. Its taste is acrid. Its sp. gr. according to Gay-Lussac is 4.948, but Thomson found it only 3.0844.

Iodine is fusible at 225° F. and, under the ordinary pressure of the atmosphere, is volatilized at a temperature somewhere near 350°.

Vapour of. 677. Its vapour is very dense, its sp. gr. being, by calculation as already given, or, as directly observed by Dumas, 8.716; hence 100 cubical inches weigh 269.8638 grains.

The volatilization of iodine at the heat of boiling water, which happens when it is distilled with that fluid, depends on its affinity for aqueous vapour.

The colour of the vapour of iodine is a beautiful violet, and hence its name, (from ἰώδης *violaceus*.)

Exp. This may be exhibited by introducing a few scales of iodine into a glass matrass, and heating it over a few coals.

Other properties. 678. Like chlorine and oxygen, iodine is a negative electric. It renders vegetable colours yellow. It is very sparingly soluble in water, that liquid not holding more than $\frac{1}{7000}$ its weight in solution; the colour of the solution is yellow. It is much more soluble in spirit of wine and in ether. It acts energetically on the animal system as an irritant poison, but is employed medicinally in very small doses with advantage.

679. Iodine manifests a strong attraction for the pure metals and for the most of the simple non-metallic substances. These combina-

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* When water is poured upon certain bodies for the purpose of extracting their saline ingredients, the process is called *lixiviation*, and the solution obtained, a *lixivium*.

For details see Ure's *Dict.*, article *Iodine.*

Iodides. tions are termed *Iodides* or *Iodurets.* It is not inflammable; but under favourable circumstances may, like chlorine, be made to unite with oxygen. A solution of the pure alkalies acts upon it giving rise to the decomposition of water. Whether a hypo-iodite and iodide are first produced, as in the case of chlorine, has not yet been determined, but on the application of heat an iodate and iodide are formed. T.

Action of imponderables. 680. Pure iodine is not influenced chemically by exposure to the direct solar rays, or to strong shocks of electricity. It may be passed through red-hot tubes, or over intensely ignited charcoal, without any appearance of decomposition; nor is it affected by the agency of galvanism. Chemists, indeed, are unable to resolve it into more simple parts, and consequently it is regarded as an elementary principle.

Test for iodine. 681. The most delicate test of the presence of iodine, is starch, and if added to any liquid containing it, with a few drops of sulphuric acid, a blue compound is formed which is insoluble in water. According to Stromeyer, a liquid containing but $\frac{1}{450.000}$ of its weight of iodine, receives a blue tinge from a solution of starch. Two precautions should be observed to ensure success. In the first place the iodine must be in a free state; for it is the iodine itself only, and not its compounds, which unite with starch. Secondly, the solution should be quite cold at the time of adding the starch; for boiling water decomposes the blue compound, and consequently removes its colour.*

Equivalent. 682. By expelling the iodine from fused iodide of silver by a current of chlorine gas and thus obtaining a chloride, the composition of which was known, Berzelius inferred the equivalent of the iodide, and from that the equivalent of iodine.

Hydriodic Acid.

Form.	*Sp. Gr.*	Composition. *Iod.*	*Hyd.*		*Equiv.*
H+I, or HI	4.3854 Air = 1	126.3 1 eq.	+ 1	=	By Wght. 127.3
	63.65 Hyd. = 1				" Vol. 200

Formed. 683. When a mixture of hydrogen and the vapour of iodine is transmitted through a red hot porcelain tube, direct combination takes place and *hydriodic acid* gas is formed.

Process. This gas may be obtained by mixing one part of phosphorus with ten of iodine moistened with water, placing it previously in a very small glass retort or flask, and applying a gentle heat with a spirit lamp.

In a short time, a brisk reaction commences, a slight explosion generally taking place within the retort from the heat produced inflaming a portion of phosphorus, and also from the disengagement of a little phosphuretted hydrogen. Dense vapours are at the same time disengaged, and the hydriodic acid

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*To render this test more sure Balard recommends the following: After mixing the liquid containing the iodine with the starch and the sulphuric acid, a small quantity of aqueous solution of chlorine is to be added which from its lightness may be made not to mix with the mixture, but float on the surface; at the place, however, where they touch, a blue zone will be developed where the two solutions are in contact, but if the whole be mixed, it will entirely disappear, if the chlorine be in excess.—*Ann. de Chim.* xxxviii. See Hayes in *Amer. Jour.* xxiii. 142.

gas may be collected by displacement; (Fig. 150) after these have been expelled, a few drops of water should be introduced from time to time, by a small pipette, as phosphuret of iodine is sublimed into the neck of the vessel when the materials are dry, and no gas is produced. Phosphuretted hydrogen is disengaged in considerable quantity towards the end of the operation; when it begins to come it is recognised by the acid gas with which it is mixed, producing a whiter coloured vapour than usual with the air, the process should then be stopped, to prevent it from accumulating. Fifty or an hundred grains of iodine, with the proper quantity of phosphorus, will be found quite sufficient, using a retort capable of containing about 5 or 6 ounces of water. Constant attention must be paid to this operation while it is going on.*

684. A number of complicated changes take place during the reaction of the different substances employed, and part of the newly formed products. The hydriodic acid gas is produced by the iodine combining with the hydrogen of a portion of water which is decomposed, the oxygen uniting with the phosphorus. Theory.

685. 100 measures of hydriodic acid gas contain precisely half their volume of hydrogen. Assuming it to consist of equal volumes of hydrogen gas and iodine vapour united without any condensation, then, since Equivalent and density.

50 cubic inches of the vapour of iodine weigh	.	134.9319 grains.
50 do. hydrogen gas	. . . .	1.0683 "
100 cubic inches of hydriodic acid gas should weigh		136.0002

These numbers are obviously in the ratio of 1 to 126.3, the equivalents of iodine and hydrogen. On the same principles the density of the gas should be 4.3854, which is probably more correct than 4.443, a number found experimentally by Gay-Lussac.† Hence 100 measures of hydriodic acid gas contain 50 measures of hydrogen gas and 50 of the vapour of iodine.

When hydriodic acid gas is conducted into water till that liquid is fully charged with it, a colourless acid solution is obtained, which emits white fumes on exposure to the air, and has a density of 1.7. T.

686. Hydriodic acid gas has a sour taste, reddens vegetable blue colours, produces dense white fumes with atmospheric air, and resembles hydrochloric acid in its odour. It combines with alkalies and forms salts called *hydriodates*. It is rapidly absorbed by water. Properties.

Remove a tube filled with the gas, having closed the open end with the finger, into a basin of water and remove the finger under the water. Exp.

687. The gas is decomposed by several substances which have a strong affinity for either of its elements. Thus oxygen gas, when heated with it unites with its hydrogen, and liberates the iodine. Chlorine effects the decomposition instantly. Decomposed,

Fill a small jar half full of hydriodic acid gas over the mercurial trough, invert it with a tray, keeping the mouth of the jar upwards, and bring cautiously in contact with it the extremity of a narrow tube, or the beak of a small retort, from which chlorine is slowly escaping; 50 or 60 grs. of peroxide of manganese may be employed with a proper proportion of hydrochloric acid, and a retort capable of holding 1 or 2 oz. measures. The chlorine combines with the hydrogen of the hydrochloric acid, and purple vapours of iodine appear which will condense. If much chlorine be brought at once in contact with the acid gas, an explosion takes place.‡ Exp.

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* Reid, *Elem.* 208. † *An. de Ch.* xci. 16.

‡ The chlorine should be allowed to come for some time before it is applied to the

Chap. III.

by mercury, Place a small jar filled with the gas over mercury, the iodine will combine with that metal and the hydrogen be left.

and nitrous acid. Invert a jar full of the gas with an earthen dish, and pour into it some strong fuming nitric and nitrous acids. The hydrogen of the hydriodic acid will combine with the oxygen of the nitrous acid and iodine be set free. The mixture often inflames even when no more than two or three cubic inches of the gas are used.

Its solution used as a test, 688. A solution of this gas in water is much employed as a test, and may be made by decomposing the iodide of starch suspended in water, by a stream of hydrosulphuric acid.*

Decomposed. 689. The solution of hydriodic acid is decomposed by mere exposure to the air, oxygen unites to its hydrogen, and the iodine is set free. Nitric and sulphuric acids also decompose it; and chlorine unites to its hydrogen to form hydrochloric acid.

Test. 690. Bichloride of platinum is a most delicate test of hydriodic acid. Pour a few drops into a glass containing an ounce or two of water, add a single drop of a solution of the bichloride of platinum, the liquid will become of a reddish brown colour, and a dark precipitate subside.

Its effect upon metallic solutions may be seen as follows: Added to solution of nitrate of silver, it affords a yellow precipitate; with bichloride of mercury, a yellow and finally a red precipitate; with acetate of lead, a yellow.

Oxide of Iodine and Iodous Acid.

691. When the vapour of iodine and oxygen gas are heated, a yellow matter of the consistence of solid oil is generated, which has been regarded as an oxide of iodine. If the supply of oxygen is continued, it is converted into a yellow liquid supposed to be iodous acid.† **Iodous acid.**

Iodic Acid.

	Composition.		
Form.	*Iod.*	*Oxy.*	*Equiv.*
$I+5O$, $\overset{\cdot\cdot\cdot\cdot\cdot}{I}$, or IO^5	126.3 1 eq. + 40	6 eq. =	166.3

Iodic acid. 692. This acid was discovered by Gay-Lussac and Davy. It is obtained by bringing iodine into contact with the euchlorine of Davy; the chlorine unites with one portion of iodine, and the oxygen

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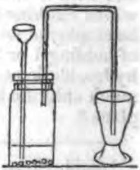
hydriodic acid gas, that all the air may be expelled. Three or four cubic inches of this gas are quite sufficient for this experiment; the operator should place the vessel from which the chlorine escapes on a retort stand and in such a situation that any excess of gas may be carried away by a current of air.

* *Jour. Sci.* N. S. No. viii.

Sixty grains of iodine are dissolved in 3 ounces of alcohol (kept cold), and an ounce of starch reduced to a very fine powder diffused in 4 ounces of water; on adding this, drop by drop, to the first solution, and stirring it constantly at the same time, iodide of starch is formed; the clear liquid is decanted after the iodide has subsided. A little water is then poured on it to remove any alcohol that may be still mixed with it, and after this has been removed, the iodide is diffused through an ounce of water, and a stream of hydrosulphuric acid gas from 400 or 500 grs. of the sulphuret of iron passed through it till it becomes white. Filter the liquid and boil for a short time to expel any excess of hydrosulphuric acid. The iodide of starch may be put into a precipitate glass, when it is diffused through water, and the hydrosulphuric acid prepared in a bottle with a bent tube fitted to it. (Fig. 166.)

Fig. 166.



† *Quart. Jour. of Sci.* N. S. 1.

with another, forming two compounds, a volatile orange coloured matter, chloride of iodine, and a white solid substance which is *iodic acid.* On applying heat, the former passes off in vapour, and the latter remains.*

Process. Another process is by boiling iodine in pure nitric acid of density 1.5; the acid, with about one fifth of its weight of iodine, is placed in a tube sealed at one end, about an inch wide and fifteen inches long. The boiling should be continued at least twelve hours. As the iodine rises and condenses on the sides of the tube, it should be restored to the liquid, either by agitation or by help of a glass rod. As soon as the iodine disappears, the nitric acid is dissipated by cautious evaporation.†

It is also obtained by the oxidizing effect of hypochlorous acid on iodine, and by several other processes.‡

Properties. 693. It is a white, semitransparent solid, having a very acid astringent taste. It acts powerfully on inflammable substances, and enters into combination with metallic oxides, forming *iodates.* These compounds, like the chlorates, yield pure oxygen by heat.

694. It forms salts with the alkalies which are soluble in water.

It is readily detected, being deoxidized by sulphurous, phosphorous, hydriodic and hydrosulphuric acids, iodine being set at liberty, which may be detected by starch.

Decomposition. 695. When decomposed by heat it is resolved into oxygen gas and pure iodine; and it was therefore termed by Davy *oxyiodine,* and by Gay-Lussac *acide iodique anhydre.*§

Teriodide of Nitrogen.

Composition.

Form.	*Iodine.*		*Nit.*		*Equiv.*
N+3I, or NI^3	378.9	3 eq. +	14.15	1 eq. =	393.05

696. From the weak affinity that exists between iodine and nitrogen, these substances cannot be made to unite directly. But when iodine is put into a solution of ammonia, the alkali is decomposed; its elements unite with different portions of iodine, and thus cause the formation of hydriodic acid and iodide of nitrogen.

Process. It may be procured by pouring a solution of ammonia upon a very small quantity of iodine. Hydriodic acid is one product, and the other a brown powder, which detonates upon the slightest touch, and is resolved into nitrogen and iodine. It may be collected by pouring off the liquid, and placing it, while moist, in small parcels upon bibulous paper, where it must be suffered to dry spontaneously.

Exp. If we collect the powder on two or more separate pieces of paper, and place them at several inches apart, the explosion of any one of them will, sometimes, cause that of the others.

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* *Phil. Trans.* 1815. † Connell in *Edin. Phil. Jour.* 1831, 72, and 1832, 337.

‡ For which see Turner, 232.

§ *Periodic Acid, Form.* I+7O, $\overset{\cdot\cdot\cdot\cdot\cdot\cdot\cdot}{\mathrm{I}}$ or IO^7, is analogous in composition to perchloric acid, and has decided acid properties. For process see Turner 232.

Chloride of iodine. *Chlorides of Iodine.* Chlorine is absorbed at common temperatures by dry iodine with evolution of heat, and a solid compound of iodine and chlorine results, which was discovered both by Davy and Gay-Lussac. The colour of the product is orange-yellow when the iodine is fully saturated with chlorine, but is of a reddish-orange if iodine is in excess. Its solution is colourless, very sour to the taste, and reddens vegetable blue colours, but afterwards destroys them. From its acid properties Davy gave it the name of *chloriodic acid.* Souberain has lately distinguished a compound of 3 eq. of chlorine and 1 of iodine.*

* *Jour. de Phar.* Feb. 1837.

When left exposed it gradually evaporates. It often explodes spontaneously. When it detonates, the purple fumes of iodine are perceptible.

697. *Iodides of phosphorus.* Iodine and phosphorus combine on being brought in contact, and so much heat is evolved that part of the phosphorus is inflamed if the air be not excluded.

Exp. A small piece of phosphorus may be placed in a wine glass and iodine let fall upon it from a card or broad knife, combustion ensues and iodine vapour escapes.

Iodine and phosphorus can combine in various proportions.*

SECTION XII. *Bromine.*

Symb.	*Sp. Gr.*		*Chem. Equiv.*	
Br	5.4017	Air = 1	By Vol.	100
	78.40	Hyd. = 1	" Wght.	78.4

Discovery. 698. In 1826 Balard† of Montpellier discovered in sea water a new substance to which he gave the name *muride;* but it has since been changed to *Bromine*, a word derived from the Greek βρωμος (*graveolentia*) signifying a strong or rank odour.

699. Bromine exists in sea water in the form of bromide of sodium or magnesium. It may apparently be regarded as an essential ingredient of the saline matter of the ocean. It has also been found in the waters of the Dead Sea, and in a variety of salt springs. It is present, however, in very small quantity;‡ and even the uncrystallizable residue called *bittern*, left after the salt has been separated from sea water by evaporation, contains but little of it.§ Daubeny has detected it in several mineral waters, and Balard in marine plants on the shores of the Mediterranean, in the ashes of sea weeds, and of some animals, as the *Ianthina violacea.*

Process for obtaining bromine. 700. It is obtained by passing a stream of chlorine through the bittern, and exposing it afterwards to heat; the bromine distils over and may be collected in a receiver. A few ounces of concentrated bittern are sufficient to show this process. In preparing the liquid,

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* *Iodide of Sulphur* is prepared with 4 parts of iodine and 1 of sulphur heated gently.

Periodide of carbon. *Periodide of Carbon* is formed when a solution of pure potassa in alcohol is mixed with an alcoholic solution of iodine, a portion of the alcohol is decomposed; its hydrogen and carbon uniting separately with iodine, give rise to periodide of carbon, and hydriodic acid. By distilling a mixture of the preceding with corrosive sublimate, the protiodide is formed.

† The original essay of Balard was published in the *Ann. de Chim. et de Phys.* Aug. 1826, and an abstract of it in the *Edin. Jour. of Sci.*

‡ One hundred pounds of sea water yield but 3.278 grains of bromine. *Quart. Jour.* 1827.

§ I have obtained it from the bittern of the salt works in the vicinity of Boston (W.), and Hayes has found it in the waters of Saratoga. *Amer. Jour.* xviii. 142.

Hayes' method of detecting bromine. Hayes recommends the following as a method of detecting the presence of *extremely minute* quantities of bromine and iodine. Mix a few drops of pure water in a conical glass, with a drop of sulphuric acid, and half a volume of a cold solution of starch: pass a few bubbles of chlorine through the mixture, which is then left at rest, that the diffused starch may unite at bottom. A glass rod, dipped in the fluid supposed to contain bromine, is then applied to the surface of the fluid in the glass; orange-coloured, dense striæ descend from the rod, and rest for some time on the starch if bromine alone is present. If the solution contains iodine also, the appearance is the same, but the striæ are deep blue; in a few seconds the blue disappears, and the characteristic orange yellow of the solution of bromine remains. *Amer. Jour.* xviii. 142.

the chlorine must be transmitted through it till the orange colour which it acquires ceases to become deeper. The chlorine which is procured from 290 or 300 grains of peroxide of manganese will be quite sufficient for passing through five or six ounces of bittern.

Theory.

701. Bittern consists principally of sulphates and hydrochlorates of soda and magnesia, with a small quantity of the hydrobromate of magnesia, the hydrobromic acid of which is composed of hydrogen and bromine. The chlorine combines with the hydrogen and disengages the bromine, which imparts a yellow colour to the liquid. The vapour of the bromine has a deep reddish brown colour and condenses into a very dark coloured liquid.

Other processes.

There are other processes. A current of chlorine may be transmitted through the bittern, and it may then be shaken with sulphuric ether, which will dissolve the bromine, and acquire a hyacinth red tint. When the ethereal solution is agitated with caustic potassa, its colour entirely disappears, owing to the formation of bromide of potassium and bromate of potassa, the former of which is obtained in cubic crystals by evaporation. The bromine may be set free by means of chlorine, or still better by sulphuric acid and peroxide of manganese in a glass retort dipping into cold water.

Properties,

Specific gravity.

702. Bromine is liquid at common temperatures with a deep hyacinthine red colour. It volatilizes readily and its vapour is highly coloured, having a density of 5.54,* 100 cubic inches at 60° should weigh 167.5158 grs. Its sp. gr. is about 3. At 116.5° it boils, and is frozen and brittle at —4°. It communicates a yellow stain to the skin and acts powerfully upon organic bodies. It is highly fatal to animal life; a bird is killed by a single drop placed on its beak. Bromine has not been decomposed; it is an imperfect conductor of electricity, and a negative electric. It is soluble in water, alcohol and ether, and has the property of bleaching.

Action on combustibles,

And metals.

703. The vapour of bromine extinguishes a lighted taper, which, at first, burns with a flame green at its base, and red at its upper part. Some inflammables take fire by contact with it. Thus antimony and tin burn in it, and the combustion of potassium is attended with intense heat and a vivid flash, and the vessel in which the experiment is made is often broken. Its affinity for metallic oxides is feeble.

Analogous to chlorine &c.

704. Bromine is analogous to chlorine and iodine in its chemical relations, and suffers the same kind of change as those bodies similarly treated. Its presence is in general easily detected by chlorine and the colour of its vapour, or of its solution in ether.

Hydrobromic Acid.

Composition.

Form.	*Sp. Gr.*		*Brom. Hyd.*		*Equiv.*	*Eq. Vol.*
H+Br., or HBr.	2.7353 Air	= 1	78.4 + 1	=	79.4	200
	39.70 Hyd.	= 1				

When formed.

705. This acid is formed when a lighted candle or piece of red-hot iron is introduced into a mixture of the vapour of bromine and hydrogen gas; and by the action of bromine on some of the gaseous compounds of hydrogen.

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* Mitscherlich.

Process.

It may be conveniently made for experimental purposes by a process similar to that for forming hydriodic acid. A mixture of bromine and phosphorus slightly moistened, yields, by the aid of gentle heat, a large quantity of pure hydrobromic acid gas, which should be collected either in dry glass bottles, or over mercury.

Properties.

706. It is a pungent, colourless, acid gas, undergoing no decomposition when transmitted through a red-hot tube, either alone or mixed with oxygen, but is decomposed instantly by chlorine. It may be preserved without change over mercury; but potassium and tin decompose it with facility.

Solution.

707. It is very soluble in water, and the solution may be made by treating bromine with hydrosulphuric acid dissolved in water, or still better by transmitting a current of hydrobromic acid gas into pure water. The liquid becomes hot during the condensation. This acid solution is colourless when pure, but possesses the property of dissolving a large quantity of bromine, and then receives the tint of that substance.

Action of chlorine.

Chlorine decomposes the solution of hydrobromic acid. Nitric acid acts upon it less suddenly, disengaging bromine. Nitro-hydrobromic acid is analogous to *aqua regia*, and possesses the property of dissolving gold.

Weight and equivalent.

708. Hydrobromic is analogous to hydriodic and hydrochloric acid gases, in containing equal measures of bromine vapour and hydrogen gas united without any change of volume; and since

		Grs.
50	cubic inches of bromine vapour weigh . . .	83.7579
50	do. hydrogen gas	1.0683
100	do. hydrobromic acid must weigh . .	84.8262

These numbers are in the ratio of 1 to 78.4, which is the composition of the gas by weight. T. The salts of hydrobromic acid are termed *hydrobromates.*

Bromic Acid.

	Composition.		
Symb.	*Brom.*	*Oxy.*	*Equiv.*
Br+5O, $\overset{\cdot\cdot\cdot\cdot\cdot}{Br}$, or BrO^5.	78.4 1 eq.	+ 40 5 eq.	= 118.4

Bromic acid.

709. *Bromic Acid* is formed by the action of bromine on potassa, when a change exactly similar to that produced by chlorine (page 656) ensues, whereby bromide of potassium and bromate of potassa are generated; and the latter, being much less soluble than the former, is readily separated by evaporation. The bromate of the other alkalies and alkaline earths may be prepared in a similar manner.

Process for,

710. Bromic acid may be procured by decomposing a dilute solution of bromate of baryta with sulphuric acid, so as to precipitate the whole of the baryta. The solution of bromic acid may be concentrated by slow evaporation until it acquires the consistence of syrup.

Properties of.

Bromic acid has scarcely any odour, but its taste is very acid, though not at all corrosive. It reddens litmus paper powerfully at first, and soon after destroys its colour. It is similar in constitution to iodic, chloric and nitric acids.*

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* *Chloride of Bromine.*—This compound may be formed at common temperatures by transmitting a current of chlorine through bromine, and condensing the disen-

SECTION XIII. *Fluorine.*

Symb. F. *Equiv.* 18.68 *Eq. Vol.* 100

Fluorine, 711. The mineral known as Derbyshire spar from the place where it occurs in great abundance, was considered to be a compound of a peculiar acid and lime, and the former was called fluoric acid. It was suggested by Ampère that this mineral is a compound of fluorine and calcium, and this was supported experimentally by Davy. The supposed base of the acid was named fluorine, but was not obtained in an insulated form until recently, and its properties are but imperfectly known.

How obtained. 712. Fluorine was first procured by Baudrimont by passing fluoride of boron over minium (red oxide of lead), heated to redness, and receiving the gas in a dry vessel. As it is mixed with much oxygen, his present method is, to treat a mixture of fluoride of calcium and peroxide of manganese with strong sulphuric acid. This process, however, does not afford it pure, hydrofluoric and fluosilicic acid gases being at the same time evolved. The presence of the latter does not prevent the observation of some of the properties of fluorine.

Properties. 713. It appears to be a gaseous body, resembling chlorine and burnt sugar in odour, and possessed of bleaching properties. It does not act on glass. It is a negative electric, and has a powerful affinity for hydrogen and metallic substances.

Hydrofluoric Acid.

Composition.

Form.	*Sp. Gr.*	*Flu.*	*Hyd.*	*Equiv.*
$H+F$, or HF.	1.0609	18.68 1 eq. +	1 1 eq.	= 19.68

Hydrofluoric acid, 714. Hydrofluoric acid was first obtained pure by Gay-Lussac and Thenard in 1810.

Process for. 715. It is prepared by acting on *fluor spar* (*fluoride of calcium*), by sulphuric acid.

The spar, carefully separated from siliceous earth and reduced to fine powder, is put into a leaden or silver retort with twice its weight of sulphuric acid; the materials are mixed together with an iron rod, and on applying a moderate heat by a chauffer, the hydrofluoric acid is disengaged: a receiver of the same metal must be used to condense it. An arrangement like that on the following page will be found convenient.*

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gaged vapours by means of a freezing mixture. The resulting chloride is a volatile fluid of a reddish yellow colour.

Bromide of iodine, &c. *Bromide of Iodine.*—These substances act readily on each other, and appear capable of uniting in two proportions.

Bromide of Sulphur.—On pouring bromine on sublimed sulphur, combination ensues, and a fluid of an oily appearance and reddish tint is generated. Bromide of sulphur is decomposed by chlorine, which unites with sulphur and displaces bromine.

Bromides of Phosphorus.—When bromine and phosphorus are brought into contact in a flask filled with carbonic acid gas, they act suddenly on each other with evolution of heat and light, and two compounds are generated. The protobromide retains its liquid form even at 52° F.

Bromide of Carbon is formed by the action of bromine on half its weight of periodide of carbon, when bromide of carbon and a subbromide of iodine are formed, the latter of which is removed by a solution of caustic potassa. At common temperatures it is liquid, but crystallizes at 32° F. Its taste is sweet, and it has a penetrating ethereal odour.

Apparatus for hydrof. acid. * It is composed of a deep leaden cup, (Fig. 167,) with a rim of lead soldered round the top, a small space being left between it and the upper part of the cup for fixing

Chap. III. **Theory.** 716. As the materials swell up considerably during the process, the retort should be capacious. At the close of the operation, pure hydrofluoric acid is found in the receiver, and the retort contains dry sulphate of lime. The chemical changes are the same as in the formation of hydrochloric acid gas (629), fluorine being substituted for chlorine, and calcium for sodium. If the sulphuric acid is of sufficient strength, all its water is decomposed, and the resulting hydrofluoric acid is anhydrous.

Properties. 717. This acid at 32° is a colourless liquid, and remains such at 59° if preserved in well stopped bottles,* but when exposed to the air, it flies off in dense white fumes. It has a very pungent smell, and is extremely destructive; if applied to the skin it instantly kills the part, producing extreme pain and extensive ulceration. The operator should carefully avoid the fumes, and the apparatus or vessels containing the acid, should be so placed that they may be carried *from* him.

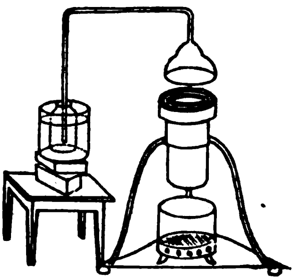
Action on glass. It acts powerfully on glass, destroying its transparency, in consequence of attacking its silica and forming with it a compound known as *fluosilicic acid gas*, hence it cannot be kept in glass vessels unless protected by wax.

Uses. 718. From its affinity for silica, it is employed for etching on glass, and for this purpose should be diluted with three or four parts of water. The glass should be covered with a varnish, prepared by melting together bees-wax and turpentine, and surrounded at the edge by a rim of the same. The varnish is then to be removed wherever it is desired to have the acid act upon the glass, as in the process for etching on copper.

Exp. On a small scale the experiment may be made by placing a small quantity of the powdered fluor spar in a platinum, silver, or leaden cup or crucible, supported over a lamp; covering the vessel with a piece of glass, coated by rubbing over it, previously warmed, a piece of wax, lines being traced through the coating so as to expose the glass. Or the cup may be held over the fire† till the vapour begins to escape, the glass is then applied and the whole covered with a wooden or pasteboard box.‡

Acid properties. 719. Hydrofluoric acid has all the characters of a powerful acid.

Fig. 167.



in the head of the apparatus when the materials have been put in. The easiest method of proceeding is to fill this intervening space with moist plaster-of-paris, and put in the cover when it begins to set, taking care to have the tube and the bottle receiver, which are used along with it, properly adjusted at the same time, that it may not be necessary to shift it afterwards. The receiver is placed in a jar or basin, and surrounded by ice. The heat should be cautiously applied; so as not to melt the leaden cup; the student should examine it occasionally with an iron rod, and withdraw the chauffer if it begins to soften or yield more than usual to the iron. The body of the retort may be rather more than two inches in diameter, and between seven and eight inches long; it is supported by an iron ring resting on three rods of iron, and bound together at bottom by a plate of sheet iron, on which the chauffer is placed. Two to four ounces of fluor spar may be used in it at a time, or even more if required. A more expensive apparatus is described in *Amer. Jour.* vol. vi. 355.

* Which should be lined with wax.

† With tongs, not by the hand.

‡ A little sand poured round the box where it rests on a table will prevent the vapours from annoying the operator.

It has a strong, sour taste, reddens litmus paper, and neutralizes alkalies, either forming salts termed *hydrofluates*, or most generally giving rise to metallic fluorides. All these compounds are decomposed by strong sulphuric acid with the aid of heat, and the hydrofluoric acid while escaping may be detected by its action on glass.

Action on metals, &c.

720. Hydrofluoric acid acts violently on some of the metals, especially on the bases of the alkalies. It is a solvent for some elementary principles which resist the action even of nitro-hydrochloric acid, with evolution of hydrogen gas; and when mixed with nitric acid, it proves a solvent for silicon which has been condensed by heat, and for titanium. Nitro-hydrofluoric acid, however, is incapable of dissolving gold and platinum.

Fluoboric Acid.

Composition.

Form.	*Flu.*			*Bor.*			*Equiv.*
$B+3F$, or BF^3.	56.04	3 eq.	+	10.9	1 eq.	=	66.94

Process.

721. This gas was procured by Gay-Lussac and Thenard from a mixture of vitrified boracic acid and fluor spar, exposed to heat in a leaden retort. It was procured by Dr Davy by mixing intimately one part of *fused* boracic acid with twice its weight of fluor spar, both in fine powder, and twelve parts of sulphuric acid in a glass flask,* heating the mixture by a lamp. Half an ounce or an ounce and a half of the fused boracic acid, with the corresponding quantity of spar and acid affords a considerable quantity of the compound. Strong sulphuric acid should be employed. The gas thus obtained contains a considerable quantity of fluosilicic acid.

Theory.

722. In the decomposition of fluor spar by vitrified boracic acid, the former and part of the latter undergo an interchange of elements. The fluorine uniting with boron gives rise to fluoboric acid gas; and by the union of calcium and oxygen, lime is generated, which combines with boracic acid, and is left in the retort as borate of lime.

Properties.

723. Fluoboric acid gas is colourless, has a penetrating pungent odour, and extinguishes flame on the instant. It reddens litmus paper as powerfully as sulphuric acid, and forms salts with alkalies which are called *fluoborates*. It has a singularly great affinity for water. When mixed with air or any gas which contains watery vapour, a dense white cloud, a combination of water and fluoboric acid, appears, thus affording an extremely delicate test of the presence of moisture in gases. Water acts powerfully on this gas, absorbing 700 times its volume, increasing in temperature and volume. The solution is limpid, fuming, and very caustic.

Fluoboric acid gas does not act on glass, but attacks animal and vegetable matters with energy, converting them, like sulphuric acid, into a carbonaceous substance.

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* *Phil. Trans.* 1812.

Fluosilicic Acid.

Composition.

Form.	*Sp. Gr.*	*Flu.*		*Si.*			*Equiv.*
$Si+3F$, or SiF^3.	3.6111	56.04	3 eq.	+22.5	1 eq.	=	78.54

Procured. 724. Is prepared by mixing one part of pounded glass with an equal weight of fluor spar and two parts of sulphuric acid. On applying a gentle heat fluosilicic acid gas is disengaged with effervescence, and may be collected over mercury.

Theory. 725. The chemical changes are differently explained. Regarding fluor spar as a compound of fluoric acid and lime, the former is thought to unite with silicic acid. If fluor spar is regarded as a compound of fluorine and calcium, it is inferred that, by the action of sulphuric acid on fluoride of calcium, hydrofluoric acid is generated, and that the elements of this acid react on those of silicic acid, and give rise to water and fluosilicic acid gas: the gas is therefore a fluoride of silicon.

Properties. 726. It is a colourless gas, extinguishing flame, powerfully irritating, and does not corrode dry glass. Mixed with atmospheric air it forms a white cloud, with its watery vapour. T. 244.

Singular appearance. 727. A singular appearance is presented when the beak of a retort, from which this gas is escaping, dips into water. Each globule of the gas, as it comes in contact with the water, assumes the appearance of a vesicle, a coating of silica being deposited on the external surface of the globule. Small tubes appear also at the beak of the retort, which is eventually plugged up, so that it is necessary at last to remove the retort altogether till they are taken away.

COMPOUNDS OF SIMPLE NON-METALLIC ACIDIFIABLE COMBUSTIBLES WITH EACH OTHER.

SECTION XIV. *Hydrogen and Nitrogen—Ammoniacal Gas.*

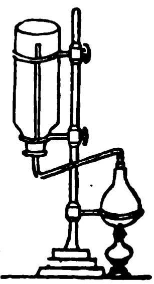
Composition.

Symb.	*Sp. Gr.*		*Hyd.*		*Nit.*			*Chem. Equiv.*
$N+3H$, or NH^3	0.5897	Air =1	3.2050	3 eq.	+15.0825	14.15	1 eq.	By Wght. 17.15
	8.75	Hyd.=1						" Vol. 200

728. This gas was first noticed by Priestley, under the name of *alkaline air;* it is also known as the *volatile alkali,* but more usually by the name *ammoniacal gas* or ammonia.

Process. 729. Ammoniacal gas is obtained from any salt of ammonia, by the action of a pure alkali or alkaline earth: but hydrochlorate of ammonia and lime are generally employed.

Fig. 168.



Equal parts of dry slaked lime, each separately powdered, are put into a small glass retort or gas bottle, and upon the application of gentle heat the ammoniacal gas is evolved, and is to be received over mercury.

Another. Persons not having a mercurial apparatus may receive this gas in a glass jar inverted over a tube bent as in Fig. 168. As the gas is evolved from the materials contained in the gas-bottle, it rises into the jar and displaces the atmospheric air. When the jar is filled with ammonia (which will be known by its pungent odour as it escapes from the neck of the jar) the tube

Sect. XIV.

may be carefully withdrawn, and a well ground stopper be inserted into the neck of the jar.

The gas may also be obtained by heating common liquid ammonia (aqua ammoniæ) in the same apparatus.

Properties.

730. Ammonia is colourless, has a strong pungent odour, and acts powerfully on the eyes and nose. It is quite irrespirable in its pure form, but when diluted with air, it may be taken into the lungs with safety. Burning bodies are extinguished by it, nor is the gas inflamed by their approach. Ammonia, however, is inflammable in a low degree; for when a lighted candle is immersed in it, the flame is somewhat enlarged, and tinged of a pale yellow colour at the moment of being extinguished; and a small jet of the gas will burn in an atmosphere of oxygen. A mixture of ammoniacal and oxygen gases detonates by the electric spark; water being formed, and nitrogen set free.

Action of electricity.

731. When an electric current is passed through a weak solution of ammonia, it is decomposed by the secondary action, hydrogen from decomposed water being evolved at the negative electrode, and nitrogen at the positive.* But if a portion of mercury form the negative electrode, no hydrogen is evolved, and the mercury is rapidly converted into a light porous substance, which has the lustre and all the characters of an amalgam. As soon as it is removed from the influence of the electric current, rapid decomposition ensues, mercury is reproduced, and hydrogen and ammoniacal gases are evolved in the ratio of one measure of the former to two of the latter, according to the observations of Gay-Lussac and Thenard. The production of this compound is explained by Berzelius on the supposition that ammonia, by uniting with an additional eq. of hydrogen, forms a compound, which has all the properties of a metal; he, therefore, calls it *ammonium*. The oxide of ammonium, the composition of which is represented by the formula NH^4+O, he considers to be the base of the ammoniacal salts. T. 246.

Ammonium.

732. Ammonical gas at the temperature of 50° and under a pressure equal to 6.5 atmospheres, becomes a transparent colourless liquid. a

Alkaline.

Ammonia has all the properties of an alkali in a very marked manner. Thus it has an acrid taste, and gives a brown stain to turmeric paper; though the yellow colour soon reappears on exposure to the air, owing to the volatility of the alkali. It combines also with acids, and neutralizes their properties completely.

Affinity for water. Exp.

Its affinity for water may be shown by filling a long tube with the gas, and opening it under water; the ammonia will be absorbed with great rapidity, and completely if the gas is pure. According to Thomson water takes up 780 times its bulk.

Exp.

Its alkaline character may be shown by using, instead of pure water, water coloured blue by litmus or cabbage, or yellow by turmeric.

Exp.

A piece of ice passed up the tube standing over mercury, is rapidly liquefied and the gas absorbed.†

Effect of heat.

733. None of the ammoniacal salts can sustain a red heat without being dissipated in vapour or decomposed, a character which arises

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* Faraday, *Phil. Trans.* 1834.

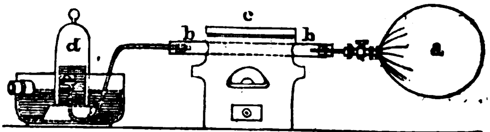
† A vessel of water or mercury should be at hand to supply the loss in the dish in which the tube is placed and prevent the entrance of air.

from the volatile nature of the alkali. If combined with a volatile acid, such as the hydrochloric, the compound itself sublimes unchanged by heat.

Decomposition.

734. Hydrogen and nitrogen gases do not unite directly, but the composition of ammoniacal gas has been determined by analysis with electricity, and by passing it through red-hot tubes. If passed over a coil of iron or copper wire in a red-hot porcelain tube, the metals become brittle, but their weight is not altered. The expansion which the gas suffers in being thus resolved into its constituents, is a singular instance of change of properties in consequence of chemical combination. The bladder *a*, (Fig. 169,) is filled with ammonia, which may be passed through the tube *b*, in the furnace *c*, the hydrogen and nitrogen may be collected in *d*.

Fig. 169.



Action of chlorine,

735. Ammonia is decomposed by chlorine, hydrochloric acid is formed by the union of the chlorine with its hydrogen, and if an excess of the gas is present, hydrochlorate of ammonia is obtained.

Phenomena attending.

When the two gases are suddenly mixed they act upon each other so powerfully as sometimes to produce detonation.

Exp.

Invert a matrass with a conical neck and wide mouth, over another with a taper neck containing a mixture of sal ammoniac and lime, heated by a lamp. As soon as the upper vessel seems to be full of ammonia, by the overflow of the pungent gas, it is to be cautiously lifted up, and inserted, in a perpendicular direction, into a wide mouthed glass decanter, or flask, filled with chlorine. On seizing the vessels thus joined, with the two hands, covered with gloves, and suddenly inverting them like a sand-glass, the heavy chlorine and light ammonia, rushing in opposite directions, unite, with the evolution of flame.

Fig. 170.

How recognised.

736. Ammonia is readily recognised by its odour, and by the white fumes which are given off when a rod dipped in hydrochloric acid is brought in contact with it.

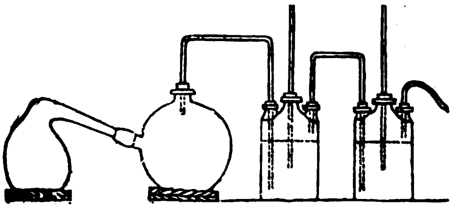
Exp.

This will be evident if we moisten the inside of a glass jar with hydrochloric acid, and pass into it a small quantity of ammonia; dense clouds of hydrochlorate of ammonia will immediately form.

Liquor ammoniæ.

737. The usual state in which ammonia is employed is in solution, both in chemistry and medicine. This solution bears the name of *Aqua Ammoniæ* in *the Pharmacopœia.* It may be obtained by passing the gas into water in a proper apparatus, (Fig. 171,) or by distilling over the water and gas together.

Fig. 171.



Phillips' process.

The following process, recommended by Phillips, answers well.

On 9 ounces of well burned lime pour half a pint of water, and when it has remained in a well closed vessel for about an hour, add 12 ounces of hydrochlorate of ammonia in powder and three pints and a half of boiling water; when the mixture has cooled, pour off the clear portion, and distil from a retort 20 fluid ounces.

The sp. gr. of this solution, which is sufficiently strong for most purposes, is 0.954.[*]

How preserved.

738. Liquid ammonia should be preserved in well-stopped glass bottles, since it loses ammonia and absorbs carbonic acid, when exposed to air; when heated to about 140°, ammonia is rapidly given off by it. When concentrated it requires to be cooled to —40° before it congeals, and then it is apparently inodorous.[†]

SECTION XV. *Compounds of Hydrogen and Carbon.*

Compounds of hydrogen and carbon.

739. Two compounds of hydrogen and carbon have long been known, and late researches have brought to light others of much interest. They are remarkable for their number; for supplying some instructive instances of isomerism; for their tendency to unite with and even neutralize powerful acids, without, in their uncombined state, manifesting any ordinary signs of alkalinity.

Distinguished by affinities.

740. Several of them are particularly distinguished by their chemical affinities; for although compound, they exhibit in their combinations with other substances, the characteristics of an element. They have hence been called compound radicals. In organic chemistry they hold a place as the roots or radicals of the various organic products, and in inorganic chemistry as compounds formed by the direct union of two elements.[‡] T.

Light Carburetted Hydrogen.

		Composition.					
Form.	*Sp. Gr.*	*Hyd.*		*Carb.*		*Equiv.*	*Eq. Vol.*
H^2C	0.5593 Air = 1 8.12 Hyd. = 1	2	+	6.12	=	8.12	100

741. This gas is sometimes called *heavy inflammable air*, the *inflammable air of marshes*, and *hydrocarburet*. It is generally termed light carburetted hydrogen.

Collected.

It may be collected, mixed however with carbonic acid and nitrogen gases, by stirring the bottom of almost any stagnant pool of water, especially if formed of clay. It should be washed, when collected, with lime water or liquid potassa, to remove the carbonic

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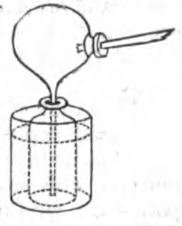
Fig. 172.



Another process.

[*] Or two parts of lime and three of sal ammoniac may be mixed, after the former has been slaked with a half of its weight of water and allowed to cool; they should both be in fine powder, and intimately blended, taking care to avoid the pungent fumes that are disengaged. The mixture is then put into an iron retort and placed in a sand bath. (Fig. 172.) The beak of the retort is then luted to a quilled globe, making the joining tight with plaster-of-paris; water, equal in weight to $\frac{3}{4}$ of the salt used, is put into a bottle or receiver. The tube from the globe should reach to the bottom of the bottle, which should not be more than half full, when the proper quantity of water has been put in. The use of the glass globe is to allow air to pass into the retort as the apparatus becomes cold, and prevent any of the water of ammonia from being carried along with it; for when the gas ceases to come and all the liquid in the bottle has been forced into the globe by the pressure of the atmosphere, air will enter by the quill tube and pass through the water to the retort.

[†] For a table of the quantity of ammonia in solutions, see Davy's *Elements*.

[‡] Those, which from their atomic constitution, or from being the products of the organic kingdom, belong to that department, will be described under that division.

acid, of which it contains $\frac{1}{20}$. This is the only convenient method of obtaining it.

Properties.

742. Light carburetted hydrogen is nearly inodorous, and without colour or taste. Water absorbs about $\frac{1}{60}$ of its volume. It does not support combustion or life, but is highly inflammable, burning with a yellowish flame.

Detonation with air and oxygen gas.

743. Mixed with atmospheric air it may be kindled by a lighted taper, and explodes with violence, provided it forms not less than $\frac{1}{12}$ of the mixture, and does not exceed $\frac{1}{6}$. With oxygen gas the detonation is louder and more violent; but it is necessary that oxygen should rather exceed the inflammable gas in volume, and yet should not be more than $2\frac{1}{4}$ times its bulk. For its perfect combustion more than twice its volume of oxygen gas is required, of which exactly two volumes are consumed, and carbonic acid is produced, equivalent in volume to the inflammable gas.

Composition and sp. gr.

744. One hundred measures of carbonic acid gas, contain 100 of carbon vapour and 100 of oxygen, just half the oxygen employed; the remaining oxygen requires 200 measures of hydrogen to form water.

Hence at 60° F. and 30 inches barom.—

100 cubic inches	of carbon vapour weigh	.	13.0714 grs.
200 "	" hydrogen gas . .	.	4.2734 "
100 "	" light carb. hyd. must weigh		17.3448 "

being in the ratio of 2 to 6.12 and the sp. gr. ought to be 0.5593 which agrees nearly with experiment. T.

Action of chlorine.

745. Chlorine and carburetted hydrogen do not act on each other at common temperatures, when quite dry, even if they are exposed to the direct solar rays. If the gases are moist, and the mixture is kept in a dark place, still no action ensues; but if light be admitted decomposition follows. The nature of the products depends on the proportion of the gases. If 4 measures of chlorine and 1 of carburetted hydrogen are present, carbonic and hydrochloric acid gases will be produced. When three measures of chlorine are present carbonic oxide is formed, one half less water being decomposed. H.

Present in coal mines.

746. The gaseous matter that often issues in large quantity from between beds of coal, and collects in the mines mixed with the atmospheric air, forms an explosive mixture that has been the cause of many fatal accidents; the first unprotected light that approaches sets fire to the whole mixture. The frequent loss of life from the explosion of this *fire damp*, led Davy to the construction of the safety lamp.*

Fire damp.

Davy's experiments.

747. In the course of his experiments Davy found that the explosive power varies with the proportions of carburetted hydrogen and air; thus with three or four times its volume of air there is no explosion, with seven or eight times its bulk of air the explosion is powerful; with fourteen times its volume it is still explosive, but with a larger quantity a taper burns in the mixture only with

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* For a full account of the elaborate experiments, &c. on this subject, the student is referred to Davy's *Essay on Flame*, and the biographies of him by Paris and Dr Davy.

Sect. XV.

an enlarged flame. He also ascertained that the temperature required for explosion was very high; and that flame cannot pass through a narrow tube, or a tissue of wire-gauze.

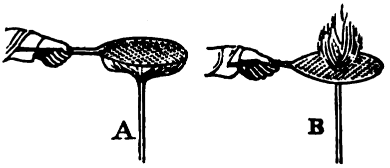
Flame.

748. Flame is gaseous matter heated so intensely as to be luminous. When it comes in contact with the sides of minute apertures, as when wire-gauze is held upon a burning jet of coal gas, or the flame of a spirit lamp, it is deprived of so much heat that its temperature instantly falls below the degree at which gaseous matter is luminous, though the gas itself passes freely through the interstices and is still very hot.

Exp.

This will be seen on bringing a piece of wire-gauze down upon the flame; as at A, (Fig. 173,) the gas will be found to pass through and may be ignited above the gauze as at B.

Fig. 173.



Theory of the safety lamp,

749. If the flame of a common lamp be everywhere properly surrounded with a wire-gauze, and in that state immersed into an explosive gaseous mixture, it will be inadequate to its inflammation, that part only being burned which is *within* the cage, communication to the inflammable air *without* being prevented by the cooling power of the metallic tissue; so that by such a lamp the explosive mixture will be consumed, but not exploded.

Fig. 174.

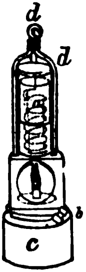
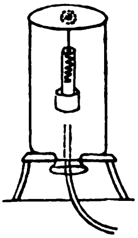


Fig. 175.



Illustrated.

Fig. 174 is a representation of the safety lamp. *a* is a cylinder of wire-gauze, with a double top, securely and carefully fastened, by doubling over to the brass rim *b*, which screws on the lamp *c*. The whole is protected and rendered convenient for carrying, by the frame and ring *d*. If the cylinder be of twilled wire-gauze, the wire should be at least of the thickness of one fortieth of an inch, and of iron or copper, and 30 in the warp, and 16 or 18 in the weft. If of plain wire-gauze, the wire should not be less than one sixtieth of an inch in thickness, and from 28 to 30 both warp and woof.*

The operation of this lamp may be shown on a small scale, by suspending it in an inverted glass jar, and then admitting a sufficient stream of coal gas from a gas-holder by a tube entering below, (Fig. 175,) to render the enclosed atmosphere explosive. The flame of the lamp first enlarges, and is then extinguished, the whole of the cage being filled with a lambent blue light;† on turning off the supply of the gas this appearance gradually ceases, and the wick becomes rekindled, when the atmosphere returns to its natural state.‡

Olefiant Gas.

Form.	*Sp. Gr.*	*Hyd.*		*Carb.*	*Equiv.*	*Eq. Vol.*
2H+2C, or H^2C^2.	0.9808 Air = 1 14.24 Hyd. = 1	2	+	12.24	2 eq. = 14.24	100

Olefiant gas.

750. This gas was discovered in 1796, by some associated Dutch chemists, and was termed by them *olefiant gas*, from its property of

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* To increase the safety of the lamp when exposed to a strong current of an explosive atmosphere, the addition of a glass cylinder and allowing the air to enter only through fine apertures below, has lately been resorted to with success.

† The platinum coil within will continue red-hot. (257).

‡ The explosion may be safely exhibited, previously, by suspending the lamp without the wire-gauze cylinder from a piece of pasteboard covering the jar, and admitting coal or oil gas. W.

forming an oily looking liquid with chlorine. It has been called by Thomson *hydroguret of carbon.*

How obtained.

751. It is usually obtained by the decomposition of alcohol by sulphuric acid.

Process.

For this purpose four parts of the acid and one of alcohol are put into a capacious retort, and heated by a lamp. The acid soon acts upon the alcohol, effervescence ensues and olefiant gas passes over. The retort should not be more than one third full, and the acid and alcohol should be shaken together before the heat is applied.

A little ether is formed at first, the solution becomes dark, sulphurous acid and carbonic oxide are formed, and carbon deposited.*

Properties.

752. This gas is colourless and inodorous. Water absorbs about $\frac{1}{8}$ of its volume. It extinguishes flame, and does not support life. It is inflammable, burning with a bright yellowish white flame. When mingled with oxygen gas, it explodes with great violence. One part by volume requires, for perfect combustion, three of oxygen; and two of carbonic acid are produced. 100 cubic inches weigh 30.4162 by calculation, and its sp. gr. is as stated.†

Decomposed.

Olefiant gas is decomposed by electricity, and by transmission through red-hot tubes.

Action of chlorine.

753. When this gas is mixed with chlorine, in the proportion of 1 to 2 by vol. the mixture, on inflammation, produces hydrochloric acid, and charcoal is abundantly deposited.

Exp.

If the gases be well mixed, and then inflamed in a tall and narrow glass jar, (about two feet high and four inches in diameter), placed with its mouth upwards, the experiment is very striking; a deep flame gradually descends through the mixture, and a dense black cloud of carbon rises into the atmosphere; fumes of hydrochloric acid are at the same time formed, and a peculiar aromatic odour is evolved.

If instead of inflaming the gases, the jar be inverted in a basin of water, or if they be mixed in a clean and dry glass globe exhausted of air, they act slowly upon each other, and a peculiar fluid is formed, which appears like a heavy oil; hence the name, *olefiant gas.* B. 1. 321.

SECTION XVI. *Compounds of Hydrogen and Sulphur.*

Hydrosulphuric Acid—Sulphuretted Hydrogen.

		Composition.					
Form.	*Sp. Gr.*	*Hyd.*		*Sul.*		*Equiv.*	*Eq. Vol.*
HS	1·1782 Air = 1	1	+	16.1	=	17·1	100
	17.10 Hyd. = 1						

Hydrosulphuric acid.

754. This gaseous compound of sulphur and hydrogen was first investigated by Scheele in 1777. It may be obtained by presenting sulphur to nascent hydrogen, which is the case when protosulphuret of iron is acted upon by dilute sulphuric acid.

Processes.

The sulphuret of iron may be prepared by heating a bar of iron to a white or welding heat, and, in this state, rubbing it with a roll of sulphur. The metal and sulphur unite, and form a liquid compound, which falls down in drops.‡ These soon congeal; and the compound must be preserved in a well closed phial. Or a mixture of two parts of iron filings and rather more than one part of sulphur, may be heated to redness in a covered crucible.§ A portion of this may be in

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* The changes are complicated; for the theory, see *Alcohol.*

† Its density by experiment is 0.97. (Thomson.)

‡ They should be received in an iron basin filled with water.

§ The gas which this affords is mixed with a good deal of hydrogen gas.

troduced into a retort or gas bottle and diluted sulphuric acid poured upon it, as in the process for obtaining hydrogen gas (378). It may also be conveniently obtained from bruised sesquisulphuret of antimony (crude antimony of the shops) with five or six times its weight of hydrochloric acid (sp. gr. 1.160 or thereabouts) contained in a retort or gas bottle, and heated by a lamp.

Theories.

755. In the first process the sulphuret and water interchange elements, hydrosulphuric acid and protoxide of iron are generated; the latter unites with sulphuric acid and the former escapes.

In the process with antimony the elements concerned are—

1 eq. sesquisulphuret and 3 eq. hydrochloric acid
$2Sb+3S$ $3(H+Cl)$

which yield

3 eq. hydrosulphuric acid and 1 eq. sesquichloride of antimony
$3(H+S)$ $2Sb+3Cl$

Absorbed by water.

756. The gas may be collected over water, though, by agitation, that fluid absorbs nearly thrice its bulk; it should be received into bottles provided with glass stoppers, and after filling them entirely with the gas, the stopper should be introduced.

Liquefaction of sulphuretted hydrogen.

757. Faraday obtained it in a liquid form by producing it under pressure. It was colourless, limpid, and with a refractive power greater than that of water. The pressure of its vapour was nearly equal to 17 atmospheres at the temperature of 50° F. Its specific gravity appeared to be 0.9.

Properties.

758. When in the form of gas, the smell is extremely offensive, resembling that of putrefying eggs, or of the washings of a gun-barrel, to which indeed it imparts their offensive odour. It exists in some mineral waters.

Unrespirable.

759. It appears to be one of the most unrespirable of all the gases, for a small bird died immediately in air containing $\frac{1}{1500}$ of its volume of hydrosulphuric acid gas; a dog perished in air mingled with $\frac{1}{800}$, and a horse in air containing $\frac{1}{250}$.*

Action on metals.

760. It tarnishes silver, mercury, and other polished metals, and instantly blackens white paint and solution of acetate of lead. By direct experiments, Henry has found that one measure of this gas, mixed with 20.000 measures of hydrogen, or of carburetted hydrogen, or common air, produces a sensible discoloration of white lead, or of oxide of bismuth, mixed with water, and spread upon a piece of card.

Inflammable.

761. It is inflammable, burning with a pale blue flame, but does not support the combustion of other bodies. Water and sulphurous acid are the products of its combustion, and sulphur is deposited.

Composition.

762. Hydrosulphuric acid contains its own vol. of hydrogen gas, and 16.66 of the vapour of sulphur; and since

16.66 cub. inches of the vapour of sulphur weigh	. .	34.4012 grs.
100 " " hydrogen gas "	. .	2.1367
100 " " hydrosulphuric acid gas must weigh	.	36.5379 T.

Salts of.

763. The salts of hydrosulphuric acid are called *hydrosulphates* or *hydrosulphurets*. They are decomposed by sulphuric or hydrochloric acids. This acid rarely unites directly with metallic oxides; but in most cases its hydrogen combines with the oxygen of the oxide, and its sulphur with the metal.

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* Thenard, iii. 601.

Use. 764. Hydrosulphuric acid, both in the state of a gas and of watery solution, precipitates most metallic solutions, and is hence an exceedingly delicate test of the presence of most of the metals.

Solution decomposed. Water impregnated with this gas, when exposed to the atmosphere, becomes covered with a pellicle of sulphur. Sulphur is even deposited when the water is kept in well closed bottles.

Chlorine, iodine and bromine decompose it with separation of sulphur, and an atmosphere charged with the gas may be speedily purified by chlorine.

Persulphuret of Hydrogen.

Composition.

Form.	*Hydr.*			*Sulph.*			*Equiv.*
HS^2	1	1 eq.	+	32.2	2 eq.	=	33.2

765. This compound was discovered by Scheele and described by Berthollet.* When protosulphuret of potassium (or of any metal of the alkalies and alkaline earths) is mixed in solution with sulphuric acid, the oxygen of water unites with potassium and its hydrogen with sulphur.†

Process. 766. Persulphuret of hydrogen is conveniently made by boiling equal parts of recently slaked lime and flowers of sulphur with 5 or 6 parts of water for half an hour, when a deep orange-yellow solution is formed, which contains persulphuret of calcium. Let this liquid be filtered, and gradually added cold to an excess of hydrochloric acid diluted with about twice its weight of water, stirring it briskly. A copious deposit of sulphur falls (the *Sulphur Præcipitatum* of the *Lond. Pharmacop.*) and persulphuret of hydrogen gradually subsides in the form of a yellowish semi-fluid matter like oil.

Theory. 767. The change which ensues in the formation of the yellow solution may be theoretically represented thus :—

2 eq. lime and	6 eq. sulph.	yield	1 eq. hyposulphs. acid and	2 eq. bisulphuret of calcium.
$2(Ca+O)$	$6S$		$2S+2O$	$2(Ca+2S)$.

The hyposulphurous acid exists in solution united with lime, and is decomposed when hydrochloric acid is added, resolving itself into sulphurous acid and sulphur.

Properties. 768. At common temperatures it is a viscid liquid of a yellow colour, with a density of about 1.769, and a consistence varying between that of a volatile and fixed oil. It has the peculiar odour and taste of hydrosulphuric acid, though in a less degree. Its elements are so feebly united, that in the cold it gradually resolves itself into sulphur and hydrosulphuric acid, and suffers the same change instantly by a heat considerably short of 212° F. Decomposition is also produced by the contact of most substances, especially of metals and oxides.

Composition. 769. The composition of persulphuret of hydrogen has been variously stated. According to Dalton it is a bisulphuret. But Thenard found its constituents to vary; whence it is probable that hydrogen is capable of uniting with sulphur in several proportions. It is sometimes regarded as an acid.

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* *Ann. de Chim.* xxv. † See Turner, 254.

Section XVII. *Hydrogen and Selenium.*

Seleniuretted Hydrogen.

Seleniuretted hydrog. 770. These bodies combine to form a gaseous compound termed *seleniuretted hydrogen* or *hydroselenic acid.* It may be obtained by dissolving protoseleniuret of iron in hydrochloric acid.

Properties. 771. It is a colourless gas, highly irritating to the lining membrane of the nose, and for a time destroying the power of smelling. Its solution smells and tastes somewhat like hydrosulphuric acid; it reddens litmus and tinges the skin brown. It is decomposed by the air, nitric acid and chlorine, and selenium is deposited. It occasions precipitates in solutions of neutral metallic salts, which are black or dark brown, with the exception of those from zinc, manganese and cerium, which are flesh-coloured.

Decomposed. 772. Seleniuretted hydrogen is easily decomposed by the action of air and water; it is absorbed by moist substances and communicates to them a red colour. The selenium is thus remarkably deposited throughout the texture of organic bodies. A piece of moist paper is penetrated by the red colour. Moist wood and even a thin piece of caoutchouc became in the same way red throughout. B. 292.

Hydroselenic acid consists of 39.6 or 1 eq. of selenium and 1 of hydrogen; its equiv. is 40.6 and its formula $H+Se$ or HSe.

Section XVIII. *Compounds of Hydrogen and Phosphorus.*

Three compounds. 773. The two compounds of hydrogen and phosphorus which have heretofore been known as phosphuretted and perphosphuretted hydrogen, have been found by Rose to be isomeric, identical in composition, and to differ only by the one being spontaneously inflammable and the other not so. Leverrier* has proved that perphosphuretted hydrogen is a mixture of phosphuretted hydrogen with about $\frac{1}{30}$ of its volume of a spontaneously inflammable compound of 31.4 parts or 2 eq. of phosphorus, and 2 parts or 2 eq. of hydrogen. In the same paper he establishes the existence of a solid compound of 2 eq. of phosphorus and 1 eq. of hydrogen. The latter is deposited on the sides of the glass vessel when moist phosphuretted hydrogen gas, recently prepared, is exposed to strong light. Solid phos. hyd.

Phosphuretted Hydrogen.

Symb.	*Density.*	*Equiv.*	*Eq. Vol.*
$2P+3H$ or P^2H^3	1.1850	34.4	200

Discovery, &c. 774. Phosphuretted hydrogen was discovered by Davy in 1812, by heating hydrated phosphorous acid in a retort; and it is evolved from hydrous hypophosphorous acid by similar treatment. It is also formed, according to Dumas, by the action of strong hydrochloric acid on phosphuret of calcium.

Process. 775. It may also be obtained, in an impure state, by boiling phosphorus with a solution of potassa, or milk of lime. Water is decomposed, the oxygen and hydrogen of which unite with different portions of phosphorus, and phosphoric acid, hypophosphorous acid, and phosphuretted hydrogen are generated.

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* See the papers of Dumas, Buff, Rose, and Graham, in *An. de Ch. et de Phys.* xxxi. 113, xli. 220, and xli. 5, *Phil. Mag.* v. 401.

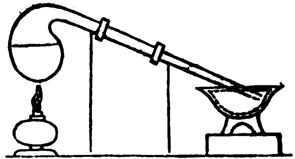
Explodes with air, &c.

776. When the gas is obtained pure from hydrated phosphorous or hypophosphorous acids, it may be mixed with air or oxygen gas at common temperatures without danger; but the mixture detonates with the electric spark or at a temperature of 300°. Even diminished pressure causes an explosion, an effect which in operating with the mercurial trough is produced simply by raising the tube, so that the level of the mercury within may be a few inches higher than at the outside.

Process.

777. In preparing the gas from phosphorus and solution of potassa in a glass retort, the atmospheric air should be removed, otherwise explosion may occur.

Fig. 176.



A retort holding a pint may be employed. About a quarter of an ounce of phosphorus may be placed in the retort and a moderately strong solution of potassa poured upon it until the neck and body of the retort are completely filled. The finger being placed over the beak it is next immersed under the surface of a portion of the same solution, contained in a glass dish or a small pneumatic trough, and the finger is then removed. The retort may be attached to a block of wood or supported securely upon the rings of a retort stand. (Fig. 176.) The superfluous solution may then be removed by passing up hydrogen gas.* The heat of a lamp is carefully applied and soon after the solution boils, the gas is evolved in abundance, and inflames on escaping into the air.

Another.

Forty grains of phosphorus, fifty of caustic potassa, and sixty drops of water, give this gas very readily when gently heated in a small retort, (capable of holding an ounce and a half or two ounces when quite full,) and with very little trouble.

The readiest mode of procuring this gas is by means of phosphuret of calcium;† lumps of which may be dropped into water acidulated with hydrochloric acid. The retort or gas bottle may be placed wholly beneath the water in the pneumatic trough, and the combustion of the bubbles of gas will take place at the surface.

Properties.

778. This gas is colourless, has a nauseous odour like onions, a very bitter taste, and inflames when mixed with air, a property

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* This may be done from a gas bottle having a long and slender leaden pipe attached to it, or by a pipe and flexible tube proceeding from the apparatus (Fig. 120.) It will be found necessary after all the solution has been expelled from the neck to incline the body of the retort so as to allow a part of what remains in the body to flow into it, which is to be expelled as at first.

A very simple method of avoiding all danger, is to moisten the interior of the retort with ether.

Mitchell's method of preparing phosphuret of calcium.

† The following method of obtaining this compound has been described by Mitchell.* I employ two Hessian crucibles, some of the inner members of a nest. The larger of the two has a hole bored through its bottom, and a test tube of a suitable size luted in with clay. The phosphorus is put into the test tube; the top of which is loosely covered with a piece of broken crucible to prevent the pieces of quicklime from running down into it. The lime is then put in so as to fill this crucible and partly fill the upper one, which serves as a cover to it, and is luted on with some fine clay a little moistened. The cover has also a small hole in its top to afford an outlet for the air, &c. The whole is placed upon the grate of a furnace, with the test tube projecting through it below, and a charcoal fire is kindled around it. The phosphorus may be kept cool, if necessary, by making the tube dip into water contained in a tin cup attached to the end of a stick. When the crucibles and contents are thoroughly red-hot, a chafing dish is substituted for the tin cup, and the phosphorus rising in vapour produces the desired change. The phosphuret should be preserved in a *sealed* phial.

* Mitchell in *Amer. Jour.* xvii. 349.

which it loses by being kept over water; water takes up two per cent. of the gas, and acquires a bitter taste and the smell of onions.

Rings. 779. If the beak of the retort (776) is plunged under water, the successive bubbles of gas as they escape, burst into flame and form rings of dense white smoke which enlarge as they ascend, retaining their shape if the air is tranquil. The wreaths are formed of metaphosphoric acid and water.

Combustion in oxygen. 780. When bubbles of phosphuretted hydrogen are let up into a jar of oxygen, they burn with greatly increased splendour.

Exp. They should be received in a large jar, but half filled with oxygen, and care must be taken not to allow them to accumulate in the jar. The safest method is to collect a few bubbles in a small phial and pass them up from that into the large jar, a bubble at a time. Similar experiments may be made with chlorine.

Composition and density. 781. One hundred measures of phosphuretted hydrogen gas contain 150 of hydrogen and 25 of vapour of phosphorus, hence as

150	cub. inches of hydrogen gas weigh	3.2050	grs.
25	" " phosphorus vapour	33.5461	"
100	" " phosphuretted hydrogen gas should weigh	36.7511	"

and its calculated density should be 1.1850, which is nearly a mean of the observations of Dumas and Rose.

Effect of light. 782. According to Leverrier, it is probable that the compound of phosphorus and hydrogen composed of two equiv. of each of its elements, which is spontaneously inflammable, communicates that property to phosphuretted hydrogen gas. This opinion is grounded on the fact that when spontaneously inflammable phosphuretted hydrogen is kept for any length of time in the dark it suffers no change, but in a strong light, solid phosphuretted hydrogen is deposited, and the residual gas is no longer spontaneously inflammable. Thus it appears that by the action of light P^2H^2 is decomposed, and P^2H and P^2H^3 are formed. T. 258.

SECTION XIX. *Compounds of Nitrogen and Carbon.*

Bicarburet of Nitrogen—Cyanogen Gas.

Form.	*Sp. Gr.*		Composition. *Nit.*	Composition. *Car.*	*Equiv.*	
$N+2C$, or NC^2, or Cy.	1.8157	Air = 1	14.15 1 eq.	12.24 2 eq.	26.39	by Wght.
	26.39	Hyd. = 1			100	" Vol.

783. This gaseous compound was discovered by Gay-Lussac, in 1815,* and was called cyanogen from χύανος, *blue*, and γεννάω, *I generate*, because it is an essential ingredient of Prussian blue. Cyanogen.

784. It is obtained by heating dried bicyanuret of mercury in a small glass retort.† This cyanuret, formerly called *prussiate of mercury*, is composed of metallic mercury and cyanogen. On exposure to a low red heat, it is resolved into its elements; the cyanogen passes over in the form of gas, and the metallic mercury is sublimed. The heat applied should be sufficient to expel the cyanogen slowly and steadily, as it is liable to be decomposed by a high temperature. Towards the end of the process, a black substance is procured, aris- Process.

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* *Ann. de Chim.* xcv.

† For the method of preparing this cyanuret, see ~~Mercury~~. Hydrocyanic acid

ing from the decomposition of part of the cyanogen, consisting of the same ingredients as the gas itself. T.

Properties. 785. Cyanogen has a strong, penetrating, and disagreeable smell, resembling that of bitter almonds. It burns with a bluish flame mixed with purple, which can be shown by igniting it at the beak of the retort, which may be drawn out to a fine point before the blow-pipe.

Collected. 786. It must be collected over mercury, as water absorbs 4.5 times its volume of the gas. The aqueous solution reddens litmus paper, an effect, however, not to be ascribed to the gas, but to acids generated by the mutual decomposition of cyanogen and water.

787. Cyanogen contains its own bulk of nitrogen and twice its volume of the vapour of carbon ; and since

100 cubic inches of nitrogen gas weigh . . .	30.1650 grs.
200 " " vapour of carbon " . . .	26.1428 "
100 " " cyanogen gas must weigh . .	56.3078 "

The ratio of its elements by weight is,

Nitrogen	30.1650 . . .	0.9727	14.15 1 eq.
Carbon	26.1428 . . .	0 8430(2+0.4215) . . .	12.24 2 eq.

Sp. gr. The sp. gr. of a gas so constituted is 0.9727+0.843=1.8157, which is near 1.8064 the number found experimentally by Gay-Lussac.

Cyanogen is a *bicarburet of nitrogen ;* but its most convenient name, *cyanogen,* may be expressed by Cy.* T. 259.

Section XX. *Compounds of Sulphur with Carbon, &c.*

Bisulphuret of Carbon.

Composition.

Form.	*Carb.*		*Sul.*		*Equiv.*	*Eq. Vol.*
$C+2S$ or CS_2	6.12	+	32.2	=	38.32	100

Carbon and sulphur, bisulphuret, or alcohol of sulphur. 788. This substance was discovered in 1796 by Lampadius who regarded it as a compound of sulphur and hydrogen, and termed it *alcohol of sulphur.*

How obtained. 789. It may be obtained by heating in close vessels the native bisulphuret of iron (iron pyrites) with one fifth of its weight of well dried charcoal, or by passing the vapour of sulphur over fragments of charcoal heated to redness in a tube of porcelain.†

Properties, 790. The bi-sulphuret of carbon is eminently transparent, and perfectly colourless. Sometimes, immediately after distillation, the

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* *Paracyanogen.* *Symb.* N^4C^8. *Eq.* 105.56? The brown matter left in the retort in the foregoing process (784) is a solid bicarburet of nitrogen, isomeric with cyanogen, but differing from it in its physical and chemical relations. Heated in the open air, several definite compounds of carbon and nitrogen may be obtained.* It is soluble in nitric and sulphuric acids and forms a compound with oxygen in which one eq. of oxygen is combined with four eq. of nitrogen and eight eq. of carbon.

Mellon. *Symb.* N^4C^6. *Eq.* 93.32. It is a lemon yellow coloured powder, insoluble in water and alcohol, but soluble and decomposable by acids and alkalies. By heat it affords one vol. of nitrogen and three of cyanogen. It is one of the compound radicals. T.

Compound of Phosphorus and Nitrogen.

Phosphuret of Nitrogen. *Symb.* $N+2P$, or NP^2. *Eq.* 45.55. When either of the chlorides of phosphorus is saturated with dry ammoniacal gas, a white solid mass is obtained, which on exposure to a strong heat, gives rise to the formation of phosphuret of nitrogen, and hydrochloric acid gas. It is a light snow white powder, insoluble in water. It is composed of 31.4 parts or 2 eq. of phosphorus, and 14.15 or one eq. of nitrogen.

† A porcelain tube an inch or more in diameter is coated with clay and wrapped round

* Brewster's *Jour.* N. S. 1. 75.

oily liquid appears a little opaque and milky; but the next day it is found to have become completely limpid. It has an acrid, pungent, and somewhat aromatic taste; its smell is nauseous and fetid. It is soluble in alcohol and ether; its refractive power in regard to light is very considerable. Its sp. gr. is 1.272; of its vapour 2.668. It boils at 110°, and does not freeze at —60°. It is very volatile, and the cold which it produces during evaporation is so intense, that by exposing a thermometer bulb, covered with fine lint, moistened with it, in the receiver of an air-pump, the temperature sunk, after exhaustion to —80°. When a mercurial thermometer is used, the metal freezes. When a few drops of this liquid are poured on the surface of a glass of water, the temperature of which is 32° F. plumose branches of ice dart to the bottom of the vessel, and the whole water is suddenly frozen. At the same time, the sulphuret becomes volatilized; and the spiculæ of ice beautifully exhibit the colours of the solar spectrum.

A sulphur-acid.

791. Bisulphuret of carbon is a *sulphur-acid*, that is, it unites with sulphur bases to constitute compounds analogous to ordinary salts, and hence called *sulphur-salts*. Thus bisulphuret of carbon unites with sulphuret of potassium, forming a sulphur salt, in which the former acts as an acid and the latter as a base. T.

Sulphuret of Phosphorus.

Process.

792. Sulphur and fused phosphorus unite frequently with violence. The experiment should not be made with more than 30 or 40 grs. of phosphorus. The phosphorus is placed in a glass tube 5 or 6 inches long, and about half an inch wide, when by a gentle heat it is liquefied, the sulphur is added in successive small portions. The compound is highly combustible.*

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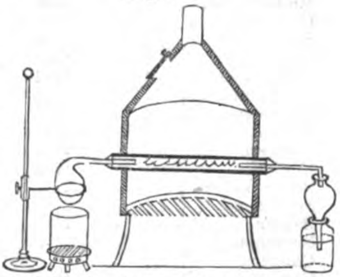
with iron wire. It is then filled with fragments of charcoal, taking care to leave room for the passage of vapour, and made to traverse a furnace as represented in Fig. 177. A retort filled about a third full of sulphur is then fitted to one end of the tube, supporting it by a retort stand, and using a mixture of clay and sand to make the joining air-tight. A bent glass tube about half an inch or rather less in diameter is attached in the same manner to the other extremity of the porcelain tube, and connected with a glass globe terminating in a small tube placed in a receiver half full of water, which must be kept cold.

Fig. 177.



When everything has been properly adjusted, fire is put into the furnace, and the tube with the charcoal brought gradually to a strong red heat. The sulphur in the retort is then made to pass over it in vapour, and as they combine, the bisulphuret which is formed condenses in drops that fall to the bottom of the water in the receiver. The use of the globe is to prevent any water passing back to the porcelain tube. The charcoal should be well prepared, and not mixed with any unchanged woody fibre. Reid.

* *Bisulphuret of Selenium* is of an orange colour, and fuses at a heat a little above 212°. Selenium also combines with phosphorus and forms a seleniuret which is very fusible.

Sulphuret of Nitrogen is formed by the reaction of chloride of sulphur on a solution of ammonia, and contains from 92 to 93 per cent. of sulphur, and 7 to 8 of nitrogen.

Seleniuret of Phosphorus may be made in the same manner as sulphuret of phosphorus. It is very fusible and decomposes water when digested in it.

Sulphuret of Nitrogen is formed by the reaction of chloride of sulphur on a solu-

CHAPTER IV.

METALS.

SECTION I. *General Properties, and Combinations.*

Number.

793. Many of the metals have been long known, while some have been recently discovered. There are fortytwo bodies of this class; they are incapable of being resolved into more simple parts, and are therefore regarded as elementary. Most of them are remarkable for their specific gravity; they are conductors of electricity and heat, they are positive electrics, opaque, possess a peculiar lustre, and are in general good reflectors of light.

794. The following table contains their names, date of discovery, specific gravity at 60° F., and symbols.

Names of Metals.	Dates of the Discovery.	Specific Gravity.	Symb.
Gold, *m.*		19.257	Au.
Silver, *m.*		10.474	Ag.
Iron, *m.*		7.788	Fe.
Copper, *m.*		8.895	Cu.
Mercury,		13.568	Hg.
Lead, *m.*		11.352	Pb.
Tin, *m.*		7.291	Sn.
Antimony,	1490	6.702	Sb.
Bismuth,	1530	9.822	Bi.
Zinc, *m.*	16th century.	6.861 to 7.1	Zn.
Arsenic,	1733	5.8843	As.
Cobalt,		7.834	Co.
Platinum, *m.*	1741	20.98	Pt.
Nickel, *m.*	1751	8.279	Ni.
Manganese,	1774	8.013	Mn.
Tungsten,	1781	17.6	W.
Tellurium,	1782	6.115	Te.
Molybdenum,	1782	8.615 to 8.636	Mo.
Uranium,	1789	9.000	U.
Titanium,	1791	5.3	Ti.
Chromium,	1797	5+	Cr.
Columbium,	1802		Ta.
Palladium, *m.*	1803	11.3 to 11.8	Pd.
Rhodium,			R.
Iridium,	1803	18.68	Ir.
Osmium,	1803		Os.
Cerium,	1804		Ce.
Potassium, *m.*		0.865	K.
Sodium, *m.*		0.972	Na.
Barium,	1807		Ba.
Strontium,			Sr.
Calcium,			Ca.
Cadmium, *m.*	1818	8.604	Cd.
Lithium,	1818		L.
Zirconium,	1824		Zr.
Aluminium,	1828		Al.
Glucinium,			G.
Yttrium,			Y.
Thorium,	1829		Th.
Magnesium	1829		Mg.
Vanadium	1830		V.
Latanium,	1839		

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tion of ammonia. It is a colourless powder. Its alcoholic solution gives with potassa a fine purple colour which is fugitive. It contains from 92 to 93 per cent. of sulphur, and 7 or 8 of nitrogen. T.

Sect. I.

795. Malleability and ductility are important properties of metals.* Those metals which are remarkable for ductility are gold, silver, platinum, iron, and copper.

Tenacity.

796. The metals also differ in tenacity, in which property iron surpasses all others. Their hardness also varies, some as titanium, iron, &c., are very hard; others, as lead, are soft, and a few, as potassium, yield to the pressure of the fingers.

Elasticity.

797. Some of the malleable and ductile metals have, also, a high degree of *elasticity*. This property fits them for being applied to the mechanical purpose of springs. Steel and iron are in this respect, superior to all other metals. Upon the properties of elasticity and hardness, appears also to depend that of *fitness for exciting sound.*

Structure.

798. Many of the metals have a distinct crystalline structure, and not only occur in nature in distinct crystals, but can be obtained in that state by careful fusion and cooling.

Crystallization.

Thus bismuth, melted in a crucible, and suffered to cool, becomes covered with a crust, and when this is pierced, and the fluid beneath allowed to flow out, the cavity is found studded with beautifully regular cubic crystals.

Fusibility of Metals.

799. Metals, with the exception of mercury, are solid at common temperatures; but they may all be liquefied by heat. The degree at which they *fuse*, or their *point* of *fusion*, is very different for different metals, as appears from the following table.

Table of the Fusibility of different Metals.

		Fahr.		
Fusible below a red heat	Mercury . . .	—39°	Different chemists.	
	Potassium . . .	136	Gay-Lussac and Thenard.	
	Sodium . . .	190		
	Cadmium . . about	442	Stromeyer.	
	Tin, ...	442	Crichton.	
	Bismuth . . .	497		
	Lead	612		
	Tellurium — rather less fusible than lead.		Klaproth.	
	Arsenic—undetermined.			
	Zinc	773	Daniell.	
	Antimony a little below a red heat.			
Infusible below a red heat.	Silver . . .	1873	Daniell.	
	Copper . . .	1996		
	Gold	2016		
	Iron, cast . . .	2786		
	Iron, malleable . .		Requiring the highest heat of a smith's forge.	
	Manganese . .			
	Cobalt—rather less fusible than iron.			
	Nickel—nearly the same as cobalt.			
	Palladium			
	Molybdenum		Almost infusible, and not to be procured in buttons by the heat of a smith's forge.	Fusible before the oxy-hydrogen blow-pipe.
	Uranium			
	Tungsten			
	Chromium			
	Titanium		Infusible in the heat of a smith's forge, but fusible before the oxy-hydrogen blow-pipe.	
	Cerium			
	Osmium			
	Iridium			
	Rhodium			
	Platinum			
	Columbium			

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* The malleable metals are designated in the table by the letter *m.*, to which may be added frozen mercury.

Chap. IV.

Volatile. 800. Some metals are volatilized by heat, others may be exposed to the intense heat of a wind furnace without being raised in vapour.

Action of metals upon each other. The metals may for the most part be combined with each other, forming a very important class of compounds, the *metallic alloys.*

Alloys. The word ALLOY is a general term for all combinations of metals with each other; and the specific name is derived from that of the metal, which prevails in the compound. Thus in the *alloy of gold with silver*, the gold is to be understood as being in greatest proportion; in the *alloy of silver with gold*, the silver is the principal ingredient.*

Amalgams. The compounds of mercury with other metals, at a very early period of chemistry, were called AMALGAMS, and the term is still retained.

801. When metals are alloyed their properties are more or less affected.

Characters of alloys. 1. We observe a change in the ductility, malleability, hardness, and colour. Malleability and ductility, are usually impaired, and often in a remarkable degree.

2. The specific gravity of an alloy is rarely the mean of its component parts; in some cases an increase, in others a diminution of density having taken place.

3. The fusibility of an alloy is generally greater than that of its components.

4. Alloys are generally more oxidizable than their constituents, taken singly.

Union with other bodies. 802. The metals, although they readily unite with the elementary substances, are little disposed to combine in the metallic state, with compound bodies, such as an oxide or an acid. Their union with the simple non-metallic substances, such as oxygen, chlorine, and sulphur, gives rise to new bodies in which the metallic character is wholly wanting. In all these combinations the tendency to unite in definite proportions is conspicuous; the chemical changes are regulated by the same general laws already described, and the same nomenclature is applicable.

Combustible. 803. Metals are of a combustible nature; that is, they are not only susceptible of slow oxidation, but, under favorable circumstances, they unite rapidly with oxygen, giving rise to all the phenomena of real combustion. Zinc burns with a brilliant flame when heated to full redness in the open air; iron emits vivid scintillations on being inflamed in an atmosphere of oxygen gas; and the least oxidable metals, such as gold and platinum, scintillate in a similar manner when heated by the oxy-hydrogen blow-pipe.

Product. 804. The product either of the slow or rapid oxidation of a metal, when heated in the air, has an earthy aspect, and was called a

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* Various processes are adopted in the formation of alloys depending upon the nature of the metals. Many are prepared by simply fusing the two metals in a covered crucible; but if there be a considerable difference in the specific gravity of the metals, the heavier will often subside, and the lower part of the bar or ingot, will differ in composition from the upper; this may be prevented by agitating the alloy till it solidifies.

When one of the metals is very volatile, it should generally be added to the other after its fusion; and if both metals be volatile, they may be sometimes united by distilling them together.

calx by the older chemists, the process of forming it being expressed by the term *calcination*. Another method of oxidizing metals is by *deflagration;* that is, by mixing them with nitrate or chlorate of potassa, and projecting the mixture into a red-hot crucible. Most metals may be oxidized by digestion in nitric acid; and nitro-hydrochloric acid is an oxidizing agent of still greater power.

805. Some metals unite with oxygen in one proportion only, but most of them have two or three degrees of oxidation. Metals differ remarkably in their relative forces of attraction for oxygen. Potassium and sodium, for example, are oxidized by mere exposure to the air; and they decompose water at all temperatures, the instant they come in contact with it. Iron and copper may be preserved in dry air without change, nor can they decompose water at common temperatures; but they are both slowly oxidized by exposure to a moist atmosphere, and combine rapidly with oxygen when heated to redness in the open air. Iron has a stronger affinity for oxygen than copper; for the former decomposes water at a red heat, whereas the latter cannot produce that effect. Mercury is less inclined than copper to unite with oxygen. Thus it may be exposed without change to the influence of a moist atmosphere. At a temperature of 650° or 700° it is oxidized; but at a red heat it is reduced to the metallic state, while oxide of copper can sustain the strongest heat of a blast furnace without losing its oxygen. The affinity of gold for oxygen is still weaker than that of mercury; for it will bear the most intense heat of our furnaces without oxidation. Union with oxygen.

806. Metallic oxides may be *reduced* to the metallic state by heat alone, by the united agency of heat and combustible matter, as in metallurgy when metals are extracted from their ores with the aid of charcoal, &c., by galvanism, and by the action of deoxidizing agents on metallic solutions, as when one metal is precipitated by another. Reduction of oxides.

To a solution of the nitrate of oxide of silver, add a small quantity of mercury, the silver will be thrown down in a metallic form, and oxide of mercury be dissolved in the nitric acid and water. Exp.

From this solution the mercury may be separated by placing in it a polished rod of copper, and a solution of nitrate of oxide of copper will be obtained, from which the copper may be precipitated by a rod of iron. Exp.

807. Metals, like the simple non-metallic bodies, may give rise to oxides or acids by combining with oxygen. The former are the most frequent products. The acids contain a larger quantity of oxygen than the oxides of the same metal. Acids from metals.

808. Many of the metallic oxides have the property of combining with acids. In some instances all the oxides of a metal are capable of forming salts with acids, as is exemplified by the oxides of iron; but, generally, the protoxide is the sole *alkaline* or *salifiable base*. Most of the metallic oxides are insoluble in water. Oxides sometimes unite with each other and form definite compounds. Oxides and acids.

809. The metals combine with chlorine, and the compounds are termed *chlorides*. In some instances the application of heat is required: the combination is in some cases slow and in others rapid, attended with the evolution of light. The attraction of chlorine for the metals is superior to that of oxygen; hence when chlorine is brought into contact with their oxides, the oxygen is liberated and a chloride of the metal is obtained, the elements of which Action of chlorine.

are so strongly united, that in some cases they are not separated by intense heat.

Characters of chlorides,

810. The metallic chlorides are mostly solid at common temperatures, fusible, and susceptible of crystallization; several of them are volatile; most of them are soluble. They are of nearly all colours.

Decomposition of,

811. The chlorides of the common metals are decomposed at a red heat by hydrogen gas, hydrochloric acid being disengaged and the metal set free. When in solution they may be recognised by yielding with nitrate of oxide of silver a white precipitate, which is chloride of silver. Several of them decompose water, giving rise to the formation of hydrochloric acid and an oxide (617), or in some cases to a hydrochlorate.*

Procured.

812. Metallic chlorides are frequently procured by dissolving metallic oxides in hydrochloric acid, evaporating to dryness, and applying heat so long as any water is expelled.

813. The same metal often forms more than one compound with chlorine, and these compounds are designated as the oxides.

Action of iodine,

814. Iodine has a strong attraction for metals; and most of the compounds which it forms with them sustain a red heat in close vessels without decomposition. But in the degree of its affinity for metallic substances it is inferior to chlorine and oxygen. The metallic iodides are generated under circumstances analogous to those mentioned for procuring the chlorides.

The action of iodine on metallic oxides, when dissolved or suspended in water, is precisely analogous to that of chlorine. On adding iodine to a solution of the pure alkalies or alkaline earths, an iodide and iodate are generated.

Of bromine,

815. Bromine, in its affinity for metallic substances, is intermediate between chlorine and iodine; for while chlorine disengages bromine from its combination with metals, metallic iodides are decomposed by bromine. The same phenomena attend the union of bromine with metals, as accompany the formation of metallic chlorides.

Of fluorine,

The nature of the action of *fluorine* upon the metals is imperfectly known; it exerts an extremely powerful affinity for them, which is the great obstacle to obtaining it in an insulated form.

Of sulphur.

816. Sulphur has a strong tendency to unite with metals. The metallic *sulphurets* are in some cases formed by heating the metal with sulphur; in others, by decomposing the sulphates; and in others, by the action of hydrosulphuric acid. The sulphurets are in general brittle; some have a metallic lustre; others are without lustre. Some are soluble, others insoluble in water.

Action of heat on sulphurets.

817. Most of the protosulphurets support an intense heat without decomposition; but, in general, those which contain more than one equivalent of sulphur, lose part of it when strongly heated. They are all decomposed without exception by exposure to the combined agency of air or oxygen gas and heat; and the products depend entirely on the degree of heat and the nature of the metal. The action

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* A difference of opinion exists among chemists as to the action of the chlorides upon water, some supposing them to become hydrochlorates when dissolved, others maintain that *some* metallic chlorides dissolve as such. The latter opinion has been adopted by Turner from considerations for which see his *Elements*, 272. See also Brande, I. 370.

of heat and air in decomposing metallic sulphurets is the basis of several metallurgic processes. The metallic bases of the alkalies and alkaline earths agree with the common metals in their disposition to unite with sulphur.

Decomposition of sulphates, &c.

818. If a sulphate be decomposed by hydrogen or charcoal, or sulphur ignited with an alkali or alkaline earth, a metallic sulphuret is always the product. Direct combination between sulphur and a metallic oxide is a very rare occurrence, nor has the existence of such a compound been clearly established.*

Seleniurets.

819. The metallic *seleniurets* have a resemblance in their chemical relations to the sulphurets. They may be prepared either by bringing selenium in contact with the metals at a high temperature, or by the action of hydroselenic acid on metallic solutions.†

Action of phosphorus,

820. Phosphorus combines with the greater number of the metals, forming a series of *metallic phosphurets*. There are three methods of forming them; either by heating a mixture of phosphorus and the metal, or projecting phosphorus upon the metal previously heated to redness; or by heating a mixture of the metal or its oxide, with phosphoric acid and charcoal, or by passing phosphuretted hydrogen over the heated metallic oxide. These phosphurets have a metallic lustre; if they contain a difficultly fusible metal they are more fusible than the metal they contain; if an easily fusible metal, less so.‡

On metallic solutions,

821. When phosphorus is introduced into the solutions of those metals which have but a feeble attraction for oxygen, it reduces them to the metallic state. Thus gold, silver, and platinum are thrown down by immersing a stick of phosphorus into their respective solutions.

Action of carbon,

822. Carbon unites to very few of the metals, and of the metallic carburets, one only is of importance, namely, carburet of iron, or *steel.*

Of hydrogen.

823. Hydrogen forms compounds with but a few of the metals, which are termed hydrogurets or hydrurets.

Action of metals on each other.

Alloys,

824. The metals may, for the most part, be combined with each other, forming a very important class of compounds, the *metallic alloys*. Various processes are adopted in the formation of alloys depending upon the nature of the metals. Many are prepared by simply fusing the two metals in a covered crucible; but if there be a considerable difference in their specific gravity, the heavier will subside, and the lower part of the bar or ingot will differ in composition from the upper; this may be to a great extent prevented by agitating the alloy till it solidifies.

Of volatile metals,

825. Where one of the metals is very volatile, it should be added to the other after its fusion; and if both metals be volatile, they may be sometimes united by distilling them together.

Union in definite proportions.

826. Metals appear to unite with one another in every proportion, thus there is no limit to the number of alloys of gold and copper. It is certain, however, that metals have a tendency to combine in defi-

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* See Turner, p. 270.

† For the different opinions in regard to these compounds see *Ibid*, p. 272.

‡ Phosphorus is said to unite with metallic oxides, as when phosphuret of lime is said to be formed by passing the vapour of phosphorus over lime at a low red heat; but it is probable that part of the metallic oxide is decomposed, and that phosphuret of calcium and phosphate of lime are formed. T.

nite proportions; for several atomic compounds of this kind occur native.*

Characters of alloys.

827. When metals are alloyed they undergo great change of properties, their malleability and ductility are usually impaired, and the colours changed. The hardness is in general increased, and the elasticity and sonorousness frequently improved. The specific gravity of an alloy is rarely the mean of its component parts, sometimes greater and sometimes less.† The fusibility of an alloy is generally greater than that of its components. Thus platinum, when alloyed with arsenic is very fusible, and an alloy of 8 parts of bismuth, 5 of lead, and 3 of tin liquefies at 212°.

Oxidation of alloys,

828. Alloys are generally more oxidizable than their constituents, taken singly; a property which is, perhaps, partly referable to the formation of an electrical combination. Thus the oxidability of zinc is increased by the presence of small quantities of iron.

Action of acids.

829. The action of acids upon alloys may generally be anticipated by a knowledge of their effects upon the constituent metals; but if a soluble metal be alloyed with an insoluble one, the former is often protected by the latter from the action of the acid. Thus, silver, alloyed with a large quantity of gold, resists the action of nitric acid in consequence of the insolubility of the latter metal in that acid; and in order to render it soluble, it should form about one fourth part of the alloy. B. i. 382.

830. To those alloys of which mercury is a constituent the term *amalgam* is applied.

Classification of metals.

831. The metals may be divided into two classes, viz: 1, those which by oxidation yield alkalies or earths, and, 2, those the oxides of which are neither alkalies nor earths. These classes may be subdivided as follows:

1st order,

1st. Metals that decompose cold water at the moment of contact, combining with its oxygen and liberating hydrogen. The resulting oxides are caustic, soluble in water, and possess alkaline properties. They are called *alkalies*, and their metallic bases *alkaline* or *alkaligenous metals*. They are, Potassium, Sodium, Lithium.

2d,

2d. Metallic bases of the *alkaline earths*. These, with the exception of magnesium, decompose water at common temperatures. They are, Barium, Strontium, Calcium, Magnesium.

3d.

3d. Metallic bases of the pure earths. Aluminium, Yttrium, Zirconium, Glucinium, Thorium.

The second class includes the greater number of the metals. They unite with oxygen, generally in more than one proportion. Their protoxides have an earthy appearance, but with few exceptions are coloured, and are insoluble in water. Most of them act as salifiable bases in uniting with acids, and forming salts; but in this respect they are much inferior to the alkalies and alkaline earths, by which they may be separated from their combinations. Several of these metals are capable of forming with oxygen, compounds, which possess the characters of acids. They may be arranged as follows:

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* This view is supported by late experiments of Rudberg, *Ann. de Ch. et de Phys.* xlviii. 363. T. 398.

† For a table exhibiting this see Thenard *Traité de Chim.* 1. 394.

Subdivision.

1. Metals which decompose water at a red heat. They are seven in number; namely,

Manganese,
Iron,
Zinc.
Cadmium,
Tin,
Cobalt,
Nickel,

2. Metals which do not decompose water at any temperature, and the oxides of which are not reduced to the metallic state by the sole action of heat. Of these there are fourteen in number; namely,

Arsenic,
Chromium,
Vanadium,
Molybdenum,
Tungsten,
Columbium,
Antimony,
Uranium,
Cerium,
Bismuth,
Titanium,
Tellurium,
Copper,
Lead.

3. Metals, the oxides of which are reduced to the metallic state by a red heat. These are

Mercury,
Silver,
Gold,
Platinum,
Palladium,
Rhodium,
Osmium,
Iridium.

T.

Section II. *Metallic Bases of the Alkalies.*

Potassium.

832. *Potassium*, K. eq. 39.15, was discovered in 1807 by Davy.[*] He obtained it by submitting caustic potassa, or potash, to the action of Voltaic electricity: the metal was slowly evolved at the negative pole.

Its existence how inferred.

From the facts which have become known respecting the powers of electrical decomposition, it appeared to be a natural inference, that the same powers applied in a state of the highest intensity, might disunite the elements of some bodies, which had resisted all other instruments of analysis.

Davy's experiments.

833. In his first experiments, Davy failed to effect the decomposition of potassa, owing to his employing the alkali in a state of aqueous solution, and to the consequent expenditure of the electrical energy in the mere decomposition of water.

Method of obtaining potassium by electricity.

834. The chief difficulty in subjecting potassa to electrical action is, that, in a perfectly dry state, it is a complete non-conductor of electricity. When rendered, however, in the least degree moist by breathing on it, it readily undergoes fusion and decomposition, by the application of strong electrical powers.

For this purpose, a piece of potassa, weighing from 60 to 70 grains, may be placed on a small insulated plate of platinum, and may be connected, in the way already described, with the opposite end of a battery, containing not less than 100 pairs of six inch plates. On establishing the connexion, the potassa will fuse at both places, where it is in contact with the platinum. A violent effervescence will be seen at the upper surface, arising from the escape of oxygen gas. At the lower or negative surface, no gas will be liberated; but small bubbles will appear, having a high metallic lustre, and being precisely similar in visible characters to quicksilver.

Some of these globules burn with an explosion and bright flame; while others are merely tarnished, and are protected from further change by a white film, which forms on their surface.

Produced in vacuo.

This production of metallic globules is entirely independent of the

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[*] *Phil. Trans.* 1808.

action of the atmosphere; for Davy found, that they may be produced *in vacuo.*

How preserved.

835. To preserve this new substance, it is necessary to immerse it immediately in a fluid which does not afford oxygen. If exposed to the atmosphere it is rapidly converted back again into the state of pure potassa.

836. Nothing could be more satisfactory than the evidence furnished by Davy's experiments, of the nature of one of the fixed alkalies. We have the evidence, both of analysis and synthesis, that potassa is a compound of oxygen with a peculiar inflammable basis.

Reasons for considering it a metal,

837. In assigning to this newly discovered substance a fit place among the objects of chemistry, Davy was induced to class it among the metals, because it agrees with them in opacity, lustre, malleability, conducting powers as to heat and electricity, and in its qualities of chemical combination.

838. In giving names to the alkaline bases, that termination was adopted which, by common consent, has been applied to other newly discovered metals. The base of potassa was called POTASSIUM, and the base of soda SODIUM; and these names have met with universal acceptation.

Other processes for obtaining potassium.

839. It is not, however, by electrical means only that the decomposition of potassa has been accomplished. Soon after Davy's discoveries were known at Paris, Gay-Lussac and Thenard succeeded in their attempts to decompose both the fixed alkalies, without the aid of a Voltaic apparatus, merely by the intervention of chemical affinities. Their process, though it affords the alkaline bases of less purity, yields them in much larger quantity, than the electrical analysis. It consists in bringing the alkalies into contact with intensely heated iron, which, at this temperature, attracts oxygen more strongly than the alkaline base retains it.

Curaudau's.

Potassium may also be prepared, as first noticed by Curaudau, by mixing dry carbonate of potassa with half its weight of powdered charcoal, and exposing the mixture, contained in a gun-barrel or spheroidal iron bottle, to a strong heat. An improvement on both processes has been made by Brunner, who decomposes potassa by means of iron and charcoal. From eight ounces of fused carbonate of potassa, six ounces of iron filings, and two ounces of charcoal mixed intimately and heated in an iron bottle, he obtained 140 grains of potassium.[*]

Wöhler's.

A modification of this process has been described by Wöhler, who effects the decomposition of the potassa solely by means of charcoal. The material employed for the purpose is carbonate of potassa, prepared by heating cream of tartar to redness in a covered crucible.[†]

Properties.

840. Potassium is a white metal of great lustre. It exists in small globules, which possess the opacity, and general appearance of mercury; so that when a globule of mercury is placed near one of potassium the eye can discover no difference between them. It in-

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[*] *Quart. Jour.* xv. 379. See also Henry's *Chem.* vol. i. Hare in *Amer. Jour.* xxiv. 312, and Gale's method *ibid*, xxi. 60. Very full practical directions are given in Reid's *Ele. of Prac. Chem.* p. 221.

[†] Poggendorff's *Annalen*, iv. 23, and Brande's *Jour.* xxii.

stantly tarnishes by exposure to air. It is ductile, and of the consistency of soft wax.

Its specific gravity is 0.865. At 150° it enters into perfect fusion; and at a bright red heat rises in vapour. At 32° it is a hard and brittle solid. If heated in air it burns with a brilliant white flame. It is an excellent conductor of electricity and of heat.

Prominent character. 841. Its most prominent chemical property is its great affinity for oxygen. It oxidizes rapidly in the air, or by contact with fluids which contain oxygen. On this account it must be preserved either in glass tubes hermetically sealed, or under the surface of liquids, of which oxygen is not an element, such as naptha, or what is better the essential oil of copaiva.

Decomposes water. 842. If heated in the open air, it takes fire and burns with a purple flame and great evolution of heat. It decomposes water on the instant of touching it, and so much heat is disengaged, that the potassium is inflamed, and burns vividly while swimming upon its surface. The hydrogen unites with a little potassium at the moment of separation; and this compound takes fire as it escapes, and thus augments the brilliancy of the combustion. When potassium is plunged under water, violent reaction ensues, but without light, and pure hydrogen gas is evolved.

Exp. Take a small piece of potassium, remove the naptha adhering to it by blotting paper, and drop it into water; after the combustion, add to the water infusion of purple cabbage, which will become green.

Exp. Place another piece upon a lump of ice, the same action takes place.

Exp. Gunpowder may be ignited by placing upon it a piece of potassium and touching the metal with a drop of water on a rod, or with ice.

Exp. Introduce a piece of the metal, wrapped up in paper, quickly into a test tube inverted in and full of water. It will rise to the top, and when the water reaches it through the paper, it will be decomposed and hydrogen be found in the upper part of the tube, which may be inflamed in the usual way.

Exp. A small piece may be dropped into a little sulphuric acid, contained in a jar 3 or 4 inches in diameter and about 10 or 12 inches deep: potassa is formed and heat and light are at the same time evolved. Care must be taken that none of the acid is thrown into the eyes.

Exp. Put 4 grains of iodine into a test tube about 4 or 5 inches long, throw a grain of potassium upon it, and hold the sealed end of the tube for a second or two in the flame of a spirit lamp. The iodine and potassium will rapidly combine with a brilliant light. The hand should be protected with a glove as the tube is usually broken.

Exp. A similar experiment may be made with half a grain of sulphur and a grain of potassium.

Equivalent. 843. The combining weight or equivalent of potassium is easily deduced from the composition of potassa and chloride of potassium, which are admitted to consist of single equivalents of their elements. Berzelius analyzed chloride of potassium by means of nitrate of oxide of silver, and inferred that 39.15 is the equivalent of potassium.

Compounds of Potassium.

Protoxide or potassa. 844. *Protoxide of Potassium—Potash,* or *Potassa,* $K+O$, $\dot{K}$ or KO, 39.15 1 eq. potas. + 8 1 eq. oxy. = 47.15 equiv., is formed when potassium is put into water, or exposed to dry air or oxygen gas; formed in the latter way it is anhydrous. It is a white caustic solid, fusing at a temperature above redness, and not decomposed by the heat of a wind furnace. It has a great affinity for water.

Protohydrate, &c.

845. There are three compounds, containing each 1 eq. of potassa with 1.3 and 5 eq. of water respectively. The *Protohydrate* is *caustic potash, potassa fusa* of the London pharmacopœia. It was formerly called *lapis causticus.* It is solid at common temperatures, is highly deliquescent, and requires about half its weight of water for solution. It is soluble in alcohol. Its sp. gr. is 1.706. In surgery it is used as a caustic, and is prepared by evaporating the aqueous solution and casting it in moulds. In this state it is impure. It is purified by solution in alcohol, and evaporation to the consistence of oil in a vessel of pure silver, which should be done expeditiously to avoid the absorption of carbonic acid.*

Use.

Purified.

Pure potassa.

846. *Potassa* thus purified is white, very acrid and corrosive, and at a bright red heat evaporates in the form of white acrid smoke. It quickly absorbs moisture and carbonic acid from the air. It is highly alkaline, and being exclusively procured from vegetables was formerly called *vegetable alkali.* When touched with moist fingers it has a soapy feel, in consequence of its action upon the cuticle. In the fused state it produces heat when dissolved in water; but in its crystallized state it excites considerable cold, especially when mixed with snow. At a natural temperature of 30°, Lowitz found that equal weights of crystallized potassa and snow depressed the thermometer to 45°.

Characters.

Potassa how distinguished.

847. Potassa may be distinguished from all other substances by the following characters. If tartaric acid be added in excess to a salt of potassa dissolved in water, and the solution be stirred with a glass rod, a white precipitate, the bitartrate of potassa, soon appears, which forms peculiar white streaks upon the glass by the pressure of the rod in stirring. A solution of chloride of platinum causes a yellow precipitate, the double chloride of platinum and potassium. Alcoholic solution of carbazotic acid throws down potassa in yellowish crystals of carbazotate of potassa, which is very sparingly soluble.

Preparation of pure potassa.

* To prepare pure potash, carbonate of potash may be dissolved by rubbing it with four times its weight of water in an earthen mortar; the solution is then decanted, and mixed with a quantity of newly slaked lime equal in weight to the carbonate employed, boiling it for a few minutes, and then filtering. To avoid absorption of carbonic acid from the air, the best method is to use a funnel, with a narrow mouth, which may easily be closed by a cork or stopper, and putting a small tube through the throat of the funnel, placing pieces of quartz or broken glass round it, and covering it with linen, so that while the solution of potassa is dropping into the bottle below, air passes through the tube at the same time from the lower to the upper vessel and supplies its place. This method, proposed by Duncan is an excellent substitute for a more complicated apparatus. When a common funnel is employed, it should be covered with a plate or tin tray, and a towel thrown over the whole. (Reid.) For an apparatus devised by Donovan for this purpose, see Turner's *Elements*, p. 279. As part of the solution of potassa adheres to the lime, a small quantity of water is to be poured on the top of what remains in the funnel after it has ceased to drop; the water presses upon the liquid it still contains, and causes it to pass slowly into the receiver below. This is continued till a quantity of liquid is obtained equal to 5 or 6 times the weight of the salt employed. It must be kept in glass bottles with good stoppers.

If the liquid contains little carbonic acid, it will give a very slight precipitate with lime water, and scarcely any effervescence will be seen with sulphuric acid. The potash may be separated from the water by adding to the solution an equal quantity of alcohol, in a large well stopped bottle, and shaking them together. After repose the alcohol floats above, holding the potash in solution and is to be poured off. From the alcoholic solution the potash is obtained by rapid evaporation in a retort when it is desirable to save the alcohol, or in an evaporating dish when not so. Or the fused potash may be dissolved at once in alcohol and the solution, after standing, be decanted, evaporated, and fused as before.

Test of.

This is the most delicate test in a solution of pure potassa; but when the alkali is combined with a strong acid, the chloride of platinum is preferable.[*]

848. *Chloride of Potassium*, $K+Cl$ or KCl, 39.15 1 eq. potas. + 35.42 1 eq. chlor. = 74.57 equiv., is formed when potassium burns in chlorine gas, and when it is heated in hydrochloric acid gas. It is also the residuum after the decomposition of chlorate of potassa by heat. It is formed when potassa is dissolved in a solution of hydrochloric acid. It was formerly called *salt of Sylvius* and *regenerated sea salt*. It crystallizes in cubes, and has a saline and bitter taste.

849. *Iodide of Potassium*, $K+I$ or KI, 39.15 1 eq. potas. + 126.3 1 eq. iod. = 165.45 equiv., is formed when potassium is heated in contact with iodine.

Process.

It may be prepared by adding iodine to a hot solution of pure potassa until the alkali is neutralized, evaporating to dryness and exposing the dry mass in a platinum crucible to a gentle red heat. The fused mass is dissolved out by water and crystallized.

Properties.

850. It fuses and rises in vapour at a heat below redness, is soluble in two thirds its weight of water at 60°. Its solution in alcohol yields colourless cubic crystals.

It should be purchased in crystals, which ought not to deliquesce in a moderately dry air, and in powder should be completely soluble in the strongest alcohol.[†]

Hydrogen and potassium.

S51. *Hydrogen and Potassium* unite in two proportions, forming in one case a solid and in the other a gaseous compound. The latter is produced when hydrate of potassa is decomposed by iron at a white heat. It inflames spontaneously in air or oxygen gas.

The solid hydruret of potassium was made by Gay-Lussac and Thenard, by heating potassium in hydrogen gas. It does not inflame spontaneously in oxygen gas.[‡]

Sulphurets,

852. *Sulphurets of Potassium.*—Potassium unites readily with sulphur by the aid of gentle heat, emitting so much heat that the mass becomes incandescent. The nature of the product depends

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[*] Turner.

[†] *Teroxide of Potassium*, $K+3O$, $\dddot{K}$ or KO^3 39.15 1 eq. potas. + 24 3 eq. oxy. = 63.15 equiv., is formed when potassium is burnt in the open air or in oxygen gas. It is the residue of the decomposition of nitre by heat in metallic vessels; provided the temperature be kept up sufficiently long. When water is added to it oxygen escapes with effervescence, and it passes to the state of potassa which is dissolved.[*] Teroxide.

Bromide of Potassium, $K+Br$ or KBr., 39.15 1 eq. potas. + 78.4 1 eq. oxy. = 117.55 equiv. This compound is formed by processes similar to that for preparing the iodide, and is analogous to it in most of its properties. It is but slightly soluble in alcohol. Bromide.

Fluoride of Potassium, $K+F$, or KF. 39.15 1 eq. potas. + 18.68 1 eq. fluor. = 57.83 equiv., is best formed by nearly saturating hydrofluoric acid with carbonate of potassa, evaporating to dryness in platinum, and igniting to expel any excess of acid. It may be obtained in cubes or rectangular four-sided prisms, which deliquesce rapidly. The solution acts on glass in which it is kept or evaporated. Fluoride.

[‡] *Carburet of Potassium* has not been obtained in a pure state; but it is thought to form part of the residue in the preparation of potassium from charcoal, (page 230).

[*] Bridges of Philadelphia, has suggested this as a convenient method of obtaining oxygen gas. See Turner's *Elem.* 280, and *N. A. Med. and Surg. Jour.* v. 241.

Chap. IV. on the proportions which are employed. The protosulphuret is readily prepared by decomposing sulphate of potassa by charcoal or hydrogen gas at a red heat.

Proto, *Protosulphuret of Potassium*, $K+S$ or KS, 39.15 1 eq. potas. + 16.1 1 eq. sulp. = 55.25 equiv., fuses below a red heat, and acquires on cooling a crystalline texture. It has a red colour, deliquesces on exposure to the air, and is soluble in water and alcohol. It takes fire when heated before the blow-pipe, and quickly acquires a coating of sulphate of potassa, which stops the combustion; but when mixed in fine division with charcoal, it kindles spontaneously, forming a good pyrophorus.[*]

Ter. *Tersulphuret of Potassium*, $K+3S$ or KS^3, 39.15 1 eq. potas. + 48.3 3 eq. sulp. = 87.45 equiv., is prepared pure by transmitting the vapour of bisulphuret of carbon over carbonate of potassa at a red heat, as long as carbonic acid or carbonic oxide gases are disengaged. It is also formed when carbonate of potassa is heated to low redness with half its weight of sulphur, until the mass appears in tranquil fusion.[†] This is known as liver of sulphur.

Sodium.

Symb. Na *Equiv.* 23.3

Discovery of sodium. 853. Sodium discovered by Davy in 1808, is obtained from soda by an operation analogous to that for procuring potassium from potassa. (832.) It is soft, easily sectile, white and opaque, and when examined under a thin film of naptha has the lustre and general appearance of silver.

Properties. 854. It is exceedingly malleable, and much softer than any of the common metallic substances. When pressed upon by a platinum blade with a small force it spreads into thin leaves; and a globule of $\frac{1}{10}$th or $\frac{1}{12}$th of an inch in diameter is easily spread over a surface of a quarter of an inch. This property is not diminished by cooling it to 32° F. Several globules, also, may, by strong pressure, be forced into one; so that the property of *welding*, which be-

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[*] *Bisulphuret of Potassium*, $K+2S$ or KS^2. 39.15 1 eq. potas. + 32.2 2 eq. sulp. = 71.35 equiv., is formed by exposing a saturated solution in alcohol of hydrosulphate of sulphuret of potassium ($KS+HS$), until a pellicle begins to form upon its surface, and then evaporating to dryness without further exposure.

[†] *Quadrosulphuret of Potassium*, $K+4S$ or KS^4, 39.15 1 eq. potas. + 64.4 4 eq. = 103.55 equiv., is prepared by transmitting the vapour of bisulphuret of carbon over sulphate of potassa at a red heat, until carbonic acid gas ceases to be disengaged.

Quintosulphuret of Potassium, $K+5S$ or KS^5, 39.15 1 eq. potas. + 80.5 5 eq. sulp. = 119.65 equiv., is formed by fusing carbonate of potassa with its own weight of sulphur, the residue containing sulphate of potassa as in preparing the tersulphuret.

These four last sulphurets are deliquescent in the air, have a sulphurous odour, and are soluble in water; and those who consider them to decompose water in dissolving, suppose the formation of corresponding compounds of hydrogen and sulphur.

Phosphurets. *Phosphurets of Potassium.*—When potassium is heated in phosphuretted hydrogen gas, it takes fire, phosphuret of potassium is formed, and hydrogen set free; and combination is also effected by gently heating phosphorus with potassium. The number and proportion of these compounds have not yet been determined.

Seleniurets. *Seleniurets of Potassium.*—These elements unite when fused together, sometimes with explosive violence, forming a crystalline fusible compound of an iron-gray colour and metallic lustre.

longs to platinum and iron at a high degree of heat only, is possessed by this substance at common temperatures.

It is lighter than water; as near as can be determined, its specific gravity is as 0.972 to 1.

Fusibility. 855. It is much less fusible than the base of potassa. At 120° F., it begins to lose its cohesion, and is a perfect fluid at 200°.

Effect of air, 856. When sodium is exposed to the atmosphere, it immediately tarnishes, and by degrees becomes covered with a white crust of soda, which deliquiates more slowly than that formed on potassium. It is not changed, however, by air that has been artificially dried.

Of oxygen. 857. It combines with oxygen, slowly and without luminous appearance, at all common temperatures. When heated to its fusing point, the combination becomes more rapid; but no light is emitted till it becomes nearly red hot. The flame which it then produces, is white, and it sends forth bright sparks, exhibiting a very beautiful effect. In common air, it burns with a similar colour to charcoal, but with much greater splendour.

Action on water, 858. When thrown on cold water, it swims, and is rapidly oxidized, though in general, without inflaming, but with hot water it scintillates, or even takes fire. If the sodium is confined to one spot and the water rests on a non-conducting substance, as charcoal, the heat rises high enough for inflammation.* In each case soda is formed, and the water acquires an alkaline reaction.

On alcohol, &c. 859. Its action on alcohol, ether, volatile oil, and acids, is similar to that of potassium; but with nitric acid a vivid inflammation is produced.

Protoxide, or soda, 860. *Protoxide of Sodium,* $Na+O$, $\dot{Na}$ or Nao, 23.3 1 eq. sod. + 8 1 eq. oxy. = 31.3 equiv., commonly called *soda*, and by the Germans *natron*, is formed by the oxidation of sodium in air and water, as potassa is from potassium. In its anhydrous state it is a gray solid, difficult of fusion, and very similar in its characters to potassa. With water it forms a solid hydrate, easily fusible by heat, very caustic, soluble in water and alcohol, has powerful alkaline properties, and in all its chemical relations is exceedingly analogous to potassa. It is prepared from the solution of pure soda, in the same manner as the corresponding preparation of potassa. The solid hydrate is composed of 31.3 parts or one equivalent of soda, and 9 parts or 1 equivalent of water.

Distinguished. 861. Soda is readily distinguished from other alkaline bases by the following characters. 1. It yields with sulphuric acid a salt, which by its taste and form is easily recognised as Glauber's salt, or sulphate of soda. 2. All its salts are soluble in water, and are not precipitated by any reagent. 3. On exposing its salts by means of platinum wire to the blow-pipe flame, they communicate to it a rich yellow colour.

Sesquioxide. 862. *Sesquioxide of Sodium,* $2Na+3O$ $\underline{\dddot{N}}a$, or Na^2O3, 46.6 2 eq. sod. + 24 3 eq. oxy. = 70.6 equiv., is formed when sodium is heated to redness in an excess of oxygen gas. It has an orange colour, has neither acid nor alkaline properties, and is resolved by water into soda and oxygen.

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* Ducatel in *Amer. Jour.* xxv. 90.

Chloride.

863. *Chloride of Sodium*, $Na+Cl$ or $NaCl$, 23.3 1 eq. sod. + 35.42 1 eq. chlor. = 58.72 equiv. Sodium, when heated in chlorine, burns and produces a white compound, of a pure saline flavour. It may also be formed by heating sodium strongly in hydrochloric acid gas; the hydrogen of which is liberated, while the chlorine combines with the metal.

How obtained.

864. Or it may be formed by saturating carbonate or hydrate of soda with hydrochloric acid, and evaporating the liquid, which yields chloride of sodium in a solid form. This chloride, also, is an abundant product of nature, being that well known substance, common salt. For purposes of experiment, the common salt may be employed which is to be found in the shops. This may be purified, by adding to a solution of it in water a solution of carbonate of soda, as long as any milkiness ensues; filtering the solution, and evaporating it till it crystallizes.

Common salt.

865. It crystallizes in solid regular cubes, or, by hasty evaporation, in hollow quadrangular pyramids, which, when the salt is pure, are but little changed by exposure to the air. The common salt of the shops, however, being impure, acquires an increase of weight, in consequence of the absorption of moisture. The various forms under which it appears, of stoved salt, fishery salt, bay salt, &c. arise from modifications in the size and compactness of the grain, rather than from any essential difference of chemical composition. Common salt always contains small quantities of sulphate of magnesia and lime, and chloride of magnesium. These may be precipitated as carbonates by boiling a solution of salt for a few minutes with a slight excess of carbonate of soda, filtering the liquid and neutralizing with hydrochloric acid.

Solution.

866. It requires for solution, twice and a half its weight of water, at 60° F., and hot water takes up very little more. Hence its solution crystallizes, not like that of nitre, by cooling, but by evaporation. When heated gradually it fuses, and forms, when cold, a solid compact mass. If suddenly heated as by throwing it on red-hot coals, it decrepitates. Its uses are well known.[*]

867. *Protosulphuret of Sodium.* $Na+S$, or NaS, 23.3 1 eq. sod. + 16.1 1 eq. sulph = 39.4 equiv. The *protosulphuret* is obtained by processes similar to those for protosulphuret of potassium, to which in its taste and chemical relations it is very similar.[†]

Iodide.

[*] *Iodide of Sodium.* $Na+I$, or NaI, 23.3 1 eq. sod. + 126.3 1 eq. iod. = 149.6 equiv. Obtained pure by processes similar to those for preparing iodide of potassium; but it is contained in sea-water, in many salt springs, and in the residual liquor from kelp (673).

Bromide.

Bromide of Sodium. $Na+Br$, or $NaBr$, 23.3 1 eq. sod. + 78.4 1 eq. brom. = 101.7 equiv. This compound is very analogous to sea-salt, and is associated with it in sea-water and most salt springs.

Fluoride.

Fluoride of Sodium. $Na+F$, or NaF, 23.3 1 eq. sod. + 18.68 1 eq. flu. = 41.98 equiv. This compound is formed by neutralizing hydrofluoric acid by soda, and by igniting the double fluoride of sodium and silicon, when the fluoride of silicon is expelled.

[*] According to Gmelin of Tubingen, sulphuret of sodium is the colouring principle of *lapis lazuli*, to which the colour of ultra-marine is owing; and he has succeeded in preparing artificial ultra-marine by heating sulphuret of sodium with a mixture of silicic acid and alumina. *Ann. de Ch. et de Ph.* xxxvii. 409.

Lithium.

Symb. L. *Equiv.* 6.44.

Discovery.

868. In the year 1818, in the analysis of a mineral called petalite, Arfwedson discovered about three per cent. of an alkaline substance, which was at first supposed to be soda; but, the further prosecution of his inquiries fully demonstrated that it possessed peculiar properties. The minerals called *spodumene*, and *lepidolite*, also afford the same substance, to which the term *lithia*, deduced from its lapideous original has been applied.

869. For preparing lithia,

Method of obtaining lithia.

One part of petalite or spodumene, in fine powder, is intimately mixed with two parts of fluor spar, and the mixture is heated with three or four times its weight of sulphuric acid, as long as any acid vapours are disengaged. The silicic acid of the mineral is attacked by hydrofluoric acid, and is dissipated in the form of fluosilicic acid gas, while the alumina and lithia unite with sulphuric acid. After dissolving these salts in water, the solution is boiled with pure ammonia to precipitate the alumina, filtered, evaporated to dryness and then heated to redness to expel the sulphate of ammonia. The residue is sulphate of lithia.* T. 286.

Action of galvanism.

870. When lithia is submitted to the action of the Voltaic pile, it is decomposed with the same phenomena as potassa and soda; a brilliant white and highly combustible metallic substance is separated, which is *lithium*.

Distinguished from potassa, &c.

871. *Lithia.* L+O, $\dot{L}$, or LO, 6.44 1 eq. lith. + 8 1 eq. oxy. = 14.44 equiv. Lithia is allied to potassa and soda, but distinguished by its greater neutralizing power, by its salts tinging the flame of the blow-pipe of a red colour. It attacks platinum when fused upon it, leaving a dull yellow trace. It is distinguished from baryta, strontia and lime by forming soluble salts with sulphuric and oxalic acids.†

SECTION III. *Metallic Bases of the Alkaline Earths.*

Barium; discovery.

872. *Barium*, Ba. eq. 68.7, was discovered by Davy, in 1808, by means of galvanism. He placed a globule of mercury in a hollow made in a paste of carbonate of baryta, on a platinum tray communicating with the positive pole of a battery of 100 double plates, while the negative wire was in contact with the mercury. The baryta was decomposed, and its barium combined with mercury. An amalgam was obtained, from which the mercury was separated by heat in a vessel free from air, and barium was left in a pure form.

Properties.

873. It is a dark gray colored metal, with a lustre inferior to that

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* For other methods see Henry's *Chemistry*, 1. 572.

† For an analysis of lithion micas and the distinguishing properties of lithia, see Turner's papers, *Edin. Jour.* iii. 137, 261, &c.; and for Berzelius' method of discovering lithia in any solution, see *Edin. Philos. Jour.* iv. 128.

Chloride of Lithium. L+CL, or LCl, 6.44 1 eq. lith. + 35.42 1 eq. chlo. = 41.86 equiv.

Fluoride of Lithium. L+F, or LF, 6.44 1 eq. lith. + 18.68 1 eq. flu. = 25.12 equiv.

of cast-iron. It is far denser than water and sinks in sulphuric acid. It greedily absorbs oxygen and is converted into baryta.

Protoxide. 874. *Protoxide of Barium*, $Ba+O$, $\dot{Ba}$, or BaO, 68.7 1 eq. bar. + 8 1 eq. oxy. = 76.7 equiv., *Barytes*, or *Baryta*, so called from the great density of its compounds, (from βαρὺς, heavy,) was discovered in the year 1744 by Scheele. It is the sole production of the oxidation of barium in air and water. It is obtained by exposing the crystals of nitrate of baryta for some time to a bright red heat. It may also be obtained by decomposing the *native carbonate of baryta.*

How obtained. Let this be powdered, and passed through a fine sieve. Work it up with about an equal bulk of wheaten flour or tar into a ball, adding a sufficient quantity of water. Fill a crucible of proper size, about one third its height, with powdered charcoal; place the ball on this; and surround and cover it with the same powder, so as to prevent its coming into contact with the sides of the crucible. Lute on a cover; and expose it, for two hours, to the most violent heat that can be raised in a wind furnace. Let the ball be removed when cold. On the addition of water, it will evolve great heat, and the baryta will be dissolved. The filtered solution, on cooling, will shoot into beautiful crystals.*

Properties. 875. Baryta is of a gray colour, and very difficult of fusion. Its sp. gr. is about 4, being the heaviest of the substances usually called earths. It eagerly absorbs water, and slakes like lime. A white hydrate is formed, composed of 76.7 parts, 1 eq. of baryta, and 9 parts or 1 eq. of water.

Solution. 876. Hydrate of baryta dissolves in three times its weight of boiling water, and in twenty parts of water at the temperature of 60° F.† A saturated solution of baryta in boiling water deposits, in cooling, transparent, flattened prismatic crystals, which are composed of 76.7 parts or one equivalent of baryta, and 90 parts or 10 equivalents of water.

The aqueous solution of baryta is an excellent test of the presence of carbonic acid in the atmosphere or in other gaseous mixtures. The carbonic acid unites with the baryta, and a white insoluble precipitate, carbonate of baryta, subsides.

Affinity for carbonic acid, Let a solution of pure baryta be exposed to the atmosphere. It will soon be covered with a thin white pellicle; which, when broken, will fall to the bottom of the vessel, and be succeeded by another. This may be continued, till the whole of the baryta is separated. The effect arises from the absorption of carbonic acid, which is always diffused through the atmosphere, and which forms, with baryta, a substance, viz. carbonate of baryta, much less soluble than the pure earth.

Exp. Or if the air from the lungs be blown, by means of a quill, or tube, through a solution of baryta, the solution will immediately become milky, in consequence of the production of an insoluble carbonate. The same effect will be produced by mingling with a solution of pure baryta, a little water, impregnated with carbonic acid.

Takes it from other bodies. 877. Baryta has so strong an affinity for carbonic acid as even to take it from other bodies.

Exp. If to a solution of a small portion of carbonate of potassa, of soda, or of ammonia we add the solution of baryta, the earth will detach the carbonic acid from the alkali, and will fall down in the state of a carbonate. By adding a sufficient quantity of a solution of baryta in hot water, the whole of the carbonic acid may thus be removed from a carbonated alkali. H. 1. 578.

Alkaline properties. 878. As baryta, like the alkalies, converts vegetable blues to green, and serves as an intermedium between oil and water, it has

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* For other processes see *Sulphate and Nitrate of Baryta.*

† Davy.

been called an *alkaline earth.* It has a very acrid, caustic taste, and is highly poisonous. It exists in two natural combinations only, viz. as sulphate and carbonate.

Peroxide.

879. *Peroxide of Barium.* $Ba+2O$, or BaO^2+6Aq, 68.7 1 eq. bar. + 16 2 eq. oxy. = 84.7 equiv. When dry oxygen gas is conducted over pure baryta at a low red heat this oxide is formed. It is employed in preparing peroxide of hydrogen, page 134. An easier process is to heat pure baryta to low redness in a platinum crucible, and then gradually to add chlorate of potassa in the ratio of about one part of the latter to four of the former.

Process.

Theory.

880. The oxygen of the chlorate goes over to the baryta, and chloride of potassium is generated. Cold water removes the chloride and the peroxide of barium is left as a hydrate with 6 eq. of water.

Chloride.

881. *Chloride of Barium.* $Ba+Cl$, or $BaCl$, 68.7 1 eq. bar. + 35.42 1 eq. chlor. = 104.12. *Chloride of Barium* may be obtained by heating baryta in chlorine, in which case oxygen is evolved: or, more easily, by dissolving carbonate of baryta in diluted hydrochloric acid. When filtered and evaporated, the solution yields regular crystals, which have most commonly the shape of flat four sided tables, very like those of heavy spar. They contain 104.12 or 1 eq. of chloride of barium and 18 parts or 2 eq. of water; formula $BaCl+2Aq$. 100 parts of water dissolve 43.5 at 60°, and 78 at 222° which is the boiling point of the solution.*

Sulphuret.

882. *Protosulphuret of Barium,* $Ba+S$ or BaS, 68.7 1 eq. bar. + 16.1 1 eq. sulp. = 84.8 equiv., is formed when dry hydrosulphuric acid gas is passed over pure baryta at a red heat, and by the action of hydrogen gas or charcoal on sulphate of baryta (818.)

Solution.

It is very soluble in hot water, and the solution supplies a ready mode of obtaining pure baryta and its salts, when the carbonate cannot be obtained. Thus its solution, boiled with black oxide of copper until it ceases to precipitate a salt of lead black, yields pure baryta, which should be filtered while hot to separate the sulphuret of copper: it is apt to retain traces of oxide of copper. With a solution of carbonate of potassa, carbonate of baryta falls, and sulphuret of potassium remains in solution; and with hydrochloric acid it interchanges elements, by which hydrosulphuric acid and chloride of barium are formed. T.

Strontium.

Symb. Sr *Equiv.* 43.8

Discovery.

883. This metal was discovered by Davy in *strontia*, by the same process as barium, which it resembles.

Strontia.

884. *Protoxide of Strontium,* $Sr+O$, $\dot{Sr}$, or SrO, 43.8 1 eq. stron. + 8 1 eq. oxy. = 51.8 equiv., or the earth *Strontia,* is so

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Iodide.

* *Iodide of Barium.* $Ba+I$, or BaI, 68.7 1 eq. bar. + 126.3 1 eq. iod. = 195 equiv.

Bromide of Barium. $Ba+Br$, or $BaBr$, 68.7 1 eq. bar. + 78.4 1 eq. brom. = 147.1 equiv.

Fluoride of Barium. $Ba+F$, or BaF, 68.7 1 eq. bar. + 18.68 1 eq. flu. = 87.38 equiv.

called from Strontian in Scotland, where it was first discovered in combination with carbonic acid.

How obtained. It may be prepared either by subjecting the carbonate to a strong heat in a crucible, or by igniting the nitrate in a porcelain retort or other close vessel. A gray substance remains which becomes very hot on the affusion of water; and when more water is added and heat applied, a considerable proportion of the earth is dissolved. On cooling, the solution deposits regular crystals; but the shape of these differs considerably from that of barytic crystals.

The crystals of strontia are thin quadrangular plates.

Composition. 885. The hydrate consists of 51.8 parts or 1 eq. of strontia, and 9 parts or 1 eq. water. The crystals contain 10 eq. water and 1 strontia. It requires 50 times its weight of water for solution.

Properties. 886. Pure strontia has a pungent, acrid taste, and when powdered in a mortar, the dust that rises irritates the lungs, and nostrils. Its specific gravity approaches that of baryta.

Salts. 887. The salts of strontia are best prepared from the native carbonate. Like those of baryta, they are precipitated by alkaline carbonates, and by sulphuric acid or soluble sulphates. But sulphate of strontia is less insoluble than sulphate of baryta: on adding sulphate of soda in excess to a barytic solution, baryta cannot afterwards be found in the liquid by any precipitant; but when strontia is thus treated, so much sulphate of strontia remains in solution, that the filtered liquid yields a white precipitate with carbonate of soda. The salts of strontia are not poisonous; and most of them, when heated on platinum wire before the blow-pipe, communicate to the flame a red tint.*

Chloride. 888. *Chloride of Strontium*, $Sr+Cl$, or $SrCl$, 43.8 1 eq. stron. + 35.42 1 eq. chlor. = 79.22 equiv. This compound is formed by processes similar to those for preparing chloride of barium, and crystallizes in colourless prismatic crystals, which deliquesce in a moist atmosphere, require only twice their weight of water at 60° for solution, and still less of boiling water, and are soluble in alcohol. The alcoholic solution, when set on fire, burns with a red flame. These characters afford a certain mode of distinguishing strontia from baryta. The crystals consist of 79.22 parts or 1 eq. of chloride of strontium, and 81 parts or 9 eq. of water, which are expelled by heat. The anhydrous chloride fuses at a red heat, and yields a white crystalline brittle mass on cooling.†

Calcium.

Symb. Ca *Eq.* 20.5

How obtained. 889. When lime is electrized negatively in contact with mercury, an amalgam is obtained, which, by distillation, affords a white met-

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Peroxide. * *Peroxide of Strontium*, $Sr+2O$ or SrO^2. 43.8 1 eq. stron. + 16 2 eq. oxy = 59.8 equiv., is prepared in the same way as peroxide of barium, and like it, is resolved by dilute acids into strontia and oxygen, the latter of which forms peroxide of hydrogen with the water.

Iodide. † *Iodide of Strontium*, $Sr+I$, or SrI, 43.8 1 eq. stron. + 126.3 1 eq. iod. = 170.1 equiv., may be prepared in the same manner as that of barium. It is very soluble in water.

Fluoride of Strontium and Protosulphuret of Strontium, $Sr+F$ or SrF, 43.8 1 eq. stron. + 18.68 1 eq. fluor. = 62.48 equiv. and $Sr+S$ or SrS, 43.8 1 eq. stron. + 16.1 1 eq. sulp. = 59.9 equiv. are obtained like those of barium.

al. It has been called *calcium*, and when exposed to air, and gently heated, it burns and produces the *oxide of calcium* or *lime*.

Protoxide or quick-lime, 890. *Protoxide of Calcium*, $Ca+O$, $\dot{Ca}$, or CaO, 20.5 1 eq. calc. 8 1 eq. oxy. = 28.5 equiv. This compound, commonly known by the name of *lime* and *quicklime*, is obtained by exposing carbonate of lime to a strong red heat, so as to expel its carbonic acid. If lime of great purity is required, it should be prepared from pure carbonate of lime, such as Iceland spar or Carrara marble. Its colour is gray, it is acrid and caustic; its sp. gr. is about 2.3.

Fusibility. 891. It is very difficult of fusion, but remarkably promotes the fusion of most other earthy bodies, and is therefore used in several metallurgic processes as a cheap and powerful flux. When quite pure it can only be fused in very minute particles by the oxy-hydrogen blow-pipe, or by the Voltaic flame. **Uses.** It is an essential ingredient in mortar, and other cements used in building. Exposed to air it becomes white by the absorption of water and a little carbonic acid.

Hydrate. 892. It has a powerful affinity for water. When a small quantity of water is poured upon lime, there is a great rise of temperature resulting from the solidification of a portion of the water, and a white powder is obtained, called *slaked lime*, which is a *hydrate*, and appears to consist of one eq. water = 9 + one eq. lime = 28.5.

Some care is necessary in its preparation, lest more water should be added, than is essential to its constitution. It affords a very convenient form of keeping lime, for occasional use in a laboratory; for the hydrate may safely be preserved in glass bottles, which are almost constantly broken by the earth, if enclosed in its perfectly dry state.

Heat. 893. The degree of heat produced by the combination of lime with water, is supposed by Dalton to be not less than 800°, and is sufficient to set fire to some inflammable bodies.

Exp. Place a large lump of well burned quicklime on an iron dish and add a small quantity of water, a piece of phosphorus resting on it will be ignited.

When a large quantity of lime is suddenly slaked in a dark place, even light, according to Pelletier, is sometimes evolved.

Milk of lime, 894. When a sufficient quantity of water has been added to reduce lime into a thin liquid, this is called *milk* or *cream of lime*. **Water of,** By the addition of more water the solution known as *lime water* is obtained. When sufficiently cool it should be poured into a well stopped bottle until the undissolved parts have subsided, and be then decanted and kept from the air.

Lime is very sparingly soluble in water, viz. in the proportion of about 1 to 778.*

Properties of lime-water. 895. Lime-water is limpid and colourless; its taste is nauseous, acrid, and alkaline, and it converts vegetable blues to green. When exposed to the air, a pellicle of carbonate of lime forms upon its surface, which, if broken, is succeeded by others, until the whole of the

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* According to Thomson 1 to 758. The experiments of Dalton tend to establish a curious fact respecting the solubility of lime, viz. that it dissolves more plentifully in cold than in hot water; he found that at 60° F. 778 grains of water dissolve 1 grain of lime, and at 212°, 1270 grains were required. He further infers that at the freezing point water would probably take up nearly twice as much lime as is dissolved by boiling water—this has been confirmed by Phillips.—*Ann. Philos.* N. S. 1. 107.

Uses. lime is thus separated in the form of an insoluble carbonate. It is used in medicine as an antacid, and is a good test of the presence of carbonic acid gas.

Exp. Into transparent lime water pass carbonic acid, or breathe into it by means of a glass tube, it will become milky and opaque from the formation of carbonate of lime. If an excess of carbonic acid is added the carbonate is dissolved and transparency restored.

Test of. 896. The most delicate test of the presence of lime is oxalate of ammonia or potassa; for of all the salts of lime, the oxalate is the most insoluble in water. This serves to distinguish lime from most substances, though not from baryta and strontia; because the oxalates of baryta and strontia, especially the latter, are likewise sparingly soluble.*

Chloride of calcium. 897. *Chloride of Calcium*, $Ca+Cl$, or $CaCl$, 20.5 1 eq. calc. + 35.42 1 eq. chlor. = 55.92 equiv., is produced by heating lime in chlorine, in which case oxygen is evolved; or by evaporating *hydrochlorate of lime* to dryness, and exposing the dry mass to a red heat in close vessels. In this case the hydrochloric acid is decomposed; its hydrogen uniting with the oxygen of the lime, escapes in the state of water; and the chlorine unites with the calcium.

Composition and properties. 898. This compound has a strong attraction for water; it deliquesces when exposed to the air, and becomes what used to be called *oil of lime*. It is difficultly crystallizable from its aqueous solution; with care, however, it may be obtained in irregular prisms, consisting of 55.92 parts or 1 eq. of chloride of calcium, and 54 parts or 6 eq. water. Its taste is bitter and acrid; one part of water at 60° dissolves four parts of the chloride. Its solubility, however, is greatly influenced by temperature. It is copiously soluble in alcohol, and much heat is evolved during the solution. When fused it acquires a phosphorescent property as was first observed by Homberg, and is hence termed *Homberg's phosphorus*. It is abundantly produced in the manufacture of carbonate of ammonia, from the decomposition of hydrochlorate of ammonia by lime.

Homberg's phosphorus.

Uses. 899. It is used for frigorific mixtures with snow, and for this purpose the hydrous chloride is preferable, prepared by evaporating its solution so far that the whole becomes a solid mass on removal from the fire. It should be kept in bottles well secured from the air.

In its fused state this compound is very useful for drying certain gaseous bodies, but where the quantity of the gas is to be ascertained, its powers of absorption in certain cases must not be overlooked.

Pelletier has stated, that if carbonic acid be passed through a solution of hydrochlorate of lime, the whole becomes a hard solid mass. If sulphuric acid be poured into a strong solution of hydrochlorate of lime, the whole congeals into a solid mass of sulphate of lime (61).

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* All these oxalates dissolve readily in water acidulated with nitric or hydrochloric acid. It is distinguished from baryta and strontia by the fact, that nitrate of lime yields prismatic crystals by evaporation, is deliquescent in a high degree, and very soluble in alcohol; while the nitrates of baryta and strontia crystallize in regular octohedrons or segments of the octohedron, undergo no change on exposure to the air, except when it is very moist, and do not dissolve in pure alcohol. T.

Peroxide of Calcium. $Ca+2O$, or CaO^2, 20.5 1 eq. calc. + 16 2 eq. oxy. = 36.5 equiv. It is prepared in the same way as peroxide of barium, and is similar in its properties.

Absorbs ammonia.

900. It absorbs large quantities of ammoniacal gas, during which it swells, cracks, and at last crumbles down into a white powder. With water it forms a strong alkaline solution. Heated it gives off ammonia and the chloride remains. Immersed in chlorine, the ammonia burns off with a pale yellow flame. Twenty grains of the compound furnish, when heated, about 20 cubic inches of ammonia; Faraday availed himself of it for the liquefaction of ammonia.*

Bleaching powder.

901. The chloride of lime is abundantly employed as a bleaching material, and known by the name of *bleaching powder;* it is manufactured by passing chlorine into leaden chambers containing hydrate of lime in fine powder, by which the gas is copiously absorbed with evolution of heat. When heated it gives off a large quantity of oxygen, and a chloride of calcium results, showing the superior attraction of calcium for chlorine compared to oxygen, the latter being expelled from the lime.

Composition.

The composition of bleaching powder has been variously stated. Dalton considers it as a hydrated subchloride of lime, containing two proportions of lime and one of chlorine;† and the same opinion is adopted by Thomson,‡ and by Welter.§ According to Ure‖ the quantity of chlorine absorbed is variable. That manufactured at Glasgow is stated by Thomson to be a compound of one atom of chlorine and one of lime.¶

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* Faraday in *Jour. Roy. Inst.* v. 74. † *Ann. of Philos.* i. 15 and ii. 6. ‡ *Ib.* xv. 401.

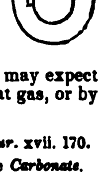
§ *Ann. de Chim. et Phys.* vii. 383. ‖ *Quart. Jour.* xiii. 21.

¶ As the value of chloride of lime depends on the quantity of chlorine which it contains, and as this varies considerably, several methods for ascertaining its strength have been proposed. One consists in adding a given quantity of the diluted solution to a solution of indigo in sulphuric acid of a known strength;* the strength of the chlorine being indicated by the quantity of the solution which it can decolorize. Morin has proposed a solution of the hydrochlorate of manganese as a substitute for this, as giving more accurate indications, the lime combining with the hydrochloric acid, and precipitating the brown oxide of manganese, while the chlorine is disengaged; the quantity of the hydrochlorate decomposed corresponding with the chlorine set at liberty.† It has also been proposed to ascertain the quantity of chlorine by observing the quantity of nitrogen gas which is disengaged when it is made into a paste or cream with water and mixed with fragments of hydrochlorate of ammonia; the lime combining with the hydrochloric acid and forming hydrochlorate of lime, while the chlorine takes hydrogen from the ammonia and disengages nitrogen (420).

Ure's method of analysis.

An instrument for the speedy analysis of this substance has been described by Ure.‡ It consists of a glass tube, (Fig. 178,) of about five cubic inches capacity, graduated into cubic inches and tenths. It is closed at top with a brass screw cap, and at its recurved end below, with a good cork. Pour mercury into the upper orifice, till the tube be nearly full, leaving merely space to insert ten grains of the bleaching powder, made into a pellet form with a drop of water. Screw in the cap-plug rendered air-tight by leather. Remove now the cork from the lower end, (also full of mercury,) and replace a little of the liquid metal by dilute hydrochloric acid (sp. gr. 1.1). By dexterous inclination of the instrument, the acid is made to flow up through the mercury. Instantly on its coming in contact with the pellet, the chlorine is disengaged, the mercury flows out into a basin ready to receive it, while the resulting film of hydrochlorate of lime protects the surface of the metal almost completely from the gas.

Fig 178.



The same instrument may be employed for ascertaining the quantity of carbonic acid in limestone, &c.§

Estimating a cubic inch of chlorine in round numbers at $\frac{3}{4}$ of a grain, we may expect 10 grains of bleaching powder to yield from 3 to 4 cubic inches of that gas, or by weight, from 20 to 30 per cent. Ure.

* As the quantity of indigo varies, this test cannot be relied upon. See *Amer. Jour.* xvii. 170.

† *Jour. Roy. Inst.* vi. ‡ *Jour. Roy. Inst.* xiii. 21. § See Ure's *Chem Dict.* article *Carbonate.*

902. *Fluoride of Calcium—Fluor Spar.* $Ca+F$, or CaF, 20.5 1 eq. cal. + 18.68 1 eq. flu. = 39.18 equiv. Fluor spar is a mineral found in many parts of the world, but in great beauty and abundance in England, and especially in Derbyshire. Here it is commonly called *Derbyshire spar*, or by the miners of that

Fluor spar.

county *blue John.*[*] It is usually found in cubic crystals, which may easily be cleaved into octohedra, sometimes considered as its primitive form. Its colours are extremely various. Its specific gravity is 3.15. It is perfectly tasteless and insoluble in water. When thrown in powder upon a plate of iron heated below redness in a dark place, it emits a phosphorescent light.[†]

Properties.

903. Fluoride of calcium fuses at a red heat without farther change. It is insoluble in water, slightly soluble in hot diluted hydrochloric acid, and is decomposed by sulphuric acid aided by gentle heat, affording hydrofluoric acid (715).[‡]

Protosulphuret.

904. *Protosulphuret of Calcium.* $Ca+S$, or CaS, 20.5 1 eq. cal. + 16.1 1 eq. sulph. = 36.6 equiv. This compound may be prepared by reduction from the sulphate by hydrogen or charcoal, and when pure is white with a reddish tint, and is very sparingly soluble in water. It has the property, in common with sulphuret of barium, of being phosphorescent after exposure to light, and appears to be the essential ingredient of Canton's phosphorus.

Bisulphuret.

When 3 parts of slaked lime, 1 of sulphur, and 20 of water, are boiled together for an hour, and the solution, without separation from the sediment, is set aside in a corked flask for a few days, a copious deposite of orange-coloured crystals takes place, which, when slowly formed, are flat quadrilateral prisms. These, from the analysis of Herschel,[§] appear to be *bisulphuret of calcium* with 3 eq. of water. They are decomposed by exposure to the air, and are of sparing solubility in water.

When either of the foregoing sulphurets is boiled in water along with sulphur, a yellow solution is formed containing calcium combined with five equivalents of sulphur.[||]

905. *Phosphuret of Calcium.* $Ca+P$, or CaP, 20.5 1 eq. cal. +

Phosphuret.

15.7 1 eq. phos. = 36.2 equiv. It is formed by passing the vapour of phosphorus over fragments of quicklime at a low red heat;[¶] when a brown matter is formed, consisting of phosphate of

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[*] It occurs in various parts of the United States—that from Shawneetown, Illinois, is particularly beautiful. For other localities see Cleaveland's and Dana's *Mineralogy.*

Process.

[†] It may be prepared artificially by digesting moist, recently precipitated, carbonate of lime in an excess of hydrofluoric acid; or by mixing a solution of chloride of calcium with fluoride of potassium or sodium. As prepared in the latter mode, it is a bulky gelatinous mass, which it is very difficult to wash; whereas the former method gives it in the state of a granular white powder, which may be washed with ease.

[‡] *Iodide of Calcium.* $Ca+I$, or CaI, 20.5 1 eq. cal.+126.3 1 eq. iod. = 146.8 equiv.
Bromide of Calcium. $Ca+Br$, or $CaBr$, 20.5 1 eq. cal. + 78.4 1 eq. brom. = 98.9 equiv.

[§] *Edin. Philos. Jour.* 1. p. 11, &c.

[||] *Bisulphuret of Calcium.* $Ca+2S$, or CaS^2, 20.5 1 eq. cal. + 32.2 2 eq. sulph. = 52.7 equiv.
Quintosulphuret of Calcium. $Ca+5S$, or CaS^5, 20.5 1 eq. cal. + 80.5 5 eq. sulph. = 101 equiv.

How prepared.

[¶] Select a green glass, or porcelain tube, closed at one end, and about 18 inches long, and one inch diameter, and carefully cover it with a clay lute containing a very little lime and phosphuret of calcium. When put into water, mutual decomposition ensues, and phosphuretted hydrogen, hypophosphorous acid, and phosphoric acid are generated (777).

Drop a small piece of it into a wine-glass of water, and in a short time bubbles of phosphuretted hydrogen gas will be produced; which, rising to the surface will take fire, and explode. If the phosphuret of lime be not perfectly fresh, it may be proper to warm the water to which it is added. Exp.

Into an ale-glass put one part of the phosphuret in pieces of about the size of a pea (not in powder), and add to it half a part of chlorate of potassa. Fill the glass with water, and put into it a funnel, with a long pipe, or narrow glass tube, reaching to the bottom. Through this pour three or four parts of strong sulphuric acid, which will decompose the chlorate; and, the phosphuret also decomposing the water at the same time, flashes of fire dart from the surface of the fluid, and the bottom of the vessel is illuminated by a beautiful green light. Exp.

Magnesium.

Symb. Mg *Equiv.* 12.7*

906. The existence of this metal was demonstrated by Davy, but it was first obtained in any quantity by Bussy, in 1830 by means of potassium. Discovery.

907. For this purpose five or six pieces of potassium, of the size of peas, were introduced into a glass tube, the sealed extremity of which was bent into the form of a retort, and upon the potassium were laid fragments of chloride of magnesium. The latter being then heated to near its point of fusion, a lamp was applied to the potassium, and its vapour transmitted through the mass of heated chloride. Vivid incandescence immediately took place, and on putting the mass, after cooling, into water, the chloride of potassium with undecomposed chloride of magnesium was dissolved, and metallic magnesium subsided. These results have been since confirmed by Liebig.† Process for.

908. Magnesium has a brilliant metallic lustre, and a white colour like silver; is very malleable, and fuses at a red heat. Moist air oxidizes it superficially; but it undergoes no change in dry air, and may be boiled in water without oxidation. Heated to redness in air or oxygen gas, it burns with brilliancy, yielding magnesia; and it inflames spontaneously in chlorine gas. It is readily dissolved by dilute acids with disengagement of hydrogen, and the solution is found to contain a pure salt of magnesia. Properties.

909. *Protoxide of Magnesium.* $MG+O$, $\dot{Mg}$, or MgO, 12.7 1

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borax. Put an ounce of phosphorus broken into small pieces into the lower end, and fill it up with pieces of clean quicklime, about the size of large peas; place it in an inclined position in a furnace, so that the end containing the phosphorus may protrude, while the upper part of the tube is heating to redness; then slowly draw the cool part into the fire, by which the phosphorus will be volatilized, and passing into the red-hot lime, convert a portion of it into phosphuret. Care should be taken that no considerable portion of phosphorus escapes and burns away at the open end of the tube, which after the process, should be corked and suffered to cool. Its contents may then be shaken upon a sheet of paper, and the brown pieces picked out and carefully preserved in a well stopped phial; the white pieces, or those which are only pale brown, must be rejected. Properties.

An easier method is, by throwing a piece of dry phosphorus into a crucible with a few fragments of lime (each about the size of a pea), at the bottom, and at a bright red heat, an assistant putting on a cover, or inverting it immediately on a flat plate of iron, at the same time throwing a quantity of sand round it to close any aperture. The experiment may be made with 20 or 30 grains of phosphorus, and about 60 or 70 of lime in a small crucible. R. See Mitchell's process, page 218, *Note.*

* Inferred by Berzelius from the quantity of sulphate obtained from a known weight of pure magnesia.

† *Ann. de Chim. et de Phys.* xlvi. 435.

Protoxide or magnesia.

eq. mag. + 8 1 eq. oxy. = 20.7 equiv. This, the only known oxide of magnesium, commonly known by the name of *magnesia*, is best obtained by exposing carbonate of magnesia to a very strong red heat, by which its carbonic acid is expelled. It is a white, friable powder, of an earthy appearance; and, when pure, it has neither taste nor odour. Its specific gravity is about 2.3, and it is exceedingly infusible. Brande once succeeded in agglutinating a small portion of this earth in the Voltaic flame, and whilst exposed to this high temperature, it was perfectly fused by directing upon it the flame of oxygen and hydrogen.

Action of water.

910. It has a weaker affinity than lime for water; for though it forms a hydrate when moistened, the combination is effected with hardly any disengagement of caloric, and the product is readily decomposed by a red heat.*

Solution.

Magnesia dissolves very sparingly in water. According to Fyfe, it requires 5142 times its weight of water at 60°, and 36.000 of boiling water for solution. The resulting liquid does not change the colour of violets; but when pure magnesia is put upon moistened turmeric paper, it causes a brown stain. From this there is no doubt that the inaction of magnesia with respect to vegetable colours, when tried in the ordinary mode, is owing to its insolubility. It possesses the still more essential character of alkalinity, that, namely, of forming neutral salts with acids, in an eminent degree. It absorbs both water and carbonic acid when exposed to the atmosphere, and, therefore, should be kept in well closed phials.

Properties.

911. Magnesia is characterized by the following properties. With nitric and hydrochloric acid it forms salts which are soluble in alcohol, and exceedingly deliquescent. The sulphate of magnesia is very soluble in water, a circumstance by which it is distinguished from the other alkaline earths. Magnesia is precipitated from its salts as a bulky hydrate by the pure alkalies. It is precipitated as carbonate of magnesia by the carbonates of potassa and soda;† but the bicarbonates and the common carbonate of ammonia do not precipitate it in the cold. If moderately diluted, the salts of magnesia are not precipitated by oxalate of ammonia. By means of this reagent magnesia may be both distinguished and separated from lime.

Process.

912. *Chloride of Magnesium.* $Mg+Cl$, or $MgCl$, 12.7 1 eq. mag. + 35.42 1 eq. = 48.12 equiv. This may be prepared by transmitting dry chlorine gas over a mixture of magnesia and charcoal at a red heat; but Liebig has given an easier process, which consists in dissolving magnesia in hydrochloric acid, evaporating to dryness, mixing the residue with its own weight of hydrochlorate of ammonia, and projecting the mixture in successive portions into a platinum crucible at a red heat. As soon as the ammoniacal salt is wholly expelled, the fused chloride of magnesium is left in a state of tranquil

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* The *native hydrate* is found at Hoboken, N. J., it consists of 70 magnesia and 30 water.

Calcined magnesia.

† The carbonate of magnesia, used in medicine, and for experimental purposes, is prepared by mixing hot solutions of carbonate of potassa and sulphate of magnesia (Epsom salts). The carbonic acid is expelled by moderate heat, and the residue is pure magnesia; being prepared by calcination, it is known as *calcined magnesia*. When incautiously used for a long time it may produce very serious evils, a remarkable case has been reported by Brande in *Jour Roy. Instit.* i.

fusion, and on cooling becomes a transparent colourless mass, which is highly deliquescent, and is very soluble in alcohol and water.*

SECTION IV. *Metallic Bases of the Earths.*

Aluminous minerals. **Aluminium.**

913. *Aluminium.* Al. eq. 13.7. Alumina constitutes some of the hardest gems, such as the sapphire and ruby; and combined with water, it gives a peculiar softness and plasticity to some earthy compounds, such as the different kinds of clay.—The experiments of Davy afforded a strong presumption that alumina is a metallic oxide; but its base, *aluminium*, he did not obtain in such a state as to make its properties an object of investigation. Yet alloys were formed which gave sufficient evidence of its existence, and the presence of oxygen in alumina was proved, by its changing potassium into potassa, when ignited with that metal.

Process for.

914. Aluminium has since been procured by Wöhler† by decomposing the chloride by means of potassium. The action is very violent, and accompanied with such intense heat that a crucible of platinum is required.

Properties.

915. The aluminium is generally in small scales of a metallic lustre, or in slightly coherent spongy masses with the lustre of tin.

Fusibility.

It conducts electricity in its fused state, but in the form of powder it does not. Its fusing point is higher than that of cast iron. At a red heat it takes fire in the air, and alumina is formed; in oxygen gas it burns with intense light and heat.

Action of water.

It is not oxidized by water at common temperatures; oxidation commences when the water is near its boiling point, but even after continued boiling it is very slight.

Alumina.

916. *Sesquioxide of Aluminium.* $2Al+3O$, $\overset{\cdots}{Al}$, or Al^2O^3, 27.4 2 eq. alum. + 24 3 eq. oxy. = 51.4 equiv. This is one of the most abundant earths in nature, being a constituent of many rocks, the different kinds of clay, and of some of the hardest gems, as the ruby and sapphire.

Obtained.

917. Alumina may be obtained by dissolving purified alum‡ in four or five times its weight of boiling water, adding a slight excess of carbonate of potassa, and after digesting for a few minutes, the bulky hydrate of alumina may be collected on a filter and well washed with hot water. If an excess of alkali is not employed the precipitate will retain some sulphuric acid.§

Properties.

918. Alumina is destitute of taste and smell; moistened with water, it forms a cohesive and ductile mass, susceptible of being kneaded into a regular form. It is not soluble in water; but retains a considerable quantity, and is, indeed, a hydrate, containing when dried at the temperature of the atmosphere, almost half its weight of

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* For other compounds see Turner's *Chem.*

† *Edin. Jour. of Sci.* No. xvii. 178.

‡ This salt, as purchased in the shops, is frequently contaminated with peroxide of iron, and consequently unfit for many chemical purposes; but it may be separated from this impurity by repeated crystallization. Its absence is proved by the alum being soluble without residue in a solution of pure potassa; whereas when peroxide of iron is present, it is either left undissolved in the first instance, or deposited after a few hours in yellowish-brown flocks.

§ But the alumina, as thus prepared, is not yet quite pure; for it retains some of the alkali with such force, that it cannot be separated by the action of water. For this water. Even after ignition, alumina has such an affinity for moisture, that it can hardly be placed on the scale without acquiring weight.* It is dissolved by the liquid fixed alkalies, and is precipitated by acids unchanged. In ammonia it is very sparingly soluble.

Effect of heat. 919. Alumina has the property of shrinking considerably in bulk, when exposed to heat. On this property was founded the *pyrometer* of Wedgwood, designed to measure high degrees of heat by the amount of the contraction of regularly shaped pieces of China clay.

Recognised. 920. Alumina is easily recognised by the following characters. 1. It is separated from acids, as a hydrate, by all the alkaline carbonates, and by pure ammonia. 2. It is precipitated by pure potassa or soda, but the precipitate is completely redissolved by an excess of the alkali.

Sesquichloride. 921. *Sesquichloride of Aluminium*, $2Al+3Cl$ or Al^2Cl^3, 27.4 2 eq. alumin. + 106.26 3 eq. chlor. = 133.66 equiv., was obtained by Oersted, by transmitting dry chlorine gas over a mixture of alumina and charcoal heated to redness. It was afterwards prepared by Wöhler as follows.

Wöhler's process. 922. He precipitated aluminous earth from a hot solution of alum by means of potassa, and mixed the hydrate, when dry, with pulverized charcoal, sugar, and oil, so as to form a thick paste, which was heated in a covered crucible until all the organic matter was destroyed. By this means the alumina was brought into a state of intimate mixture with finely divided charcoal, and while yet hot, was introduced into a tube of porcelain, fixed in a convenient furnace. After expelling atmospheric air from the interior of the apparatus by a current of dry chlorine gas, the tube was brought to a red heat. The formation of sesquichloride of aluminium then commenced, and continued, with disengagement of carbonic oxide gas, during an hour and a half, when the tube became impervious from sublimed sesquichloride collected within it. The process was then necessarily discontinued.

Properties. 923. It is of a pale greenish colour, translucent, lamellated, and like talc. Exposed to air, it emits fumes having an odour like hydrochloric acid, and deliquesces. It dissolves in water with a hissing noise and much heat. It is volatile a little above 212° and fuses.†

Glucinium.

Symb. G. *Equiv.* 26.5.

Glucinium. 924. This is the metallic base of the earth glucina, and was obtained in 1828 by Wöhler, by the action of potassium on the chloride, as in the case of the last described metal; it appeared as a gray powder but acquired a metallic lustre by burnishing, and was easily oxidized.‡

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reason the precipitate must be re-dissolved in dilute hydrochloric acid, and thrown down by means of pure ammonia, or its carbonate. This precipitate, after being well washed and exposed to a white heat, yields pure anhydrous alumina. Ammonia cannot be employed for precipitating aluminous earth directly from alum, because sulphate of alumina is not completely decomposed by this alkali. (Berzelius.) An easier process, proposed by Gay-Lussac, is to expose sulphate of alumina and ammonia to a strong heat, so as to expel the ammonia and sulphuric acid.

For other processes see Ure's *Dict.* 3. 147.

* Berzelius found, that 100 parts of alumina, after being ignited gained 15¼ from a dry atmosphere, and 33 from a humid one. For a full saturation, 100 grains of alumina, he ascertained, require 54 of water.* It does not affect vegetable colours.

† Aluminium combines with sulphur, phosphorus and selenium, for which see Turner, 299. ‡ *Phil. Mag.* and *Annals*, v. 392.

* *Ann. de Chim. et Phys.* v. 101.

Sesquioxide or glucina,

925. *Sesquioxide of Glucinium or Glucina*, $2G+3O$, $\overset{\cdots}{\underline{G}}$, or G^2O3, was discovered by Vauquelin in the beryl, emerald and euclase.

Process for,

The process proposed by Berthier for obtaining it, is to mix the beryl in fine powder with its own weight of marble and expose the mixture in a crucible to a strong heat. A glass is obtained which when in fine powder is attacked by hydrochloric or sulphuric acid. The mass is then dissolved in dilute hydrochloric acid, and the solution evaporated to perfect dryness; by which means the silicic acid is rendered quite insoluble. The alumina and glucina are then redissolved in water acidulated with hydrochloric acid, and thrown down together by pure ammonia. The precipitate, after being well washed, is macerated with a large excess of carbonate of ammonia, by which glucina is dissolved; and on boiling the filtered liquid, carbonate of glucina subsides. By means of a red heat its carbonic acid is entirely expelled.

Properties,

926. Glucina is a white powder, which has neither taste nor odour, and is quite insoluble in water. Its sp. gr. is 3. Vegetable colours are not affected by it. The salts which it forms with acids have a sweetish taste, a circumstance which distinguishes glucina from other earths, and from which its name is derived. (From γλυκὺς, sweet.)

Distinguished,

927. Glucina may be known chemically by the following characters. 1. Pure potassa or soda precipitates glucina from its salts, but an excess of the alkali redissolves it. 2. It is precipitated permanently by pure ammonia as a hydrate, and by fixed alkaline carbonates as a carbonate of glucina. 3. It is dissolved completely by a cold solution of carbonate of ammonia, and is precipitated from it by boiling. By means of this property, glucina may be both distinguished and separated from alumina. T.

Yttrium.

Symb. Y

Yttrium,

928. *Yttrium* is the metallic base of an earth which was discovered in the year 1794 by Gadolin, in a mineral found at Ytterby in Sweden, from which it received the name of *yttria*. The metal itself was prepared by Wöhler in 1828, by a process similar to that above described.

Properties,

929. Its texture, by which it is distinguished from glucinium and aluminium, is scaly, its colour grayish black, and its lustre perfectly metallic. In colour and lustre it is inferior to aluminium, bearing in these respects nearly the same relation to that metal, that iron does to tin. It is a brittle metal, while aluminium is ductile. It is not oxidized either in air or water; but when heated to redness, it burns with splendour even in atmospheric air, and with far greater brilliancy in oxygen gas. The product, yttria, is white, and shows unequivocal marks of fusion. It dissolves in sulphuric acid, and also, though less readily, in solution of potassa; but it is not attacked by ammonia. It combines with sulphur, selenium, and phosphorus.*

Characters of its salts,

930. The salts of yttria have in general a sweet taste, and the sulphate, as well as many of its salts, has an amethyst colour. It is precipitated as a hydrate by the pure alkalies, and it is not redissolved by an excess of the precipitant; but alkaline carbonates, es-

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* *Phil. Mag.* and *Annals*, v. 393.

pecially that of ammonia, dissolve it in the cold, though less freely than glucina, and carbonate of yttria is precipitated by boiling. Of all the earths it bears the closest resemblance to glucina; but it is readily distinguished from it by the colour of its sulphate, by its insolubility in pure potassa, and by yielding a precipitate with ferrocyanuret of potassium.*

Equivalent. 931. The equivalent of yttrium, as deduced by Berzelius, is 32.2; and that of yttria, which is probably a protoxide, is 40.2. T.

Thorium.

Symb. Th *Equiv.* 59.6

Discovery, 932. The earthy substance formerly called *thorina*, was found by Berzelius to be phosphate of yttria; but in 1828 he discovered a new earth, so similar in some respects to what was formerly called thorina, that he applied this term to the new substance.

Process for, 933. The metallic base of thorina (thorium) was procured by the action of potassium on chloride of thorium, decomposition being accompanied with a slight detonation. On washing the mass, thorium is left in the form of a heavy metallic powder, of a deep leaden-gray colour; and when pressed in an agate mortar, it acquires metallic lustre and an iron-gray tint.

Oxidation of, 934. Thorium is not oxidized either by hot or cold water; but when gently heated in the open air, it burns with great brilliancy, comparable to that of phosphorus burning in oxygen. The resulting thorina is as white as snow, and does not exhibit the least trace of fusion. It is not attacked by caustic alkalies at a boiling heat, is scarcely at all acted on by nitric acid, and very slowly by the sulphuric; but it is readily dissolved with disengagement of hydrogen gas by hydrochloric acid. T.

Thorina, 935. *Thorina* was procured from a rare mineral from Norway, called *thorite*, of which it constitutes 57.91 per cent.

Properties, 936. Thorina is a white earthy substance, of sp. gr. 9.402 insoluble in all the acids except the sulphuric; it dissolves even in that with difficulty. It is precipitated from its solutions by the caustic alkalies as a hydrate, and in this state absorbs carbonic acid from the atmosphere, and dissolves readily in acids. Its exact composition is not known; but its equivalent is about 67.6.

Distinguished. 937. Thorina is distinguished from alumina and glucina by its insolubility in pure potassa; from yttria by forming with sulphate of potassa a double salt which is quite insoluble in a cold saturated solution of sulphate of potassa.

Zirconium.

Symb. Zr *Eq.* about 33.7 ?

Zirconium, 938. The experiments of Davy proved zirconia to be an oxidized body, and afforded a presumption that its base, *Zirconium*, is of a metallic nature. When potassium was brought into contact with zirconia ignited to whiteness, potassa was formed, and dark particles of a metallic aspect were diffused through the alkali. The decomposition of this earth, however, had not been effected in a satisfactory

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* Berzelius.

manner until the year 1824, when Berzelius succeeded in obtaining zirconium in an insulated state.

How procured,

939. Zirconium is procured by heating a mixture of potassium with the double fluoride of zirconia and potassa, carefully dried, in a tube of glass or iron, by means of a spirit lamp. The reduction takes place at a temperature below redness, and without emission of light. The mass is then washed with boiling water, and afterwards digested for some time in dilute hydrochloric acid. A small portion of hydrate of zirconia however still adheres to the zirconium.

Properties,

940. Zirconium thus obtained, is in the form of a black powder, which may be boiled in water without being oxidized, and is attacked with difficulty by the sulphuric or nitro-hydrochloric acids; but is dissolved readily, and with disengagement of hydrogen by hydrofluoric acid.

Combustion of.

941. Heated in the open air it takes fire at a temperature far below incandescence, burns brightly and is converted into zirconia.

942. Zirconium may be pressed out into thin shining scales of a dark gray colour, and of a lustre which may be called metallic, but its particles adhere together very feebly. It is a non-conductor of electricity.

Sesquioxide or zirconia,

943. *Sesquioxide of Zirconium*, or *Zirconia*, $2Zr+3O$, $\overset{\cdots}{\underline{Z}}r$, or Zr^2O^3, was discovered in 1789 by Klaproth. It is obtained from the zircon or jargon of Ceylon. The zircon in fine powder may be fused with litharge in the ratio of 17 to 21, when a glass is obtained which is soluble in acids.

Properties,

944. Zirconia is in the form of a fine white powder, which, when rubbed between the fingers, has somewhat of the harsh feel of silica. It is entirely destitute of taste or smell. Its specific gravity exceeds 4. It is insoluble in water, yet appears to have some affinity for that fluid, retaining when slowly dried after precipitation, one third its weight, and appearing like gum arabic.

Effect of heat.

945. Exposed to a strong heat, zirconia fuses, assumes a light gray colour; and such hardness, on cooling, as to strike fire with steel, and to scratch even rock crystal.*

SECTION V. *Metals, the Oxides of which are neither Alkalies nor Earths.*

1. METALS WHICH DECOMPOSE WATER AT A RED HEAT.

Manganese.

Symb. Mn *Equiv.* 27.7

946. The common ore of manganese is the black or peroxide, which is found native in great abundance.

Process for obtaining metallic manganese.

The metal is obtained by mixing this oxide, finely powdered, with pitch, making it into a ball, and putting this into a crucible, with powdered charcoal, one tenth of an inch thick on the sides, and one fourth of an inch deep at the bottom. The empty space is then to be filled with powdered charcoal, a cover is to be luted on, and the crucible exposed, for one hour, to the strongest heat that can be raised.

Manganese is a hard brittle metal, of a grayish-white colour, and granular texture. When exposed to air it becomes an oxide. Its specific gravity is 8.013. It is not attracted by the magnet, except when contaminated with iron.

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* For other characters see Turner's *Elements*, 303.

Equivalent. 947. It slowly decomposes water at common temperatures, and rapidly at a red heat.

Oxides of Manganese.[*]

Protoxide, 948. *Protoxide* Mn+O, $\dot{Mn}$, or MnO, 27.7 1 eq. mang. + 8 1 eq. oxy. = 35.7 equiv., is that oxide of manganese which is a strong salifiable base present in all the ordinary salts of this metal, and which appears to be its lowest degree of oxidation.

Process for, It may be formed by exposing the peroxide, sesquioxide, or red oxide of manganese to the combined agency of charcoal and a white heat; or by exposing either of the oxides of manganese, contained in a glass or iron tube, to a current of hydrogen gas at a high temperature. For this purpose the red oxide, prepared from the nitrate of oxide of manganese, is the best.

Another, It is also obtained by fusing the chloride in a platinum crucible with about twice its weight of carbonate of soda and dissolving the chloride of sodium in water.

Properties. 949. It is of a green colour, and, according to some, attracts oxygen rapidly from the air, but in Turner's experiments was very permanent, undergoing no change during nineteen days.[†] It oxidized at 600°. It unites with acids producing the same salts as the carbonate. If quite pure it should dissolve in cold dilute sulphuric acid.[‡]

Salts. 950. The salts of manganese are in general colourless if pure, but often have a shade of pink from the presence of red oxide or permanganic acid. The alkalies precipitate the protoxide as a white hydrate, the carbonates give a white carbonate, and ferrocyanuret of potassium gives a white ferrocyanuret of manganese, a character by which the absence of iron may be demonstrated. The white precipitates become brown from absorption of oxygen.

Sesquioxide, 951. *Sesquioxide* 2Mn+3O, $\underline{\dddot{Mn}}$, or Mn^2O^3, 55.4 2 eq. mang. + 24 3 eq. oxy. = 79.4 equiv., occurs nearly pure in nature, and is found as a hydrate at Ilefeld in the Hartz. It may be formed artificially by exposing peroxide of manganese for a considerable time to a moderate red heat, and, therefore, is the chief residue of the usual process for procuring a supply of oxygen gas.

Properties. 952. The colour varies with the source from which it is derived. That which is procured by means of heat from the native peroxide or hydrated sesquioxide has a brown tint; but when prepared from nitrate of oxide of manganese, it is nearly as black as the peroxide, and the native sesquioxide is of the same colour. With sulphuric and hydrochloric acids, it yields oxygen and chlorine gases. It is more easily attacked than the peroxide by cold sulphuric acid. With strong nitric acid, it yields a soluble protonitrate and the peroxide.

Peroxide, 953. *Peroxide* Mn+2O, 27.7 1 eq. mang. + 16 2 eq. oxy. = 43.7 equiv. This is the well known ore commonly called

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[*] In studying metallic oxides, it is necessary, as remarked by Turner, to distinguish oxides formed by the direct union of oxygen and a metal, from those that consist of two other oxides united with each other, and which therefore, in composition, partake of the nature of a salt rather than of an oxide.

[†] *Phil. Trans. Edin.* 1828, and *Phil. Mag.* iv.

[‡] For the method of preparing pure salts from common peroxide of manganese, see Turner's *Elements*, 6th ed., p. 305.

from its colour the black oxide. It generally occurs massive, of an earthy appearance, and mixed with other substances, such as siliceous and aluminous earths, oxide of iron and carbonate of lime. It also occurs crystallized, with an imperfect metallic lustre. It may be made artificially by exposing the nitrate of manganese to a commencing red heat, until the whole of the nitric acid is expelled.

Properties,

954. The peroxide of manganese undergoes no change on exposure to the air. It is insoluble in water, and does not unite either with acids or with alkalies. When boiled with sulphuric acid, it yields oxygen gas, and a sulphate of the protoxide is formed (365). With hydrochloric acid, a hydrochlorate is generated, and chlorine is evolved (608). On exposure to a red heat, it is converted with evolution of oxygen gas, into the sesquioxide of manganese.

Uses.

955. The peroxide of manganese is employed in the arts, in the manufacture of glass, and in preparing chlorine for bleaching. In the laboratory it is used for procuring chlorine and oxygen gases, and in the preparation of the salts of manganese.

Black wad,

956. The hydrated peroxide of manganese which is sometimes called *black wad*, and which occurs in froth-like coatings on other minerals, is remarkable for its spontaneous inflammation with oil.

Spontaneous inflammation of.

If half a pound of this be dried before a fire, and afterwards suffered to cool for about an hour, and it be then loosely mixed or kneaded with two ounces of linseed oil; the whole, in something more than half an hour, becomes gradually hot, and at length bursts into flame. U. 573.

Red oxide,

957. *Red oxide Manganese.* $MnO+Mn^2O^3$, or $2MnO+MnO^2$, 83.1 3 eq. mang. + 32 4 eq. oxy. = 115.1 equiv. The substance called red oxide of manganese, *oxidum manganoso-manganicum* of Arfwedson, occurs as a natural production, and may be formed artificially by exposing the peroxide or sesquioxide to a white heat either in close or open vessels. It is also produced by absorption of oxygen from the atmosphere when the protoxide is precipitated from its salts by pure alkalies, or when the anhydrous protoxide or carbonate is heated to redness.

Fused, &c.

958. Fused with borax or glass it communicates a beautiful violet tint, a character by which manganese may be easily detected before the blow-pipe; and it is the cause of the rich colour of the amethyst. By cold concentrated sulphuric acid it is dissolved in small quantity. The liquid has an amethyst tint, which disappears when heat is applied, or by the action of deoxidizing substances.

Composition.

959. It may be doubted whether the red oxide is not rather a kind of salt composed of two other oxides, than a direct compound of manganese and oxygen. From the ratio of its elements it may consist either of

Sesquioxide . .	79.4 or one eq.	or	Peroxide . .	43.7 or one eq.
Protoxide . .	35.7 or one eq.		Protoxide . .	71.4 or two eq.
	115.1			115.1

It contains 27.586 per cent. of oxygen, and loses 6.896 per cent. when converted into the green or protoxide.* T.

Varvicite.

* *Varvicite.* $Mn^2O^3+2MnO^2$ (probably), 110.8 4 eq. mang. + 56 7 eq. oxy. = 166.8 equiv. This compound is known only as a natural production, having been first noticed a few years ago by Phillips among some ores of manganese found at Hartshill, in Warwickshire. The locality of the mineral suggested its name. Varvicite was at

Manganic acid.

960. *Manganic Acid.* $Mn+3O, \dddot{M}$, or MnO^3, 27.7 1 eq. mang. + 24 3 eq. oxy. = 51.7 equiv. Manganese is capable of forming an acid with oxygen. Manganate of potassa is generated when hydrate or carbonate of potassa is heated to redness with peroxide of manganese; and nitre may be used successfully, provided the heat be high enough to decompose the nitrate of potassa.*

Mineral chameleon.

961. The materials absorb oxygen from the air when fused in open vessels; but manganate of potassa is equally well formed in close vessels, one portion of oxide of manganese then supplying oxygen to another. The product has been long known under the name of *mineral chameleon,* from the property of its solution to pass rapidly through several shades of colour: on the first addition of cold water, a green solution is formed which soon becomes blue, purple, and red; and ultimately a brown flocculent matter, hydrated peroxide of manganese, subsides, and the liquid becomes colourless.†

Exp.

Put equal quantities of this substance into two separate glass vessels, and pour on the one hot, and on the other cold water. The hot solution will have a beautiful green colour, and the cold one a deep purple. The same material, with water of different temperatures, assumes various shades of colour.

Theory.

The phenomena are owing to the formation of manganate of potassa of a green colour, and to its ready conversion into the red permanganate of potassa, the blue and purple tints being due to a mixture of these compounds. Manganic acid itself cannot be obtained in an uncombined state, because it is then resolved into the hydrated peroxide and oxygen.

Manganate of potassa.

962. Manganate of potassa is obtained in crystals by forming a concentrated solution of mineral chameleon in cold water, very pure and free from carbonic acid, allowing it to subside in a stoppered bottle, and evaporating the clear green solution in vacuo with the aid of sulphuric acid. All contact of paper and other organic matter must be carefully avoided, since they deoxidize the acid, and the process be conducted in a cool apartment. The crystals are anhydrous, and permanent in the dry state; but in solution the carbonic acid of the air suffices to decompose the acid, or even simple dilution with cold water. Mixed with a solution of potassa, the manganate may be crystallized a second time in vacuo without change.

Permanganic acid.

963. *Permanganic Acid,* $^2Mn+7O, \underline{\overset{\cdot\cdot\cdot\cdot\cdot\cdot\cdot}{Mn}}$, or Mn^2O7, 55.4 2 eq. mang. + 56 7 eq. oxy. = 111.4 equiv., is obtained by heating a solution of mineral chameleon.

Wöhler's process.

The process of Wöhler consists in fusing chlorate of potassa in a platinum crucible, and adding peroxide of manganese in fine powder. Gregory has improved this; he mixes 4 parts of the peroxide with 3½ parts of the chlorate, adds it to 5 parts of hydrate of potassa dissolved in a small quantity of water, evaporates to

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first mistaken for peroxide of manganese, but is readily distinguished by its stronger lustre, greater hardness, more lamellated texture, and by yielding water freely when heated to redness. Its sp. gr. is 4.531. When strongly heated it is converted into red oxide, losing 5.725 per cent. of water, and 7.385 of oxygen.

* One part of manganese well mixed with three or four of nitre may be exposed to a bright red heat for half an hour in a crucible. The crucible should be but one third full.

† These changes, which are more rapid by dilution and with hot water, have been successively elucidated by Chevillot and Edwards, Forchammer and Mitscherlich. *An. de Ch. et de Ph.* viii. and xlix. 113, and *An. of Phil.* xvi.

dryness, and exposes the fine powder in a platinum crucible to a low red heat. The mass not fused is again powdered and added to a large quantity of boiling water; when this is clear it is to be decanted, rapidly concentrated, and crystallized. The crystals are to be washed in a little cold water and redissolved in the smallest possible quantity of boiling water.

Acid obtained,

The acid may be obtained by adding to a solution of permanganate of baryta dilute sulphuric acid to precipitate the baryta.

Properties,

964. This acid has a rich red colour; contact with paper or linen as in filtering, particles of cork, organic particles floating in the atmosphere decompose it rapidly; colouring matters are bleached by it; and in pure water its decomposition begins at 86°, and is complete at 212°. On these occasions oxygen gas is abstracted or given out, and hydrated peroxide of manganese subsides.

Its salts.

965. The salts of permanganic acid are more permanent than the free acid; so that most of them may be boiled in solution, especially if concentrated. When heated they give out oxygen gas; they deflagrate like nitre, and detonate powerfully with phosphorus.

Composition.

966. In constitution this acid bears a remarkable analogy to perchloric acid.*

Perchloride,

967. *Perchloride of Manganese.* $2Mn+7Cl$, or Mn^2Cl^7, 55.4 2 eq. mang. + 247.94 7 eq. chlor. = 303.34 equiv. This compound is formed by putting a solution of permanganic into strong sulphuric acid, and then adding fused sea-salt.

The best mode of preparation is to form the green mineral chameleon, and acidulate with sulphuric acid: the solution, when evaporated, leaves a residue of sulphate and permanganate of potassa. This mixture, treated by strong sulphuric acid, yields a solution of permanganic acid, to which are added small fragments of sea-salt, as long as coloured vapour continues to be evolved.†

Properties.

968. The perchloride, when first formed, appears as a vapour of a copper or greenish colour; but on traversing a glass tube cooled to —4°, it is condensed into a greenish-brown coloured liquid. When generated in a capacious tube, its vapour gradually displaces the air, and soon fills the tube. If it is then poured into a large flask, the sides of which are moist, the colour of the vapour changes instantly on coming into contact with the moisture, a dense smoke of a pretty rose tint appears, and hydrochloric and permanganic acids are generated.

Composition.

It is hence analogous in composition to permanganic acid, its elements being in such a ratio that

1 eq. perchloride and 7 eq. water yield 1 eq. permang. acid and 7 eq. hydrochloric acid.
$2Mn+7Cl$ $7(H+O)$ $2Mn+7O$ $7(H+Cl)$.

Perfluoride.

969. *Perfluoride of Manganese.* $2Mn+7F$, or Mn^2F^7, 55.4 2 eq. mang. + 130.76 7 eq. oxy. = 186.16 equiv. This gaseous compound‡ is formed by mixing common mineral chameleon with half its weight of fluor spar, and decomposing the mixture in a platinum vessel by fuming sulphuric acid. The fluoride is then

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Protochloride.

* *Protochloride of Manganese*, $Mn+Cl$, or $MnCl$, 27.7 1 eq. mang. + 35.42 1 eq. chlor. = 63.12 equiv., is best prepared by evaporating a solution of the chloride to dryness by a gentle heat, and heating the residue to redness in a glass tube, while a current of hydrochloric acid gas is transmitted through it. The heat of a spirit-lamp is sufficient for the purpose. It fuses readily at a red heat, and forms a pink-coloured lamellated mass on cooling. It is deliquescent, and of course very soluble in water.

† *Edin. Jour. of Sci.* viii. 179.

‡ Discovered by Dumas and Wöhler, *Edin. Jour. of Sci.* ix.

disengaged in the form of a greenish-yellow gas or vapour, of a more intensely yellow tint than chlorine. When mixed with atmospheric air, it instantly acquires a beautiful purple-red colour; and it is freely absorbed by water, yielding a solution of the same red tint. It acts instantly on glass, with formation of fluosilicic acid gas, a brown matter being at the same time deposited, which becomes of a deep purple-red tint on the addition of water.[*]

Iron.

Symb. Fe *Equiv.* 28 ?

Iron.

970. The most important native combinations of iron, whence the immense supplies for the arts of life are drawn, are the oxides. Iron is also found combined with sulphur, and with several acids; it is so abundant that there are few fossils free from it. It is also found in some animal and vegetable bodies, and in several mineral waters.

Native.

Iron is sometimes found native,[†] and is usually regarded as of meteoric origin, for it is invariably alloyed by a portion of the metal nickel, and a similar alloy is found in *meteoric stones*. *Native Iron* is flexible, cellular, and often contains a green substance of a vitreous appearance. It has been found in Africa, in America, and in Siberia, where a mass of it weighing 1600 lbs. was discovered by Pallas. The mass found in Peru, described by Don Rubin de Celis, weighed 15 tons.

Properties.

971. Iron is a metal of a blue white colour, fusible at a white heat. Its specific gravity is 7.88. It has not been so long known as many of the other metals; it was, however, employed in the time of Moses for cutting instruments. It is extremely ductile, but cannot be hammered out into very thin leaves.

Combines with oxygen.

972. Exposed to heat and air iron quickly oxidizes, or in common language, rusts. If the temperature of the metal be raised, this change goes on more rapidly, and when made intensely hot, takes place with the appearance of actual combustion. Thus the small fragments, which fly from a bar of iron during forging, undergo a vivid combustion in the atmosphere; and iron filings, projected upon the blaze of a torch, burn with considerable brilliancy. The oxide, obtained in these ways is of a black colour, and is still attracted by the magnet.

Effect of water, at common temperatures.

973. By contact with water at the temperature of the atmosphere, iron becomes slowly oxidized, and hydrogen gas is evolved. When the steam of water is brought into contact with red-hot iron, the iron is converted into black oxide; and an immense quantity of hydrogen gas set at liberty (405). The iron is afterward found to have lost all its tenacity, and may be crumbled down into a black powder, to which the name of *finery cinder* was given by Priestley.

Of steam.

Protosulphuret.

[*] *Protosulphuret of Manganese*, $Mn+S$, or MnS. 27.7 1 eq. mang. + 16.1 1 eq. sulph. = 43.8 equiv., may be procured by igniting the sulphate with one sixth of its weight of charcoal in powder.[*] It is also formed by the action of hydrosulphuric acid gas on the protosulphate at a red heat.[†] It occurs native in Cornwall, and at Nagyag in Transylvania. It dissolves completely in dilute sulphuric or hydrochloric acid, with disengagement of very pure hydrosulphuric acid gas.

[†] Native iron of terrestrial origin has been observed at Canaan, Conn., and in Guilford Co. N. C. J. D. Dana's *System of Mineralogy*, 1837.

[*] Berthier. [†] Arfwedson in *Ann. of Phil.* vol. vii. N. S.

Of sulphuric acid.

974. When iron is dissolved in diluted sulphuric acid, the acid is not decomposed; but the metal is oxidized at the expense of the water and hydrogen gas is obtained (378).*

The eq. of iron has not been determined with accuracy.

Protoxide,

975. *Protoxide of Iron,* Fe+O, $\dot{\mathrm{F}}\mathrm{e}$, or $\dot{\mathrm{F}}\mathrm{eO}$, 28 1 eq. iron + 8 1 eq. oxy. = 36 equiv. This oxide is the base of the native carbonate of iron, and of the green vitriol of commerce. It is doubtful if it has ever been obtained in an insulated form. Its salts, particularly when in solution, absorb oxygen from the atmosphere with such rapidity that they may even be employed in eudiometry. This protoxide is always formed with evolution of hydrogen gas when metallic iron is put into dilute sulphuric acid; and its composition may be determined by collecting and measuring the gas which is disengaged.

Precipitated.

976. Protoxide of iron is precipitated from its salts as a white hydrate by pure alkalies, as a white carbonate by alkaline carbonates, and as a white ferrocyanuret by ferrocyanuret of potassium. The two former precipitates become first green and then red, and the latter, green and blue by exposure to the air. The solution of gall-nuts produces no change of colour. Hydro-sulphuric acid does not act if the protoxide is united with any of the stronger acids; but alkaline hydrosulphates cause a black precipitate, protosulphuret of iron.

Sesquioxide,

977. *Sesquioxide of Iron.* 2Fe+3O, $\dddot{\underline{\mathrm{F}}}\mathrm{e}$, or Fe^2O^3, 56 2 eq. iron + 24 3 eq. oxy. = 80 equiv. The red or sesquioxide is a natural product, known as *red hæmatite.* It occurs massive and fibrous. It may be made by dissolving iron in nitro-hydrochloric acid, and adding an alkali. The hydrate of the red oxide, consists of 80 parts or one eq. of the sesquioxide, and 18 parts or two eq. of water.

Properties.

978. It is not attracted by the magnet. Fused with vitreous substances, it communicates to them a red or yellow colour. It combines with most of the acids, forming salts, the greater number of which are red. Its presence may be detected by very decisive tests, The pure alkalies, fixed or volatile, precipitate it as the hydrate. Alkaline carbonates have a similar effect, peroxide of iron not forming a permanent salt with carbonic acid. With ferrocyanuret of potassium it forms Prussian blue. Sulphocyanuret of potassium causes a deep blood-red; and infusion of gall-nuts, a black colour. Hydrosulphuric acid converts the sesquioxide into protoxide of iron, with deposition of sulphur. These reagents, and especially ferrocyanuret and sulphocyanuret of potassium, afford an unerring test of the presence of minute quantities of sesquioxide of iron. On this account it is customary, in testing for iron, to convert it into the

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Action of nitric acid.

* The action of nitric acid on iron is attended by a series of very remarkable phenomena, which have been recently observed by Schönbein. He observed that this acid of sp. gr. 1.35 though capable of acting with violence on ordinary iron, was inert on an iron wire, one extremity of which had been previously made red-hot. He found, too, that this indifference to nitric acid, may be communicated, by mere contact, from one iron wire to another, by submersion for a few moments into strong nitric acid, or by making it the positive electrode of a galvanic current, the negative electrode having been previously introduced into the acid. Under these circumstances the wire does not combine with the oxygen liberated. Faraday has found that the same property is given to iron by contact with platinum, and that the effect is not limited to nitric acid. See the original papers in *Phil. Mag.* and *Ann.* ix. 53, x. 133, &c.

sesquioxide, an object which is easily accomplished by boiling the solution with a small quantity of nitric acid.

Black or magnetic oxide,

979. *Black, or Magnetic Oxide.* $FeO+Fe^2O^3$, 36 1 eq. protox. iron + 80 1 eq. sesquiox. iron = 116 equiv. This substance, the *oxidum ferroso-ferricum* of Berzelius, long supposed to be protoxide of iron, contains more oxygen than the protoxide, and less than the red oxide. It cannot be regarded as a definite compound of iron and oxygen; but it is composed of the two real oxides. It occurs native, frequently crystallized in the form of a regular octohedron; and it is not only attracted by the magnet, but is itself sometimes magnetic. It is always formed when iron is heated to redness in the open air; and is likewise generated by the contact of watery vapour with iron at elevated temperatures.

Composition,

980. The composition of the product, however, varies with the duration of the process and the temperature which is employed. Thus, according to Buchholz, Berzelius, and Thomson, 100 parts of iron, when oxidized by steam, unite with nearly 30 of oxygen; whereas in a similar experiment performed by Gay-Lussac, 37.8 parts of oxygen were absorbed.

Action of acids on.

981. The nature of the black oxide is farther elucidated by the action of acids. On digesting the black oxide in sulphuric acid, an olive-coloured solution is formed, containing two salts, sulphate of the sesquioxide and protoxide, which may be separated from each other by means of alcohol.* The solution of these mixed salts gives green precipitates with alkalies, and a very deep blue ink with infusion of gall-nuts. The black oxide of iron is the cause of the dull green colour of bottle glass.

Protochloride,

982. *Protochloride of Iron.* Fe+Cl, or FeCl, 28 1 eq. iron + 35.42 1 eq. chlor. = 63.42 equiv. This compound is formed by transmitting dry hydrochloric acid gas over iron at a red heat, when hydrogen gas is evolved and the surface of the iron is covered with a white crystalline protochloride which at a stronger heat is sublimed. Also, on acting with hydrochloric acid on iron, which is dissolved with evolution of hydrogen gas, evaporating to dryness, and heating to redness in a tube without exposure to the air.

Solution.

983. Protochloride of iron dissolves freely in water, yielding a pale green solution, from which rhomboidal prisms of the same colour are obtained by evaporation. The crystals contain several equivalents of water of crystallization, deliquesce by exposure to the air, owing to the formation of sesquichloride, and are soluble in alcohol as well as water. The aqueous solution absorbs oxygen from the air, and becomes yellow from the formation of sesquichloride of iron: one portion of iron takes oxygen from the air, and yields its chlorine to another portion of iron, whereby sesquichloride and sesquioxide of iron are generated, and the latter falls as an ochreous sediment combined with some of the sesquichloride.

Sesquichloride.

984. *Sesquichloride of Iron,* 2Fe+3Cl, or Fe^2Cl^3, 56 2 eq. iron + 106.26 3 eq. chlor. = 162.26 equiv., is formed by the combustion of iron wire in dry chlorine gas, and by transmitting that gas over iron moderately heated; when it is obtained in small iridescent plates of a red colour, which are volatile at a heat a little above 212°,

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* Proust and Gay-Lussac.

deliquesce readily, and dissolve in water, alcohol, and ether. On agitating ether with a strong aqueous solution of the sesquichloride, the ether abstracts a part of it, and acquires a gold-yellow colour. The readiest mode of obtaining a solution of the sesquichloride is to dissolve sesquioxide of iron in hydrochloric acid. On concentrating to the consistence of syrup and cooling, it separates as red crystals, which by distillation yield at first water and hydrochloric acid, and then anhydrous sesquichloride of iron, leaving a compound of sesquioxide and sesquichloride of iron in crystalline laminæ. **Process,**

985. *Protiodide of Iron.* $Fe+I$, or FeI, 28 1 eq. iron + 126.3 1 eq. iod. = 154.3 equiv. It exists as a pale green solution when iodine is digested with water and iron wire, the latter being in excess; and on evaporating the solution, without exposure to the air, to dryness, and heating moderately, the protiodide is fused, and on cooling becomes an opaque crystalline mass of an iron-gray colour and metallic lustre. It is deliquescent and very soluble in water and alcohol. **Protiodide,**

986. Its aqueous solution attracts oxygen rapidly from the air, undergoing the same kind of change as the protochloride: to preserve a solution of protiodide as such, a long piece of iron wire should be kept permanently in the liquid. This compound has been very successfully employed in medical practice.* **Solution,** **Use.**

987. *Sulphurets of Iron.* These elements have for each other a remarkably strong affinity, and unite under various circumstances and in several proportions. The two lowest degrees of sulphuration, the *tetrasulphuret* and *disulphuret*, were prepared by Arfwedson by transmitting a current of hydrogen gas, at a red heat, over the anhydrous disulphate of sesquioxide of iron to procure the tetrasulphuret, and over anhydrous sulphate of protoxide of iron for the disulphuret. In both cases sulphurous acid and water are evolved, and the resulting sulphurets are left as grayish-black powders, susceptible of a metallic lustre by friction. They both dissolve in dilute sulphuric acid with evolution of hydrogen and hydrosulphuric acid gases.† **Sulphurets.**

988. *Protosulphuret of Iron,* $Fe+S$, or FeS, 28 1 eq. iron + 16.1 1 eq. sulph. = 44.1 equiv., is prepared by heating thin laminæ **Protosulphuret.**

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* *Sesquiodide of Iron,* $2Fe+3I$, or Fe^2I^3, 56 2 eq. iron + 378 9 3 eq. iod. = 434 9 equiv., of a yellow or orange colour according to the strength of the solution, is obtained by freely exposing a solution of the protiodide to the air, or digesting iron wire with excess of iodine. gently evaporating and subliming the sesquiodide. It is a volatile red compound, deliquescent, and soluble in water and alcohol.

The *bromides* of iron are formed under similar conditions to the chlorides and iodides, and are very analogous to them in their properties.

Protofluoride of Iron, 28 1 eq. iron + 18.68 1 eq. fluor. = 46.68 is best prepared by dissolving iron in a solution of hydrofluoric acid, out of which it crystallizes as the acid becomes saturated, in small white square tables, which are sparingly soluble in water, and become pale yellow by the action of the air. By heat they part with their water of crystallization, and afterwards bear a red heat without decomposition. Berzelius.

Sesquifluoride of Iron, $2Fe+3F$, or Fe^2F^3, 56 2 eq. iron + 56.04 3 eq. fluor. = 112.04 equiv., is formed by dissolving sesquioxide of iron in hydrofluoric acid and yields a colourless solution even when saturated. By evaporation it is left as a crystalline mass of a pale flesh-colour, and of a mild astringent taste. It is sparingly soluble in water.

† *Tetrasulphuret of Iron.* $4Fe+S$, or Fe^4S, 112 4 eq. iron + 16.1 1 eq. sulph. = 128.1 equiv.

Disulphuret of Iron. $2Fe+S$, or Fe^2S, 56 2 eq. iron + 16.1 1 eq. sulph. = 72.1 equiv.

of iron to redness with sulphur in a covered Hessian crucible, and continuing the heat until any excess of sulphur is expelled. The iron is found with a crust of protosulphuret, which is brittle, of a yellowish-gray colour and metallic lustre, and is attracted by the magnet. When pure it is completely dissolved by dilute sulphuric acid, yielding pure hydrosulphuric acid (754). The protosulphuret of iron exists in nature as an ingredient in variegated copper pyrites; and it falls on mixing hydrosulphate of ammonia with sulphate of protoxide of iron as a black precipitate, which oxidizes rapidly by absorbing oxygen from the air, as soon as the excess of hydrosulphate of ammonia is removed by washing.

Sesquisulphuret. 989. *Sesquisulphuret of Iron*, 2Fe+3S, or Fe^2S^3, 56 2 eq. iron + 48.3 3 eq. sulph. = 104.3 equiv., is formed in the moist way by adding sesquichloride of iron drop by drop to hydrosulphate of ammonia or sulphuret of potassium in excess, and falls as a black precipitate, which is oxidized readily by the air. In the dry way it is slowly produced by the action of hydrosulphuric acid gas on sesquioxide of iron at a heat not exceeding 212°, water being also formed; and by the action of the same gas on the hydrated sesquioxide at common temperatures. This sulphuret, when anhydrous, has a yellowish-gray colour, is not attracted by the magnet, and dissolves in dilute sulphuric or hydrochloric acid, yielding hydrosulphuric acid and a residue of bisulphuret of iron.*

Bisulphuret. 990. *Bisulphuret of Iron.* Fe+2S, or FeS^2, 28 1 eq. iron + 32.2 2 eq. sulph. = 60.2 equiv. This, the iron pyrites of mineralogists, exists abundantly in the earth. It occurs in cubes or some allied form, has a yellow colour, metallic lustre, a density of 4.981, and is so hard that it strikes fire with steel. Some varieties have a white colour; but these usually contain arsenic. Others occur in rounded nodules, have a radiated structure divergent from a common centre, are often found in beds of clay and are much disposed by the influence of air and moisture to yield sulphate of protoxide of iron.

Action of acids. 991. Bisulphuret of iron is not attacked by any of the acids except the nitric, and its best solvent is the nitro-hydrochloric acid. Heated in close vessels it gives off nearly half its sulphur, and is converted into magnetic iron pyrites.

Magnetic. 992. *Magnetic Pyrites.* $5FeS+FeS^2$, 60.2 1 eq. bisulph. of iron + 220.5 5 eq. protosuph. of iron = 280.7 equiv. This is a natural product, termed magnetic pyrites from being attracted by the magnet, and was formerly regarded as protosulphuret of iron; but it may be regarded as a compound of bisulphuret and protosulphuret. It is formed by heating the bisulphuret to redness in close vessels, by fusing iron filings with half their weight of sulphur, or by rubbing sulphur upon a rod of iron heated to whiteness (754). It yields hydrosulphuric acid gas.†

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* Berzelius.

Diphosphuret. † *Diphosphuret of Iron.* 2Fe+P, or Fe^2P, 56 2 eq. iron + 15.7 1 eq. phosph. = 71.7 equiv. It is prepared by exposing the phosphate of protoxide of iron to a strong heat in a covered crucible lined with charcoal, the excess of phosphorus being dissipated in vapour. It is a fused granular mass, of the colour and lustre of iron, but very brittle, and is not attacked by hydrochloric acid. It is sometimes contained in metallic iron, to the properties of which it is very injurious by rendering it brittle at common temperatures.

Perphos. of Iron. 3Fe+4P, or Fe^3P^4, 84 3 eq. iron+62.8 1 eq. phosph.=146.8 equiv.

Carburets.

993. *Carburets of Iron.* Iron combines with carbon in various proportions; and the varieties of proportion occasion great differences of properties in the compounds. On these varieties, and the occasional combination of a small proportion of oxygen, depend the qualities of the different kinds of iron used in the arts, as cast-iron, steel, &c. &c.

Graphite,

994. The substance termed *Graphite, Plumbago*, and *Black lead*, is a mechanical mixture of charcoal and iron; the artificial graphite is a real carburet. The last may be formed by exposing iron with excess of charcoal to a violent and long continued heat.

Uses.

The first is not an uncommon mineral, though rarely found of sufficient purity for the manufacture of pencils:* the coarser kinds and the dust, are melted with sulphur to form common carpenters' pencils: crucibles are sometimes made of it, and it forms an ingredient in compositions for covering cast-iron, and for diminishing friction in machines. It contains from 4 to 10 per cent. of iron.

Effect of heat, &c.

995. Plumbago burns with great difficulty: when intensely heated in a Toricellian vacuum by a Voltaic battery, Davy found that its characters remained wholly unaltered, neither could any evidence of its containing oxygen be derived from the action of potassium. But when exposed to the focus of a powerful burning lens in oxygen gas, it was observed that the gas became clouded, and that dew was deposited, indicating the presence of hydrogen or of water.†

Varieties of iron,

996. An extremely important part of the chemical history of iron relates to the varieties of the metal which are found in commerce. These are much too numerous to be dwelt upon here; the principal of them are *cast iron, wrought iron*, and *steel.*

Cast iron,

Of cast iron, there are two principal varieties, distinguished by the terms *white* and *gray*. The first is very hard and brittle, and when broken, of a radiated texture. Acids act upon it but slowly, and exhibit a texture composed of a congeries of plates, aggregated in various positions.

Gray iron.

Gray or mottled iron is softer and less brittle; it may be bored and turned in the lathe. When immersed in dilute hydrochloric acid, it affords a large quantity of black insoluble matter, which Daniell considers as a triple compound of carbon, iron, and silicon, and which has some very singular properties. The texture of the metal resembles bundles of minute needles.

Cast iron always contains impurities, such as charcoal, undecomposed ore, and earthy matters, which are often visible by mere inspection; and sometimes traces of chromium, manganese, sulphur, phosphorus and arsenic are present. It fuses readily at 2786° F.,‡ which is a full red heat, and in cooling it acquires a crystalline granular texture.

Process of puddling.

997. Cast iron is converted into wrought iron by a curious process, called *puddling*. The cast iron is put into a reverberatory furnace, and when in fusion is stirred, so that every part may be exposed to the air and flame. After a time the mass heaves, emits a

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* See a description of the mine at Borrowdale, in *Bost. Jour. Philos.* ii. 332.

† On the fusion of plumbago by means of Hare's deflagrator, see *Amer. Jour.* vi. 344, &c.

‡ Daniell.

blue flame, and gradually grows tough and becomes less fusible, and at length congeals. In that state it is passed successively between rollers, by which a large quantity of extraneous matter is squeezed out, and the bars are now malleable. They are cut into pieces, placed in parcels in a very hot reverberatory furnace, and again hammered and rolled out into bars. They are thus rendered more tough, flexible and malleable, but much less fusible.

Difference in quality. 998. The difference in the quality of the two kinds of cast iron, appears owing to the mode of combination, rather than to a difference in the proportion of carbon. According to Karsten, the carbon of the white is combined with the whole mass of iron, and amounts as a maximum to 5.25 per cent.; the gray, on the contrary, contains from 3.15 to 4.65 per cent. of carbon, of which about three fourths are in the state of graphite.

Structure of wrought iron. 999. A bar of wrought iron, when its texture is examined in the mode pointed out by Daniell, presents a fasciculated appearance, the fibres running in a parallel and unbroken course throughout its length. This structure may be well seen by tearing a bar of wrought iron asunder.

Steel. 1000. Steel is commonly prepared by the process of cementation, which consists in filling a large furnace with alternate strata of bars of the purest malleable iron and powdered charcoal, closing every aperture so as perfectly to exclude atmospheric air, and keeping the whole during several days at a red heat. By this treatment the iron gradually combines with from 1.3 to 1.75 per cent. of carbon, its texture is greatly changed, and its surface is *blistered*. It is subsequently hammered at a red heat into small bars and beaten, it is then called *tilted steel;* and this broken up, heated, welded and again drawn out into bars, forms *shear steel.* Mackintosh of Glasgow, has introduced an elegant process of forming steel by exposing heated iron to a current of coal gas; when carburetted hydrogen is decomposed, its carbon enters into combination with iron, and hydrogen gas is evolved.

Properties. 1001. In ductility and malleability it is far inferior to iron; but exceeds it greatly in hardness, sonorousness, and elasticity. Its texture is also more compact, and it is susceptible of a higher polish. It sustains a full red heat without fusing, and is, therefore, less fusible than cast iron; but it is much more so than malleable iron. By fusion it forms cast steel, which is more uniform in composition and texture, and possesses a closer grain than ordinary steel.

Tempering. 1002. When steel is heated to a cherry-red colour, and then plunged into cold water, it becomes so extremely hard and brittle, as to be unfit for almost any practical purpose. To reduce it from this extreme hardness, is called by the workmen *tempering*, and is effected by again heating the steel to a certain point. The surface being a little brightened exhibits, when heated, various colours which constantly change as the temperature is increased, and by these colours it has been customary to judge of the temper of the steel.*

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* For more extended accounts of iron and steel, see Brande's *Chem.* ii. 35—Aikin's *Dict.* art. *Iron—Phil. Mag.* ii.—Supplement to *Encyclop. Brit.—Report of Brit. Assoc.* 1837—Dumas' *Traité de Chim.* iv. 599, and Thomson's *Inorg. Chem.* i. 481, 495.

Alloys. 1003. Steel admits of being alloyed with several other metals, and the alloys, as appears from a recent investigation of Stodart and Faraday* are applicable to various uses.

Zinc.

Symb. Zn *Equiv.* 32.3

Ore, 1004. This metal is obtained from carbonate of zinc or *calamine* and from the native sulphuret or *blende*.† The zinc of commerce or *spelter*, is generally impure, containing sulphur, lead, arsenic, copper, &c. **Reduction of.** It may be freed from these by distillation at a white heat in an earthern retort, to which a receiver full of water is adapted; but the first portions should be rejected as liable to contain arsenic and cadmium.

Properties of zinc. 1005. Zinc is a bluish white metal, its specific gravity varies from 6.8 to 7.1, it is malleable at 300°, but very brittle when its temperature approaches that of fusion, which is about 773°.‡ It is somewhat ductile, but its wire possesses little tenacity.

At a red heat it takes fire, burns with a bright flame, and is converted into a white flocculent substance, formerly called *pompholix*, *nihil album*, and *flowers of zinc*.

Oxidized. It is also oxidized by dilute sulphuric or hydrochloric acid, and the hydrogen evolved contains a small quantity of metallic zinc in combination.§

Protoxide. 1006. *Protoxide of Zinc.* $Zn+O$, $\dot{Zn}$, or ZnO, 32.3 1 eq. zinc +8 1 eq. oxy. = 40.3 equiv. This is the only oxide of zinc which acts as a salifiable base, and the only one of known composition. It is generated during the solution of zinc in dilute sulphuric acid, and may be obtained in a dry state by collecting the flakes which rise during the combustion of zinc, or by heating the carbonate to redness. At common temperatures it is white; but when heated to low redness, it assumes a yellow colour, which gradually disappears on cooling. It is quite fixed in the fire. It is insoluble in water.

1007. The protoxide is precipitated from its solutions as a white hydrate by pure potassa or ammonia, and as carbonate by carbonate of ammonia, but is completely redissolved by an excess of the precipitant. The fixed alkaline carbonates precipitate it permanently as white carbonate of protoxide of zinc.

Action of water. When metallic zinc is exposed for some time to air and moisture, or is kept under water, it acquires a superficial coating of a gray matter, which Berzelius describes as a *sub-oxide*. It is probably a mixture of metallic zinc and the protoxide.

Chloride. 1008. *Chloride of Zinc.* $Zn+Cl$, or $ZnCl$, 32.3 1 eq. zinc + 35.42 1 eq. chlor. = 67.72 equiv. This compound is formed, with evolution of heat and light, when zinc filings are introduced into chlorine gas; and it is readily prepared by dissolving zinc in hy-

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* *Phil. Trans.* 1822, and *Boston Jour. Philos.* i. 130.

† For the process see Brande ii. 48. ‡ Daniell.

§ Zinc may be obtained in small fragments for introduction into a retort in preparing hydrogen gas, by dropping it in fusion into cold water. A preferable method is to cast it into bars of about quarter of an inch in diameter and afterwards break them into pieces of about half an inch in length. W.

drochloric acid, evaporating to dryness, and heating the residue in a tube through which dry hydrochloric acid gas is transmitted. It is colourless, fusible at a heat a little above 212°, has a soft consistence at common temperatures, hence called *butter of zinc*, sublimes at a red heat, and deliquesces in the air.

Sulphuret or blende.

1009. *Sulphuret of Zinc.* $Zn+S$, or ZnS, 32.3 1 eq. zinc + 16.1 1 eq. sulph. = 48.4 equiv. This compound is well known to mineralogists under the name of *zinc blende*, and occurs in dodecahedral crystals or some allied form. Its structure is lamellated, lustre adamantine, and colour variable, being sometimes yellow, red, brown, or black. It may be formed artificially by igniting, in a closed crucible, a mixture of oxide of zinc and sulphur, or sulphate of oxide of zinc and charcoal, or by drying the hydrated sulphuret of zinc. Zinc combines also with Iodine, Bromine and Fluorine.

Uses of zinc.

1010. It has been proposed to apply zinc to the purpose of culinary vessels, pipes for conveying water, sheathing for ships, &c.; but it is rendered unfit for the first object, by the facility with which the weakest acids act upon it, and for the remaining ones, by its considerable though slow oxidation, when exposed to the operation of air and moisture.*

Cadmium.

Symb. Cd *Equiv.* 55.8

Cadmium,

1011. This metal discovered by Stromeyer in 1817, is contained in certain ores of zinc, and especially in the *black fibrous blende* of Bohemia. It has been detected in the calamine of Derbyshire, and in the zinc of commerce,† and in the sublimate which in the process for obtaining zinc, rises before that metal, forming what the workmen call the *brown blaze*.‡ It was called cadmium from *καδμεια*, a term applied both to calamine and to the volatile matters which rise from the furnace in preparing brass.

Separation of,

1012. A very elegant process for separating zinc from cadmium was proposed by Wollaston. The solution of the mixed metals is put into a platinum capsule, and a piece of metallic zinc is placed in it. If cadmium is present, it is reduced, and adheres so tenaciously to the capsule, that it may be washed with water without danger of being lost. It may then be dissolved either by nitric or dilute hydrochloric acid.§

Properties.

1013. Cadmium, in colour and lustre, has a strong resemblance to tin, but is somewhat harder and more tenacious. It is very ductile and malleable. Its sp. gr. is 8.604 before being hammered, and 8.694 afterwards. It melts at about the same temperature as tin, and is nearly as volatile as mercury. When heated in the open

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* It has been employed in the U. S. as a covering for the roofs of buildings, but is in many situations quite unfit for that purpose. See a paper on this subject by Gale, in *Amer. Jour.* vol. xxxii. 315.

† *Ann. of Philos.* xv. 272, and N. S. iii. 123.

‡ *Ann. Philos.* iii. 435. Some portions of this substance yielded from 12 to 20 per cent. of cadmium. *Ann.* of *Philos.* xiv. and xvii.

§ For Stromeyer's process see Turner, p. 321.

air, it absorbs oxygen, and is converted into an oxide, and is readily oxidized and dissolved by nitric acid, which is its proper solvent.[*]

Tin.

Symb. Sn *Equiv.* 58.9

Tin.

1014. The properties of tin must be examined in the state of grain-tin or block tin; what is commonly known by the name of tin, being nothing more than iron plates with a thin covering of this metal. Several varieties of tin are met with in commerce.[†]

1015. This metal has been known from the remotest ages. It was in common use in the time of Moses, and was obtained at a very early period from Spain and Britain by the Phœnicians.[‡]

To obtain pure tin.

The native oxide, found in Cornwall and some other counties, is the principal ore of tin;[§] the metal is obtained by heating it to redness with charcoal. To obtain pure tin the metal should be boiled in nitric acid, and the oxide which falls down reduced by heat in contact with charcoal in a covered crucible.[||] U.

Properties.

1016. Tin has a silvery white colour, is considerably harder than lead, scarcely at all sonorous, very malleable, though not very tenacious. Under the hammer it is extended into leaves, called *tin-foil*, which are about $\frac{1}{1000}$ of an inch thick.[¶] Its sp. gr. is about 7.291. It melts at 442°, and by exposure to heat and air is gradually converted into a gray protoxide.[**] Placed upon ignited charcoal under a current of oxygen gas, it burns very brilliantly.

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[*] *Oxide of Cadmium.* Cd+O, $\dot{\text{Cd}}$, or CdO, 55.8 1 eq. cad. + 8 1 eq. oxy. = 63.8 equiv. The only known *oxide of cadmium*, is prepared by igniting its carbonate, has an orange colour, is fixed in the fire, and is insoluble in water.

Sulphuret of Cadmium. Cd+S, or CdS, 55.8 1 eq. cad. + 16.1 1 eq. sulph. = 71.9 equiv. It occurs in mixture or combination in some kinds of zinc blende. Cadmium combines with Chlorine, Iodine and Fluorine.

[†] For the discrimination of which and the means of judging of its purity, Vauquelin has given useful instructions in the 77th vol. of the *Ann. de Chim* and an interesting account of the ores of tin, and of the processes for extracting the metal in Cornwall, has been given by Taylor in the 5th vol. of the *Trans. Geolog. Soc. Lond.*

[‡] Pliny, lib. iv. cap. 34, and xxxiv. cap. 47.

Stream tin.

[§] In some of the valleys of Cornwall, tin is found in rounded nodules, of various sizes, mixed with pebbles and rounded fragments of rocks. To separate the tin from the alluvial matter, currents of water are passed over it, and hence these deposits have been called *stream works*, and the tin ore, *stream tin*. A modification of stream tin is called *wood* tin. It usually appears in small banded fragments of globular masses.

[||] The process is described at length in Aikin's *Dict.* Art. Tin.

[¶] The process of making tin-foil consists simply in hammering out a number of plates of the metal, laid together upon a smooth block or plate of iron. The smallest sheets are the thinnest.

Powdered tin.

[**] A preparation under the name of *powdered tin* is sometimes directed to be prepared for pharmaceutical use, by shaking the melted metal in a wooden box rubbed with chalk on the inside: *tin filings* have also a place in some *Pharmacopœiæ*, and have been used as a vermifuge These preparations are, however, both dangerous, the metal being rendered poisonous in the former case by a slight oxidation,[*] and often creating very dangerous irritation when giving in filings.

Moiree metallique.

The *moiree metallique*, or crystallized tin plate as it is called, is prepared as follows. The sheet or plate of tinned iron is heated until a drop of water allowed to fall upon its surface begins to boil immediately; one of the sides is then washed with a mixture of 4 parts by measure of water, 1 of nitric and 1 of hydrochloric acid. The

[*] Orfila, *Traite des Poisons*, T. i. 2me partie, p. 18.

Chap. IV.

Protoxide, 1017. *Protoxide of Tin.* $Sn+O$, $\dot{Sn}$, or Sno, 58.9 1 eq. tin, + 8 1 eq. oxy. = 66.9 equiv. When protochloride of tin in solution is mixed with an alkaline carbonate, hydrated protoxide of tin falls, which may be obtained as such in a dry form by washing with warm water, and drying at a heat not above 196°, with the least possible exposure to the air. The best mode of obtaining the anhydrous protoxide is by heating the hydrate to redness in a tube from which air is excluded by a current of carbonic acid gas. The same oxide is formed when tin is kept for some time fused in an open vessel. T. 323.

Properties, 1018. Protoxide of tin has a sp. gr. of 6.666. At common temperatures it is permanent in the air, but if touched by a red hot body, it takes fire and is converted into the binoxide. It is dissolved by the sulphuric and hydrochloric acids, as also by dilute nitric acid; and the pure fixed alkalies likewise dissolve it. From the alkaline solution, metallic tin is gradually deposited, and binoxide of tin remains in solution.

Characters of its salts. 1019. Its salts are remarkably prone to absorb oxygen, both from the air and from compounds which yield oxygen readily. Thus it converts sesquioxide of iron into protoxide, and throws down mercury, silver, and platinum in the metallic state from their salts. Purple of Cassius. With a solution of gold it causes a purple precipitate, the *purple of Cassius*, which appears to be a compound of binoxide of tin and protoxide of gold.* By this character protoxide of tin is recognized with certainty. It is thrown down by hydrosulphuric acid as black protosulphuret of tin.

Sesquioxide. 1020. *Sesquioxide of Tin*, $2Sn+3O$, $\underline{\dddot{Sn}}$, or Sn^2O^3, 117.8 2 eq. tin + 24 3 eq. oxy. = 141.8 equiv., may be made by mixing recently precipitated and moist hydrated sesquioxide of iron with a solution of protochloride of tin. Its solution in hydrochloric acid strikes the purple of Cassius with gold.

Binoxide. 1021. *Binoxide of Tin*, $Sn+2O$, $\ddot{Sn}$, or SnO^2, 58.9 1 eq. tin + 16 2 eq. oxy. = 74.9 equiv., is most conveniently prepared by the action of nitric acid on metallic tin. Nitric acid, in its most concentrated state, does not act easily upon tin; but when a small quantity of water is added, violent effervescence takes place owing to the evolution of nitrous acid and binoxide of nitrogen, and a white powder, the hydrated binoxide is produced. On edulcorating this substance, and heating it to redness, watery vapour is expelled, and the pure binoxide, of a straw-yellow colour, remains. In this process ammo-

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surface assumes a beautiful crystalline appearance, and by heating the plate at particular parts with the blow-pipe, or exposing different parts to higher and lower temperatures, a great variety of figures may be produced, which will be seen on washing the plate with water. The various colours which it is made to assume are communicated by giving it a coating of different coloured varnishes. The tin plates used for this purpose should have a good coating of metallic tin, or the iron below will be exposed.

Purple of Cassius. * This compound is used to colour glass of a purple colour, and is made by dissolving a few grains of tin in hydrochloric acid, diluting the solution with a large quantity of distilled water, as a gallon to a drachm measure of the solution, and dropping into the diluted liquid 20 or 30 drops of the solution of gold in nitro-hydrochloric acid (637) to each gallon. In the space of three or four days, a purple precipitate is obtained, which is separated by filtration, washed and dried. Gray's *Operative Chem.* 720.

nia is generated, a circumstance which proves water as well as nitric acid to be decomposed. Binoxide of tin may likewise be obtained by precipitation from a solution of bichloride of tin, by potassa, ammonia, or alkaline carbonates.

Stannates.

1022. It is apt to separate from acids spontaneously as a gelatinous hydrate. It acts the part of a feeble acid and forms soluble compounds with the alkalies called *stannates.* When melted with glass it forms *white enamel.*

Protochloride,

1023. *Protochloride of Tin,* $Sn+Cl$, or $SnCl$, 58.9 1 eq. tin + 35.42 1 eq. chlor. = 94.32 equiv., is obtained by transmitting hydrochloric acid gas over tin heated in a glass tube, and hydrogen gas is evolved; or by distilling a mixture of granulated tin, with an equal weight of bichloride of mercury, or of an amalgam of tin with calomel, urging the heat till the mercury is expelled. A gray fusible solid of a resinous lustre is obtained. It is obtained also in crystals from a concentrated solution of the chloride.

Solution.

1024. A solution of protochloride of tin is obtained by heating granulated tin in strong hydrochloric acid as long as hydrogen gas continues to be evolved. This solution is much employed as a deoxidizing agent.

Bichloride,

1025. *Bichloride of Tin.* $Sn+2Cl$, or $SnCl^2$, 58.9 1 eq. tin + 70.84 2 eq. chlor. = 129.74 equiv. When protochloride of tin is heated in chlorine gas, or on distilling a mixture of 8 parts of granulated tin with 24 of bichloride of mercury, a very volatile, colourless liquid passes over, which is bichloride of tin. In an open vessel it emits dense white fumes, caused by the moisture of the air, and hence it was formerly called the *fuming liquor* of Libavius, who discovered it. At 248° it boils, and the sp. gravity of its vapour was found by Dumas to be 9.1997. With one third of its weight of water it forms a solid hydrate, and in a larger quantity of water dissolves.

Solution or permuriate.

1026. The solution commonly called *permuriate of tin,* is much used in dyeing, and is prepared by dissolving tin in nitro-hydrochloric acid. The process requires care; for if the action be very rapid, as is sure to happen if strong acid be employed and much tin added at once, the peroxide will be spontaneously deposited as a bulky hydrate, and be subsequently redissolved with great difficulty. But the operation will rarely fail if the acid is made with two measures of hydrochloric acid, one of nitric acid, and one of water, and if the tin is gradually dissolved, one portion disappearing before another is added. The most certain mode of preparation, however, is to prepare a solution of the protochloride, and convert it into the bichloride either by chlorine, or by gentle heat and nitric acid.

Sulphurets,

1027. *Protosulphuret of Tin,* $Sn+S$, or SnS, 58.9 1 eq. tin + 16.1 1 eq. sulph. = 75 equiv., is prepared by pouring melted tin upon its own weight of sulphur, and stirring rapidly with a stick during the action; as some tin usually escapes the sulphur from the latter being rapidly expelled, the product should be pulverized, mixed with its weight of sulphur, and projected in successive portions into a hot Hessian crucible, and then heated to redness. It is a brittle compound, of a bluish-gray, nearly black colour, and metallic lustre, which fuses at a red heat, and acquires a lamellated texture in cooling. It is dissolved by hydrochloric acid with evolution of hydrosulphuric acid.*

Aurum musivum, 1028. *Bisulphuret of Tin*, $Sn+2S$, or SnS^2, 58.9 1 eq. tin + 32.2 2 eq. sulph. = 91.1 equiv., (*aurum musivum*,) is formed by heating sulphur with peroxide of tin, or, by heating in a matrass a powdered amalgam of 12 parts of tin and 6 of mercury, mixed with 7 parts of flowers of sulphur and 6 of hydrochlorate of ammonia.† A gentle heat is to be applied till the white fumes cease to appear, when the heat is to be raised to redness, and kept so for some time. On cooling, the *aurum musivum* (or *Mosaic Gold*) may be obtained by breaking the matrass. It is of a beautiful gold colour, and flaky in its structure.

Properties, 1029. It has no taste, is not soluble in water, acids or alkaline solutions. It is used as a pigment for giving a golden colour to small statue or plaster figures. It is likewise said to be mixed with melted glass to imitate lapis lazuli.

Of its salts. 1030. The salts of tin are mostly soluble in water; they are precipitated of an orange colour, by hydriodic acid and by hydrosulphuret of ammonia, provided no excess of acid be present.

Alloys. 1031. Tin forms useful alloys with many of the metals. *Pewter* is one of these; and the best kind of it is entirely free from lead, being composed chiefly of tin with small proportions of antimony, copper, and bismuth. An amalgam formed by gradually adding three parts of mercury to twelve of tin melted in an iron ladle, and stirring the mixture, is much used in silvering looking glasses. With potassium and sodium, tin forms brittle white alloys. Its alloy with manganese is not known. It does not readily combine with iron, but tin-plate may be considered as an imperfect alloy of those metals. With zinc it forms a hard brittle alloy.‡

Cobalt.§

Symb. Co *Equiv.* 29.5

Cobalt, 1032. This metal occurs combined with arsenic, sulphur, iron and nickel; and according to Stromeyer is a constant ingredient in meteoric iron. It is chiefly obtained in Saxony.

How obtained pure. 1033. It may be obtained from the *zaffre* of commerce which is an impure oxide, and which, heated with a mixture of sand and potash, affords the beautiful blue glass known, in powder, as *smalt*. Dissolve zaffre in hydrochloric acid and transmit through the solution a current of hydrosulphuric acid gas until the arsenious acid is completely separated in the form of orpiment. The filtered liquid is then boiled with a little nitric acid, in order to convert the protoxide into sesquioxide of iron, and an excess of carbonate of potassa is added. The precipitate,

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Sesquisulphuret. * *Sesquisulphuret of Tin*, $2Sn+3S$, or Sn^2S^3, 117.8 2 eq. tin + 48.3 3 eq. sulph. = 166.1 equiv., is formed by mixing the protosulphuret in fine powder with a third of its weight of sulphur, and heating the mixture to low redness until sulphur ceases to escape. Its colour is of a deep grayish-yellow; it is reconverted by a strong heat into the protosulphuret, and dissolves in hydrochloric acid gas, yielding hydrosulphuric acid gas and a residue of bisulphuret of tin.

† Or heat two parts of binoxide of tin, two of sulphur, and one of sal ammoniac to a low red heat as long as sulphurous acid rises.

‡ On the alloys of tin, a memoir of Dussaussoy may be consulted in the 6th vol. of *Ann. de Chim. et Phys.*; and Chaudet's paper in the same, and in the 7th volume.

§ Its name is derived from the term *Kobold, an evil spirit*, applied to it by the German miners at a time when they were ignorant of its value, and considered it unfavourable to the presence of valuable metals.

consisting of sesquioxide of iron and carbonate of protoxide of cobalt, after being well washed with water, is digested in a solution of oxalic acid, which dissolves the oxide of iron and leaves the oxide of cobalt in the form of an insoluble oxalate.* On heating this oxalate in a retort from which atmospheric air is excluded, a large quantity of carbonic acid is evolved, and a black powder, metallic cobalt, is left.†

The pure metal is easily procured also by passing a current of dry hydrogen gas over oxide of cobalt heated to redness in a tube of porcelain. In this state it is porous, and if formed at a low temperature it inflames spontaneously.

Properties.

1034. Cobalt is a brittle metal, of a reddish-gray colour, and weak metallic lustre. Its density, according to Turner, is 7.834. It fuses at a heat rather lower than iron, and when slowly cooled it crystallizes. It has usually been considered to be attracted by the magnet, but the pure metal is not so.‡

1035. By exposure to the atmosphere cobalt is tarnished, but not oxidized to any extent. In an intense heat it burns with a red flame; but, if pure, it is not easily oxidized by a moderate temperature. It is oxidized by nitric acid, and decomposes water at a red heat.

Protoxide,

1036. *Protoxide of Cobalt.* $Co+O$, $\dot{Co}$, or CoO, 29.5 1 eq. cob. + 8 1 eq. oxy. = 37.5 equiv. This oxide is of an ash-gray colour, and is the basis of the salts of cobalt, most of which are of a pink hue. When heated to redness in open vessels it absorbs oxygen, and is converted into the sesquioxide. It may be prepared by decomposing carbonate of the protoxide by heat in a vessel from which atmospheric air is excluded. It is recognised by giving a blue tint to borax when melted with it; and is employed in the arts in the form of smalt, for communicating a similar colour to glass, earthenware, and porcelain.

Precipitated.

1037. Protoxide of cobalt is precipitated from its salts by pure potassa as a blue hydrate. Pure ammonia likewise causes a blue precipitate, which is redissolved by the alkali if in excess. It is thrown down as a pale pink carbonate by carbonate of potassa, soda, or ammonia; but an excess of the last redissolves it with facility. Hydrosulphuric acid produces no change, unless the solution is quite neutral, or the oxide is combined with a weak acid. Alkaline hydrosulphates precipitate it as a black protosulphuret.§

Chloride.

1038. *Chloride of Cobalt.* $Co+Cl$, or $CoCl$, 29.5 1 eq. cob. + 35.42 1 eq. chlor. = 64.92. equiv. It is obtained in solution on dissolving metallic cobalt, its protoxide, or either of the other oxides in hydrochloric acid, with evolution of hydrogen gas with the first and of chlorine with the latter. It yields a pink-coloured solution, and by evaporation small crystals of the same colour containing water of crystallization. When deprived of water its colour is blue, a character on which is founded its use as a sympathetic ink: when letters are written with a dilute solution of the chloride, the colour is so pale that it is invisible in the cold; but on heating gently, the letters

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* Laugier. † Thomson in *Ann. of Philos.*, N. S. i. ‡ Faraday.

§ When a salt of cobalt is treated with pure ammonia in close vessels, part of the cobalt is dissolved, and part subsides in form of a blue powder. On admitting atmospheric air, this substance passes to a higher state of oxidation, and is gradually dissolved. If nitrate of cobalt is used, a double salt may be obtained in crystals, which L. Gmelin believes to consist of nitrate and *cobaltate* of ammonia. The existence of this acid, however, has not yet been established.

appear of a blue colour, and disappear as soon as the chloride has recovered its moisture from the atmosphere. When iron or nickel is present, the dry chloride of cobalt is green instead of blue.*

Alloys. 1039. The alloys of cobalt are unimportant. The chief use of this metal is in the state of oxide as a colouring material for porcelain, earthenware, and glass; it is principally imported from Germany in the state of *zaffre* and *smalt*, or *azure*. Smalt and azure are made by fusing zaffre with glass or by calcining a mixture of equal parts of roasted cobalt ore, common potash, and ground flints. A blue glass is formed which, while hot, is dropped into water, and afterwards reduced to a very fine powder.

Nickel.

Symb. Ni *Equiv.* 29.5

Ores, 1040. Nickel is found native, and is a constituent of meteoric iron.† It occurs likewise in the copper-coloured mineral of Westphalia, termed *copper-nickel*, a native arseniuret of nickel, which in addition to its chief constituents, contains sulphur, iron, cobalt and copper. The combinations of nickel may be prepared from its ore, or from the artificial arseniuret called *speiss*.‡

The metal may be procured by heating the oxalate in close vessels, or by the combined action of heat and charcoal, or hydrogen, on protoxide of nickel.§

Reduced. 1041. Crystals of nitrate of nickel, when placed in a cavity scooped out of a piece of charcoal, and exposed to the oxy-hydrogen blow-pipe, afford a bead of metallic nickel. This, however, is a process obviously adapted to yield only very minute quantities of nickel.

Properties. 1042. Nickel is of a white colour between that of tin and silver, with a strong lustre, and is ductile and malleable. It is attracted by

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Sympathetic ink. * This solution has been termed *Hellot's sympathetic ink*. It may be prepared as follows: One part of cobalt, or, still better, of zaffre, may be digested in a sand heat, for some hours, with four parts of nitric acid. To the solution, add one part of sea-salt; and dilute with four parts of water. Characters written with this solution are illegible when cold; but when a gentle heat is applied, they assume a beautiful blue or green colour. This experiment is rendered more amusing by drawing the trunk and branches of a tree in the ordinary manner; and tracing the leaves with the solution. The tree appears leafless, till the paper is heated, when it suddenly becomes covered with beautiful foliage. The addition of a little nitrate of copper to the solution forms a sympathetic ink, which by heat gives a rich greenish yellow colour. When a small quantity of hydrochlorate of soda, of magnesia, or of lime, is added to the ink, its traces disappear very speedily on removal from the fire. U. 346.

† For an account of meteoric stones, masses of iron, &c. which have fallen from the heavens, from the earliest period down to 1819, see *Edin. Philos. Jour.* vol. i. p. 221. See also Cleaveland's *Mineralogy*, p. 773, and Brande's *Chem.* ii. 149.

‡ For details see Thomson's *Chemistry of Inorganic Bodies*, ii. 526, &c., and Turner, 329.

§ For other processes see Thomson, ii., Henry, ii. 169, *Quart. Jour.* xliv. 396, and N. S. iii. 209.

Wollaston's process for detecting nickel. To detect the presence of nickel in iron, Wollaston recommends that a small portion, which need not exceed .01 of a grain, should be filed from the sample, and dissolved in a drop of nitric acid; evaporate this to dryness, and add a drop or two of liquid ammonia, which, when gently warmed, will dissolve any oxide of nickel that may be present. The transparent part of the fluid is then to be conducted by the end of a glass rod to a small distance from the precipitated oxide of iron, and mixed with a drop of ferrocyanate of potassa, which, if nickel be present, will cause an immediate milkiness, not discernible in a solution of common iron, formed and treated in the same way. B. ii. 148.

the magnet, and may like iron be rendered magnetic, but loses this power at 630°.* Its sp. gr. is about 8.279. It is very infusible, suffers no change by exposure, but at a red heat absorbs oxygen, and decomposes water. It is oxidized by nitric acid. Its eq. is estimated at 29.5.

Fusibility.

1043. *Protoxide of Nickel.* $Ni+O$, $\dot{Ni}$, or NiO, 29.5 1 eq. nick. + 8 1 eq. oxy. = 37.5 equiv. This oxide may be formed by heating the carbonate, oxalate, or nitrate to redness in an open vessel, and is then of an ash-gray colour; but after exposure to a white heat, its colour is a dull olive-green. It is not reducible by heat unaided by combustibles. It is not attracted by the magnet. It is a strong alkaline base, and nearly all its salts have a green tint. It is precipitated as a hydrate of a pale-green colour by the pure alkalies, but is redissolved by ammonia in excess; as a pale-green carbonate by alkaline carbonates, but is dissolved by an excess of carbonate of ammonia; and as a black sulphuret by alkaline hydrosulphates. Hydrosulphuric acid occasions no precipitate, unless the solution is quite neutral, or the oxide combined with a weak acid.†

Protoxide.

Section VI. *Metals which do not Decompose Water at any Temperature, and the Oxides of which are not reduced to the Metallic State by the sole action of Heat.*

1044. *Arsenic.* As, 37.7 eq. Metallic arsenic occurs native, but more commonly in combination with other metals. The substance known in the shops by the name arsenic, is an oxide, from which the metal may be obtained by mixing it with half its weight of black flux,‡ and introducing the mixture into a Florence flask, placed in a sand bath gradually raised to a red heat; a brilliant metallic sublimate of pure arsenic collects in the upper part of the flask.

Arsenic,

Or mix it with about twice its weight of charcoal, both perfectly dry, and expose the mixture to heat in a crucible, luting another over it in an inverted position to collect the product.§

Obtained.

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* Faraday.

† *Sesquioxide of Nickel,* $2Ni+3O$, $\dddot{\underline{Ni}}$, or Ni^2O^3, 59 2 eq. nick. + 24 3 eq. oxy. = 83 equiv., has a black colour, and is formed by transmitting chlorine gas through water in which the hydrate of the protoxide is suspended, does not unite with acids, is decomposed by a red heat, and with hot hydrochloric acid forms the chloride with disengagement of chlorine gas.

Sesquioxide.

Chloride of Nickel, $Ni+Cl$, or $NiCl$, 29,5 1 eq. nick + 35.42 1 eq. chlor. = 64.92 equiv., is formed by acting with hydrochloric acid on metallic nickel, its protoxide, or sesquioxide; hydrogen gas being evolved with the former, and chlorine with the latter. It forms an emerald-green solution, and by evaporation yields crystals of the same tint, which lose water or deliquesce, according as the air is dry or moist.

Chloride.

Protosulphuret of Nickel, $Ni+S$, or NiS, 29.5 1 eq nick. + 16.1 1 eq. sulph. = 45.6 equiv., is formed by processes similar to those for preparing protosulphuret of cobalt. The precipitated sulphuret is dark brown or nearly black.

‡ This is an extremely useful compound for effecting the reduction of many of the metallic oxides. It consists of charcoal and subcarbonate of potassa, and is best prepared by deflagrating in a crucible a mixture of one part of nitre and two of powdered tartar. The mixture remains in fusion at a red heat, and thus suffers the small globules of reduced metal to coalesce into a button.

Black flux.

§ A small opening should be left for the escape of gaseous matters. The lower crucible should be placed in a sand bath furnace, and the upper one be kept as cool as possible and completely out of the sand; the process may be easily conducted with a small chauffer. Care must be taken not to inhale the vapour.

Characters.

1045. Arsenic is of a steel-blue colour, quite brittle, and of a specific gravity = 5.884. It readily fuses, and in close vessels may be distilled at a temperature of 360°, which is lower than its fusing point. Its vapour has a very strong smell, resembling that of garlic. Heated in the air it easily takes fire, burns with a blue flame, and produces copious white fumes of oxide.

Fly-powder.

In general it speedily tarnishes by exposure to air and moisture, acquiring upon its surface a dark film, which is extremely superficial; but Berzelius remarks that he has kept some specimens in open vessels for years without loss of lustre, while others are oxidized through their whole substance, and fall into powder. The product of this spontaneous oxidation, which is known under the name of ***fly-powder***, is supposed by Berzelius to be an oxide; but it is more generally regarded as a mixture of white oxide and metallic arsenic.

Arsenious acid,

1046. *Arsenious Acid*, $2As+3O$, $\underline{\overset{\cdots}{As}}$, or As^2O^3, 75.4 2 eq arsen. + 24 3 eq. oxy. = 99.4 equiv., or, as it is commonly called, *white arsenic*, or *white oxide of arsenic*, is the best known, and most commonly occurring compound of this metal; and as cases of poisoning by it are frequent, every person should be well acquainted with its characteristic properties.

How obtained,

1047. Arsenious acid may easily be procured by the combustion of the metal; but as it is formed during certain metallurgic processes, that mode is rarely resorted to. It is abundantly prepared in Bohemia, from arsenical cobalt ores, which are roasted in reverberatory furnaces, and the vapours condensed in a long chimney, the contents of which, submitted to a second sublimation, afford the *white arsenic* of commerce.

Properties,

1048. Arsenious acid is white, semi-transparent, brittle, and of a vitreous fracture. Its sp. gr. is 3.7. Its taste has been usually described as acrid, but it appears that this is incorrect. It excites a very faint impression of sweetness and perhaps of acidity.*

Dimorphous.

1049. Arsenious acid is *dimorphous*, that is, susceptible of assuming two crystalline forms belonging to different systems of crystallization. By slow sublimation in a glass tube, it is always obtained in distinct octohedral crystals of adamantine lustre and perfectly transparent. Its unusual form is that of six-sided scales derived from a rhombic prism.

Solubility.

1050. According to Klaproth and Buchholz, 1000 parts of water at 60° dissolve 2.5 of white arsenic,† 1000 parts of water at 212°, dissolve rather more than 77 parts, and about 30 parts are retained in permanent solution.

Poisonous effects.

Guibourt has lately observed that the transparent and opaque varieties of arsenic differ in solubility. He found that 1000 parts of temperate water dissolve, during 36 hours, 9.6 of the transparent, and 12 5 of the opaque variety: that the same quantity of boiling water dissolves 97 parts of the transparent variety, retaining 18

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* See Cristison's experiments. *Edin. Philos Jour.* xiv. 380.

† It would take a long time to prepare a saturated aqueous solution of white arsenic, by contact of the powder with water, or even by agitation; but by boiling the water with the powder for half an hour, leaving it to cool, and afterwards filtering it, a saturated solution will be at once obtained. Faraday, *Chem. Manip.* 174.

when cold, but takes up 115 of the opaque variety, and retains 29 on cooling. By the presence of organic substances, such as milk or tea, its solubility is materially impaired.*

Poisonous effects. 1051. It is virulently poisonous, producing inflammation and gangrene of the stomach and intestines; it also proves fatal when applied to a wound; and as the local injury is in neither case sufficient to cause death, it is probable that an induced affection of the nervous system and of the heart is the cause of the mischief. To get rid of the poison by producing copious vomiting and purging, and to pursue the usual means of subduing and preventing inflammation, are the principal points of treatment to be adopted in cases where this poison has been taken.†

Methods of detecting arsenic, 1052. As arsenic either accidentally or intentionally taken, is a very frequent cause of death, and often the subject of judicial inquiry, it becomes of importance to point out the most effectual modes of discovering its presence. Where arsenic proves fatal, it is very seldom found in the contents of the stomach after death, but is generally previously voided by vomiting or by stool; and we often can detect it in the matter thrown off the stomach, in the form of a white powder, subsiding in water. The inflammation of stomach which results is generally a secondary effect, and takes place equally, whether the poison be swallowed or applied to a wound.

Tests of. 1053. Several tests have been proposed for detecting minute quantities of arsenic in the fluids likely to be met with in the stomach, the most valuable are the ammoniaco-nitrate of silver, ammoniaco-sulphate of copper, hydrosulphuric acid and hydrogen gas.

Methods of proceeding. 1054. The first object is to obtain a concentrated solution of the substances ejected, or, in case of death, of the liquids contained in the stomach, or of any that may adhere to its interior surface. This is to be effected by means of washing in pure water, filtration, and evaporation. A solution having been obtained, the tests are to be applied, it having been previously ascertained that they are perfectly pure, as also the vessels in which the experiments are to be made.

Ammoniacal nitrate of silver. 1. The ammoniacal-nitrate of silver is made by dropping into a rather strong solution of lunar caustic, ammonia, till the oxide of silver at first thrown down is *nearly* all dissolved. This liquid contains the precise quantity of ammonia required to neutralize the nitric acid of the nitrate of silver. On dropping it into the suspected liquid, if arsenic is present, a yellow insoluble arsenite of silver will be formed.

Ammoniacal sulphate of copper. 2. Ammoniacal-sulphate of copper, is made by adding ammonia to a solution of sulphate of protoxide of copper, until the precipitate is nearly all dissolved. This test affords a green precipitate with arsenious acid, which has long been known as *Scheele's green.*

Hydrosulphuric acid. 3. The hydrosulphuric acid gas, is to be obtained from the usual materials (754) and conducted by means of a suitable glass tube into the suspected liquid; if arsenious acid is present, the liquid becomes yellow and turbid from the formation of orpiment or sesquisulphuret of arsenic.‡

On drying the sulphuret, mixing it with black flux, and heating

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* Christison on Poisons.

† See Christison's *Experiments, Edin. Philos. Jour.* xiv. 380.

‡ The apparatus (Fig. 166), page 200, will be found convenient.

Chap. IV.

Reduction.

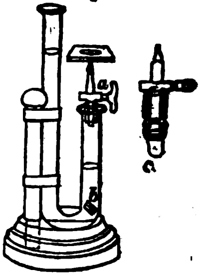
the mixture contained in a glass tube to redness by means of a spirit-lamp, decomposition ensues, and a metallic crust of an iron-gray colour externally, and crystalline on its inner surface, is deposited on the cool part of the tube. This character alone is quite satisfactory; but it is easy to procure additional evidence, by reconverting the metal into arsenious acid, so as to obtain it in the form of resplendent octohedral crystals. This is done by holding that part of the tube to which the arsenic adheres about three-fourths of an inch above a very small spirit-lamp flame, so that the metal may be slowly sublimed. As it rises in vapour it combines with oxygen, and is deposited in crystals within the tube. The character of these crystals, with respect to volatility, lustre, transparency, and form, is so exceedingly well marked, that a practised eye may safely identify them, though their weight should not exceed the 100th part of a grain. This experiment does not succeed unless the tube be quite clean and dry.*

Marsh's process by hydrogen gas.

4. For the application of hydrogen we are indebted to Marsh of Woolwich.† Its utility depends on the fact that, whenever nascent hydrogen is brought into contact with any compound of oxygen and arsenic, water and arseniuretted hydrogen are formed. If the gas be inflamed as it escapes into the air from a fine tube, it burns with the production of watery vapour, and the deposition of metallic arsenic. By holding a piece of clean glass over the flame, its surface is instantly covered with a thin coating of metallic arsenic; and if the flame be made to burn in the centre of a glass tube open at both extremities, so as to admit a larger supply of atmospheric oxygen, it is covered in half a minute with arsenious acid.

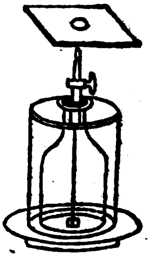
The hydrogen is obtained by introducing a portion of the suspected liquid into a tube about thirteen inches in length and three fourths of an inch internal diameter, or the glass bucket *c*, in which is a small piece of pure zinc *b*, sulphuric acid is added and the gas passes out through the jet *a*, while the stop-cock is open. When it is closed the gas accumulates in the upper part of the short leg; on opening the stop-cock, the liquor descends from the longer leg and drives out the gas.

Fig. 179.



When large quantities of the suspected liquid can be obtained, the apparatus (Fig. 180) is employed; see 379.

Fig. 180.



Liebig's improvement.

Liebig recommends that a fragment of porcelain be held in the flame instead of the glass, as a very thin film of metallic arsenic is better seen on the white opaque ground of the former. To avoid the deposition of other metals, that may be carried up by the hydrogen, he recommends that the gas be transmitted through a fine tube of difficultly fusible glass, instead of

181.

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* A tube of the annexed form (Fig. 181,) has been recommended by Berzelius, it should be perfectly dry, and the mixture introduced by means of a small funnel descending within the ball, through which the mixture may be passed without soiling the tube.

† *Edin. Philos. Jour.* Oct. 1836, and *Trans. Soc. Arts*, LI.

burning it at the jet; on bringing a part of the glass to a red heat by a spirit-lamp, the arseniuretted hydrogen is decomposed as it passes, and the metallic arsenic is deposited just beyond the heated part of the glass, while other metals are deposited in the hot parts themselves.*

1055. The extreme delicacy of this method of testing for arsenic has been fully confirmed, but it also has been ascertained that it is not the only one to be relied upon. Other metals may be present, as antimony, which has been found to form a gaseous compound, and to give results that resemble those with arsenic. By decomposing the gases while passing through a fine tube, as proposed by Liebig, and obtaining the metals, they can readily be distinguished.†

Arsenic acid.

1056. *Arsenic Acid.* $2AS+5O$, $\underline{\overset{\cdot\cdot\cdot\cdot\cdot}{\mathrm{As}}}$, or As^2O^5, 75.4 2 eq. arsen. + 40 5 eq. oxy. = 115.4 equiv. This compound is made by dissolving arsenious acid in concentrated nitric, mixed with a little hydrochloric acid, distilling in glass till it acquires the consistence of syrup, and then exposing it in a platinum crucible for some time to a heat somewhat short of low redness to expel the nitric acid. The acid thus prepared has a sour metallic taste, reddens vegetable blue colours, and with alkalies forms neutral salts, which are termed *arseniates.* It is much more soluble in water than arsenious acid. It is an active poison.

Decomposed.

1057. Arsenic acid is decomposed by hydrosulphuric acid gas, and yields a sulphuret of arsenic very like orpiment in colour, but containing a greater proportional quantity of sulphur. The soluble arseniates, when mixed with the nitrates of lead and silver, form insoluble arseniates, the former of which has a white, and the latter a brick-red colour.‡

Sesquichloride.

1058. *Sesquichloride of Arsenic,* $2As+3Cl$, or As^2Cl^3, 75.4 2 eq. arsen. + 106.26 3 eq. chlor. = 181.66 equiv. When arsenic in

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* Liebig *Ann.* xxiii. 217.

† For minute details, the manipulation, precautions, sources of error, &c., the student must be referred to Turner's *Elements* p. 332; Christison *on Poisons*; Marsh *on the separation of arsenic*; *Trans. Soc. of Arts.* Li. and *Edin. Philos. Jour.* Oct. 1836; Reid's *Prac. Chem.* 341; Henry's *Elem. of Chem.* vol. ii. p. 588, 10th edit.; to Murray's *System*, vol. iii. p. 441, 4th edit.; to Bostock's *Paper* in the *Edin. Med. and Surg. Jour.* vol. v. p. 166; Hume's *Essay* in the *Phil. Mag.* vol. xxxiii.; and *Lond. Med. and Phys. Jour.* vol. xxiii.; Marcet's *Paper*, in the *Medico-Chirurg. Trans.* vol. ii.; Sylvester's *Observations* in *Nicholson's Jour.* vol. xxxiii.; Beck's *Med. Juris.* vol. ii.; Traill's *Paper*, in *Boston Jour. of Philos.* 1, 543; *Edin. Medico. Chirurg. Trans.* vol. ii.

From late investigations arsenic possesses the property of preserving from decay the bodies of those poisoned with it. The antiseptic effects sometimes extend only to the stomach and intestines, that is, to the parts directly in contact with it; but in some instances the whole body is preserved. The stomach and intestines of persons killed with arsenic have been found entire and firm at the distance of five, six, and fourteen months, or even of two years and a half after death; and in some of these instances the poison itself was detected. *Edin. Philos. Jour.* vii. 381.

A voltaic battery made to act on a little arsenious solution placed on a bit of glass, develops metallic arsenic at the negative pole, and if this wire be copper, it will be whitened like tombac.

Protochloride.

‡ *Protochloride of Arsenic.* $As+Cl$, or $AsCl$, 37.7 1 eq. arsen. + 35.42 1 eq. chlor. = 73.12 equiv. It is prepared by introducing into a tubulated retort a mixture of arsenious acid with ten times its weight of concentrated sulphuric acid; and after raising its temperature to near 212°, fragments of sea-salt are thrown in.*

* *See Quart. Jour. Scien.* N. S. i. 225.

Chap. IV.

powder is thrown into a jar full of dry chlorine gas, it takes fire and sesquichloride of arsenic is generated; and the same compound may be formed by distilling a mixture of six parts of corrosive sublimate with one of arsenic. It is a colourless volatile liquid which fumes strongly on exposure to the air, hence called *fuming liquor of arsenic*, and is resolved by water into hydrochloric and arsenious acids.[*]

Arsenic and hydrogen.

1059. *Arseniuretted Hydrogen*, $2As+3H$, or As^2H^3, 75.4 2 eq. arsen. + 3 3 eq. hydrog. = 78.4 equiv. When arsenic is presented to nascent hydrogen a portion of the metal combines with the gas.

The compound is obtained by adding a portion of metallic arsenic, or of white arsenic, to the mixture of zinc and dilute sulphuric acid usually employed for the production of hydrogen. It may also be obtained by acting on water with a triple alloy of arsenic, potassium, and antimony. This alloy may be formed by heating strongly, for two hours, in a close crucible, two parts of antimony, two of cream of tartar, and one of white arsenic. When two or three drachms of this alloy are thrown quickly under a jar inverted in water, abundance of *arseniuretted hydrogen* is disengaged.

The greatest caution should be used to avoid its deleterious effects, which were fatal to M. Gehlen.[†] The gas may be collected over water, which, however, absorbs one fifth.

Decomposed.

1060. It suffers gradual decomposition when mixed with atmospheric air, water being formed, and metallic arsenic, together with a little oxide, deposited. With iodine it yields hydriodic acid gas and iodide of arsenic, and sulphur and phosphorus produce analogous changes. By its action on salts of the easily reducible metals, such as silver and gold, the metal is revived, and its oxygen uniting with the elements of the gas constitutes arsenious acid and water.

Action of chlorine.

It is decomposed by chlorine, bubbles of which may be passed up into a jar of arseniuretted hydrogen, standing over warm water; flame and explosion are often produced, hydrochloric acid is formed and the metal set free. But if the gas be passed in the same way into chlorine, no inflammation results, absorption takes place, and hydrochloric acid and chloride of arsenic are formed. If the chlorine be not very pure, and when the gases are cold, inflammation seldom follows their mixture. B. ii. 123.

Effect of heat, &c.

1061. Arseniuretted hydrogen in a glass tube is completely decomposed by the heat of a spirit-lamp, and its hydrogen occupies one and a half as much space as when in combination. When mixed with oxygen, and detonated by the electric spark, each volume of the gas, in forming water and arsenious acid, requires one and a half its volume of oxygen gas. The oxygen, therefore, is equally divided between the arsenic and hydrogen; and arseniuretted hydrogen consists of two equivalents of arsenic and three of hydrogen.

Composition.

By volume, it is composed of half a volume of the vapour of arsenic, and three vols. of hydrogen, condensed into two volumes.[‡]

Sulphurets of Arsenic.

Sulphurets.

1062. *Protosulphuret of Arsenic*, $As+S$, or AsS, 37.7 1 eq. arsen. + 16.1 1 eq. sulph. = 53.8 equiv. Sulphur unites with

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[*] Dr Davy.

[†] *Ann. de Chim. et Phys.* iii. 135.

[‡] *Ann. de Chim.* xliii. 407.

arsenic in at least three proportions, forming compounds, two of which occur in the mineral kingdom, and are well known by the names of *realgar* and *orpiment*. Realgar or the *protosulphuret* may be formed artificially by heating arsenious acid with about half its weight of sulphur, until the mixture is brought into a state of perfect fusion. The cooled mass is crystalline, transparent, and of a ruby red colour; and may be sublimed in close vessels without change.

Orpiment.

1063. *Orpiment*, or *Sesquisulphuret of Arsenic*, 2As+3S, or AsS^3, 75.4 2 eq. arsen. + 48.3 3 eq. sulph. = 123.7 equiv., may be prepared by fusing together equal parts of arsenious acid and sulphur; but the best mode of obtaining it quite pure is by transmitting a current of hydrosulphuric acid gas through a solution of arsenious acid. Orpiment has a rich yellow colour, fuses readily when heated, and becomes crystalline on cooling, and in close vessels may be sublimed without change. It is dissolved with great facility by the pure alkalies, and yields colourless solutions.

Uses.

1064. Orpiment is employed as a pigment, and is the colouring principle of the paint called *King's yellow*. Braconnot has proposed it likewise for dyeing silk, woollen, or cotton stuffs of a yellow colour; the cloth being soaked in a solution of orpiment in ammonia, and then suspended in a warm apartment. The alkali evaporates, and leaves the orpiment permanently attached to the cloth.[*]

Persulphuret.

1065. *Persulphuret of Arsenic*, 2As+5S, or As^2S^5, 75.4 2 eq. eq. arsen. + 80.5 5 eq. sulph. = 155.9 equiv., is prepared by transmitting hydrosulphuric acid gas through a moderately strong solution of arsenic acid; or by saturating a solution of arseniate of potassa or soda with the same gas, and acidulating with hydrochloric or acetic acid. The oxygen of the acid unites with the hydrogen of the gas, and persulphuret of arsenic subsides. In colour it is very similar to orpiment.[†]

Alloys.

1066. Arsenic forms alloys with most of the metals, and they are generally brittle.

Uses.

1067. Arsenic is used in a variety of the arts. It enters into metallic combinations, wherein a white colour is required. Glass manufacturers use it; but its effect on the composition of glass does not seem to be clearly explained.

Chromium.

Symb. Cr *Eq.* 28

Discovery.

1068. Chromium[‡] was discovered by Vauquelin in 1797, in a beautiful red mineral, the native dichromate of oxide of lead. It has since been detected in the mineral called *chromate of iron*, a compound of the sesquioxides of chromium and iron which occurs in several places in Europe and in this country.

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[*] *An. de Ch. et de Ph.* xii.

[†] The experiments of Orfila have proved that the sulphurets of arsenic are poisonous, though in a much less degree than arsenious acid. The precipitated sulphuret is more injurious than the native orpiment. The antidote to arsenious acid is hydrated sesquioxide of iron. (Bunson.)

[‡] From Χρῶμα, *colour*, indicative of its remarkable tendency to form coloured compounds.

How obtained. 1069. Chromium, which has been procured in small quantity, owing to its powerful attraction for oxygen, may be obtained by exposing the sesquioxide of chromium mixed with charcoal to the most intense heat of a smith's forge.

A more convenient process is to decompose the sesquichloride by heat and ammoniacal gas, in which case, the metal has a chocolate-brown colour. In this finely divided state, it takes fire when heated in the open air.*

Properties, &c. 1070. It is a brittle metal, of a grayish white colour, and very infusible. Its sp. gr. is 5.9.

When fused with nitre it is oxidized, and converted into chromic acid. With a smaller quantity of oxygen it forms the green or sesquioxide.

Sesquioxide. 1071. *Sesquioxide of Chromium*, $2Cr+3O$, $\underline{\overset{\cdots}{\mathrm{Cr}}}$, or Cr^2O^3, 56 2 eq chrom. + 24 3 eq. oxy. = 80 equiv. This, the only known oxide of chromium, is prepared by dissolving chromate of potassa in water, and mixing it with a solution of nitrate of protoxide of mercury; when an orange coloured precipitate, chromate of that oxide, subsides. On heating this salt to redness in an earthen crucible, the mercury is dissipated in vapour, and the chromic acid is resolved into oxygen and sesquioxide of chromium.

Crystals. 1072. It may also be obtained in small tabular crystals by exposing the bichromate of potassa to a strong red heat; 1 eq. of chromic acid loses oxygen, while the other forms a neutral salt with the potassa. The latter is readily removed by boiling water.

Wöhler's process. 1073. Wöhler has obtained this oxide in fine crystals by conducting the vapour of the oxychloride of chromium (formerly *terchloride*) through a red-hot glass tube; it is decomposed and the sesquioxide is deposited in fine crystals, a mixture of oxygen and chlorine gases is evolved.

Properties. 1074. As obtained by either of the first processes, it is a green powder; but the crystals of Wöhler are black, and possess a strong metallic lustre, resembling specular iron ore; it is as hard as corundum, and has a sp. gr. of 5.21; its powder is green.

Solubility, &c. 1075. It is insoluble in water, and after being strongly heated resists the action of the strongest acids. It is oxidized when deflagrated with nitre. It communicates a green colour to borax, a good test of its presence, and a useful property in the arts. To it the emerald owes its colour.

Salts of. 1076. Sesquioxide of chromium is a salifiable base, and its salts, which have a green colour, may easily be prepared in the following manner.

To a boiling solution of chromate of potassa in water, equal measures of strong hydrochloric acid and alcohol are added in successive small portions, until the red tint of the chromic acid disappears entirely, and the liquid acquires a pure green colour. On pouring an excess of pure ammonia into this solution, a pale green bulky hydrate subsides, which consists of one equivalent of the oxide and twentysix equivalents of water.†

The oxide, in this state, is readily dissolved by acids. On expelling the water by heat, the sudden approximation of the particles,

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* *An. de Ch. et de Ph.* xlviii. 297.

† Thomson.

which abruptly occurs at a certain temperature, causes such intense evolution of heat that the whole mass becomes vividly incandescent.

The anhydrous sesquioxide is formed when bichromate of potassa is briskly boiled with sugar and a little hydrochloric acid.

Chromic acid. 1077. *Chromic Acid*, $Cr+3O$, $\overset{\dots}{Cr}$, or CrO^3, 28 1 eq. chr. + 24 3 eq. oxy. = 52 equiv., may be procured from the ore called *chromate of iron*[*] by the following process.

Process. Reduce the ore to fine powder, heat it red-hot for two hours, mixed with half its weight of nitre; wash the contents of the crucible, and add to the lixivium nitric acid to neutralize the excess of potassa; a solution of nitrate and chromate of potassa is obtained. Upon adding nitrate of lead to this solution, chromate of lead is precipitated in the form of a yellow powder, which is to be washed, dried, and heated to redness. Of this chromate four parts are then well mixed with three of finely powdered and pure fluor spar (previously heated red-hot), and five of highly concentrated sulphuric acid; this mixture is introduced into a distillatory apparatus of lead or platinum, and gently heated; a red vapour is liberated, which is conducted into distilled water contained in a vessel of platinum; it is then condensed into a dark orange-coloured liquid; the red vapour is a *fluoride of chromium*, and is resolved by water into hydrofluoric and chromic acids, the solution of which, evaporated in a platinum vessel, leaves pure chromic acid. If, instead of conducting the vapour into water, it be received into a platinum vessel, containing pieces of moist blotting paper, it is decomposed as before; but the chromic acid is deposited in beautiful acicular crystals which soon deliquesce. B.

Hayes's process. It may be obtained by dropping hydrochloric acid into a mixture of chromate of silver and distilled water, until the red brown colour is reduced to white with a tinge of red; at the same time filtering and cautiously adding a few drops of hydrochloric acid, till a white precipitate ceases to be formed. When large quantities are required, the bichromate of lead may be added to strong hydrochloric acid, and the mixture placed on a warm sand-bath for a few hours, occasionally stirring the mass. Water may then be added, and filtered from the chloride of lead, and the filtered fluid used instead of the hydrochloric acid in decomposing the chromate of silver; in either process a solution of pure chromic acid is obtained.[†]

Properties. 1078. Chromic acid, according to Turner, is black while warm, and of a dark red colour when cold; according to Hayes it is yellowish-brown when dry. It is very soluble in water, rendering it red or yellow according to the degree of dilution; when the solution is concentrated by heat and allowed to cool it deposits red crystals which are deliquescent. The solution has an acid and astringent taste, it bleaches litmus and blue paper.

Deoxidized. 1079. Chromic acid is converted into the sesquioxide, with evolution of oxygen, by exposure to a strong heat. It is more or less completely converted into the oxide by being boiled with sugar, starch, or various other organic principles. It destroys the colour of indigo, and of most vegetable and animal colouring matters; a property ad-

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[*] Hayes in *Amer. Jour.* xiv. 136.

[†] Maus's method. Another method consists in decomposing a hot concentrated solution of bichromate of potassa by silicated hydrofluoric acid. The chromic acid, after being separated from the sparingly soluble fluoride of silicon and potassium, is evaporated to dryness in a platinum capsule, and then redissolved in the smallest possible quantity of water. By this means the last portions of the double salt are rendered insoluble, and the pure chromic acid may be separated by decantation. The acid must not be filtered in this concentrated state, as it then corrodes paper like sulphuric acid, and is converted into chromate of the sesquioxide of chromium. When it is wished to prepare a large quantity of chromic acid by this process, porcelain vessels may be safely employed in the first part of the operation, provided care is taken to add a quantity of silicated hydrofluoric acid not quite sufficient for precipitating the whole of the potassa. *Edin. Jour. of Sci.* viii. 175; see also Henry's *Chem.* ii. 62, Brewster's *Jour.* xvii. 175, and Gray's *Oper. Chem.* 750.

vantageously employed in calico printing, and which manifestly depends on the facility with which it is deprived of oxygen.

Colour, &c. 1080. Chromic acid is characterized by its colour, and by forming coloured salts with alkaline bases. The most important of these salts is chromate of protoxide of lead, which is found native in small quantity, and is easily prepared by mixing chromate of potassa with a soluble salt of lead. It is of a rich yellow colour, and is employed in the arts of painting and dyeing to great extent.*

Process. 1081. *Perfluoride of Chromium.* CrF^5 ? When a mixture of three parts of fluor spar and four of chromate of protoxide of lead is distilled with five parts of fuming or even common sulphuric acid in a leaden retort, a red-coloured gas is disengaged, which acts rapidly on glass, with deposition of chromic acid and formation of fluo-silicic acid gas. Properties. It is absorbed by water, and the solution is found to contain a mixture of fluoric and chromic acids. The watery vapour of the air effects its decomposition, so that when mixed with air, red fumes appear, owing to the separation of minute crystals of chromic acid. Its true composition is not yet determined.

Oxychloride. *Oxychloride of Chromium*, $CrCl^3+2CrO^3$, 238.26 equiv., was discovered at the same time as the preceding, and was obtained by the action of fuming sulphuric acid on a mixture of about equal weights of chromate of protoxide of lead and chloride of sodium. It is a heavy red liquid, volatile and yielding red vapours when exposed to the air. It is decomposed by water into hydrochloric and chromic acids.

Vanadium.

Symb. V *Equiv.* 68.5

Discovery. 1082. Vanadium, so called from *Vanadis*, the name of a Scandinavian Deity, was discovered in the year 1830, by Sefström, of Fahlun, in iron prepared from the iron-ore of Taberg, in Sweden. He afterwards found a more abundant source in the slag or cinder formed during the conversion of the cast iron of Taberg into the malleable iron. Soon after, the same metal was found, by Johnson, in a a mineral from Wanlock-head, in Scotland, where it occurs as a vanadiate of protoxide of lead. A similar mineral, found at Zimapan in Mexico, was examined in the year 1801 by del Rio.

1083. Vanadium was obtained by a complicated process† from the slag, but may be more easily procured from native vanadiate of lead.

Process. The ore is dissolved in nitric acid, the lead and arsenic are precipitated by hydrosulphuric acid, a blue solution is formed and evaporated to dryness. The residue is dissolved by ammonia, and the vanadiate of ammonia precipitated by a piece of sal ammoniac. The vanadic acid is thus separated from arsenic, phosphoric, and hydrochloric acids with which it is generally associated.

Appearance, &c. 1084. Vanadium was separated in a pulverulent state, by means of potassium, having but little tenacity or appearance of a metal. But

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* *Sesquichloride of Chromium.* $2Cr+3Cl$, or Cr^2Cl^3, 56 2 eq. chrom. + 106.26 3 eq. chlor. = 162.26 equiv. It is prepared by transmitting dry chlorine gas over a mixture of oxide of chromium and charcoal heated to redness in a tube of porcelain; when the sesquichloride gradually collects as a crystalline sublimate of a peach-purple colour, which in thin layers is transparent, but in thicker masses is opaque. The sesquichloride of chromium dissolves slowly forming a deep green solution.

† For the details see Turner's *Elements*, 344.

under strong pressure it assumed a lustre like that of graphite. By a process of Rose's it had more of a metallic appearance, a white colour, and strong lustre.

Properties, &c.

1085. It is so extremely brittle that it cannot be removed without falling into powder. It is not oxidized either by air or water; although by continued exposure to the air its lustre gradually grows weaker, and it acquires a reddish tint. It is not dissolved by boiling sulphuric, hydrochloric, or hydrofluoric acid; but by nitric and nitro-hydrochloric acid it is attacked, and the solution has a beautiful dark blue colour. It is not oxidized by being boiled with caustic potassa, nor by carbonated alkalies at a red heat.

Protoxide.

1086. *Protoxide of Vanadium.* $V + O$, $\dot{V}$, or VO, 68.5 1 eq. vanad. + 8 1 eq. oxy. = 76.5 equiv. This compound is readily formed from vanadic acid by the combined agency of heat and charcoal or hydrogen gas. When rendered coherent by compression it possesses a property very unusual in oxides, that of conducting electricity, and in relation to zinc of being as strongly electro-negative as silver or copper.

Binoxide.

1087. *Binoxide of Vanadium.* $V + 2O$, $\ddot{V}$, or VO^2, 68.5 1 eq. vanad. + 16 2 eq. oxy. = 84.5 equiv. This oxide is best prepared, in the dry way, by heating to full redness an intimate mixture of 10 parts of the protoxide with 12 of vanadic acid in a vessel filled with carbonic acid, or from which combustible matter on the one hand, and oxygen gas on the other, are carefully excluded.

The salts of the binoxide of vanadium are distinguished by their blue colour, and by forming with solution of gall-nuts a black compound, a tannate of the binoxide, very similar to ink.

The binoxide is disposed to act the part of an acid by uniting with alkaline bases, with which it forms definite and in some cases crystalline compounds.

Vanadic acid,

1088. *Vanadic Acid,* $V + 3O$, $\dddot{V}$, or VO^3, 68.5 1 eq. vanad. + 24 3 eq. oxy. = 92.5 equiv., is tasteless, insoluble in alcohol, and very slightly soluble in water, which takes up rather less than $\frac{1}{1000}$ of its of its weight, acquiring a yellow colour and an acid reaction. Heated with combustible matter it is deoxidized, being converted into the protoxide or binoxide, or mixtures of these oxides. In solutions it is deprived of oxygen by all deoxidizing agents.

Salts of,

1089. Vanadic acid unites with salifiable bases often in two or more proportions, forming soluble salts with the alkalies, and in general sparingly soluble salts with the other metallic oxides. Those with excess of acid are commonly of a red or orange-red colour. Most of the neutral salts are yellow.

Vanadic acid is distinguished from all other acids except the chromic by its colour, and from this acid by the action of deoxidizing substances, which give a blue solution with the former and a green with the latter.

Sulphurets..

1090. *Sulphurets.* When the binoxide of vanadium is heated to redness in a current of hydrosulphuric acid gas, it is converted into protoxide, and both water and sulphur are obtained: on continuing the process the protoxide is decomposed, hydrogen gas and water pass over, and *bisulphuret* of vanadium is generated. (Bisulphuret of Vanadium, $V+2S$, or VS^2, 68.5 1 eq. vanad. + 32.2 2 eq. sulph. = 100.7 equiv.)

Tersulphuret. 1091. When a solution of vanadic acid in hydrosulphate of ammonia is acidulated by hydrochloric or sulphuric acid, the hydrated *tersulphuret* of vanadium subsides. Its colour is of a much lighter brown than the bisulphuret, becomes almost black in drying, and is resolved by a red heat in close vessels into the bisulphuret, with loss of water and sulphur.*

Molybdenum.

Symb. Mo *Equiv.* 47.7

Ore. 1092. The sulphuret is the most common natural compound of this metal.

When this ore, in fine powder, is digested in nitro-hydrochloric acid until completely decomposed, and the residue is briskly heated, in order to expel sulphuric acid, molybdic acid remains in the form of a white heavy powder. From this acid metallic molybdenum may be obtained by exposing it with charcoal to the strongest heat of a smith's forge; or by conducting over it a current of hydrogen gas while strongly heated in a tube of porcelain.†

Properties. 1093. Molybdenum is a brittle metal, very infusible, and of a white colour. It has been procured but in small quantities, and its properties are known imperfectly. Its sp. gr. is 8.615. When heated in open vessels it absorbs oxygen, and is converted into *molybdic acid.*

Molybdenum and oxygen.

Protoxide. 1094. *Protoxide of Molybdenum.* $Mo+O$, $\dot{Mo}$ or MoO, 47.71 eq. molyb. + 8 1 eq. oxy. = 55.7 equiv. This oxide is obtained, according to Berzelius, by precipitating the hydrochloric solution of molybdic acid by zinc. It is in the form of a brown hydrate and gives dark coloured solutions with the acids.

Binoxide. 1095. *Binoxide of Molybdenum,* $Mo+2O$, $\ddot{Mo}$, or MoO^2, 47.7 molyb. + 16 oxy. = 63.7 equiv., is obtained as a deep brown anhydrous powder by mixing molybdate of soda with half its weight of sal ammoniac in fine powder, projecting the mixture into a red-hot crucible which is to be instantly covered, and the heat continued until vapours of sal ammoniac cease to appear.

Hydrate. 1096. The hydrate, of a rust-brown colour, may be formed by digesting molybdenum in powder with molybdic acid dissolved in hydrochloric acid, until the liquid acquires a deep red colour, and then adding ammonia; or by adding ammonia to a solution of the bichloride.

Anhydrous. 1097. The anhydrous binoxide is insoluble in acids and is changed into molybdic acid by strong nitric acid. The hydrate is very like hydrated peroxide of iron, is dissolved by acids with which it forms red salts, is insoluble in the alkalies, but dissolves in alkaline carbonates. It is soluble, though sparingly, in pure water.

Molybdic acid. 1098. *Molybdic Acid.* $Mo+3O$, or MoO^3, 47.7 1 eq. molyb. + 24 3 eq. oxy. = 71.7 equiv. When sulphuret of molybdenum is roasted in an open crucible kept at a low red heat, and stirred until sulphurous acid ceases to escape, a dirty yellow powder is left, which contains impure molybdic acid. The acid is taken up by am-

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* See Turner, 347.

† Berzelius.

monia and the filtered solution evaporated to dryness; it is again taken up by water, a little ammonia being added, and filtered; and it is then purified by crystallization. On heating gently in an open platinum crucible, taking care to prevent fusion, the ammonia is expelled, and the pure acid remains. It is also obtained by oxidizing the binoxide with nitric acid.

Molybdic acid is a white powder, of sp. gr. 3.49, fusible by a red heat into a yellow liquid. It requires 570 times its weight of water for solution. It is soluble in the alkalies, forming colourless molybdates, from which molybdic acid is precipitated by the stronger acids.

Sulphurets.

1099. *Sulphurets.* Molybdenum combines with sulphur in three proportions. The lowest grade is the *bisulphuret*, which is the most common ore of molybdenum, and is usually associated with ores of tin, has a lead-gray colour and metallic lustre resembling graphite, for which it was formerly mistaken. Its density varies from 4.138 to 4.569. It bears a strong heat in close vessels without change, but is oxidized by nitric acid.

Tungsten.

Symb. W *Equiv.* 94.8

Tungsten.

1100. Tungsten, or Tungstenum, signifies a *heavy stone*, and is a name given by the Swedes to a mineral, which Scheele found to contain a peculiar metal, as he supposed in the state of an acid, united with lime. The same metallic substance was afterwards found united with iron and manganese in wolfram.

1101. The metal is obtained by exposing a mixture of tungstic acid and charcoal to a strong heat. It is difficult of fusion, very hard, brittle, and of an iron colour. Its sp. gr. is 17.5. By the action of heat and air, tungsten is converted into tungstic acid.

Wolfram.

1102. *Wolfram* is found in primitive countries generally accompanying tin ores; its colour is brownish black; it occurs massive and crystallized.*

Binoxide.

1103. *Binoxide of Tungsten*, $W+2O$, $\ddot{W}$, or WO^2, 94.8 1 eq. tungst. + 16 2 eq. oxy. = 110.8 equiv., is formed by the action of hydrogen gas on tungstic acid at a low red heat; but the best mode of procuring it both pure and in quantity, is that recommended by Wöhler.

Properties.

Binoxide of tungsten, when prepared by means of hydrogen gas, has a brown colour, and when polished acquires the colour of copper; but when procured by Wöhler's process, it is nearly black. It does not unite, so far as is known, with acids; and when heated to near redness, it takes fire and yields tungstic acid.

Tungstic acid.

1104. *Tungstic Acid.* $W+3O$, $\dddot{W}$, WO^3, 94.8 1 eq. tungst. + 24 3 eq. oxy. = 118.8 equiv. A convenient method of preparing tungstic acid is by digesting native tungstate of lime,† very finely levigated, in nitric acid; by which means nitrate of lime is formed,

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* For Wöhler's process for obtaining the binoxide from this ore, see *Quart. Jour. of Sci.* xx. 177, and Turner, p. 352.

Tungstate of lime.

† A whitish semi-transparent substance, found in England, Saxony, Bohemia, and Sweden, and occurring crystallized and massive. Its most usual form is the octohedron.

and tungstic acid separated in the form of a yellow powder. Tungstic acid may also be prepared by the action of hydrochloric acid on wolfram. It is also obtained by heating the binoxide to redness in open vessels.

Tungstic acid is of a yellow colour, is insoluble in water, and has no action on litmus paper. With alkaline bases it forms salts called *tungstates*, which are decomposed by the stronger acids. Heated in open vessels, it acquires a green colour, and becomes blue when exposed to the action of hydrogen gas at a temperature of 500° or 600° F.

Chlorides. 1105. *Chlorides.* Tungsten and chlorine unite in two proportions. When metallic tungsten is heated in chlorine gas, it takes fire and yields the *bichloride;* ($W+2Cl$, or WCl^2, 94.8 1 eq. tungst. $+$ 70.84 2 eq. chlor. $=$ 165.64 equiv.) Wöhler has described another chloride formed at the same time which is converted by water into hydrochloric and tungstic acids. It exists in beautiful crystals of a fine red colour.

Bisulphuret. 1106. *Bisulphuret of Tungsten,* $W+2S$, or WS^2, 94.8 1 eq. tungst. $+$ 32.2 2 eq. sulph. $=$ 127 equiv., is obtained by passing hydrosulphuric acid gas, or the vapour of sulphur, over tungstic acid heated to whiteness in a tube of porcelain.

Columbium.

Symb. Ta *Equiv.* 185

Discovery. 1107. This metal was discovered in 1801, by Hatchett, in a black mineral in the British museum, which had been sent by Gov. Winthrop to Sir Hans Sloane, from the vicinity of New-London in Connecticut.*

Tantalite and yttro-tantalite. Tantalum. A metal analogous in its properties to columbium, was discovered by Ekeberg, a Swedish chemist, in two different minerals, called Tantalite and Yttro-tantalite. To this metal he gave the name of *tantalum*. The identity of these metals, however, was established, in 1809, by Wollaston.

Columbic acid. 1108. Columbic acid is with difficulty reduced to the metallic state by the action of heat and charcoal; but Berzelius succeeded in obtaining this metal by the same process which he employed in the preparation of zirconium and silicon, namely, by heating potassium with the double fluoride of potassium and columbium. On washing the reduced mass with hot water, columbium is left in the form of a black powder. In this state it does not conduct electricity; but in a denser state it is a perfect conductor. By pressure it acquires metallic lustre, and has an iron-gray colour.

Properties. 1109. It is not fusible at the temperature at which glass is fused. When heated in the open air, it takes fire yielding columbic acid. It is dissolved with heat and disengagement of hydrogen gas by hydrofluoric acid, and still more easily by a mixture of nitric and hydrofluoric acids. It is also converted into columbic acid by fusion with hydrate of potassa, the hydrogen gas of the water being evolved.

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* Probably Haddam, where it was rediscovered by Torrey (*Amer. Jour.* iv. 52). A crystal weighing fourteen pounds was found by Johnson, *Ibid*, xxx. 387.

Binoxide.

1110. *Binoxide of Columbium*, $Ta+2O$, $\ddot{Ta}$, or TaO^2, 185 1 eq. columb. + 16 2 eq. oxy. = 201 equiv., is generated by placing columbic acid in a crucible lined with charcoal, luting carefully to exclude atmospheric air, and exposing it for an hour and a half to intense heat. When reduced to powder its colour is dark brown. It is not attacked by any acid, but it is converted into columbic acid either by fusion with hydrate of potassa, or deflagration with nitre.

Columbic acid.

1111. *Columbic Acid.* $Ta+3O$, $\dddot{Ta}$, or TaO^3, 185 1 eq. columb. + 24 3 eq. oxy. = 209 equiv. Columbium exists in most of its ores as an acid, united either with the oxides of iron and manganese, as in tantalite, or with the earth yttria, as in the yttro-tantalite. This acid is obtained by fusing its ore with three or four times its weight of carbonate of potassa, when a soluble columbate of that alkali results, from which columbic acid is precipitated as a white hydrate by acids.

Properties.

1112. Hydrated columbic acid is tasteless and insoluble in water; but when placed on moistened litmus paper, it communicates a red tinge. It is dissolved by the sulphuric, hydrochloric, and some vegetable acids; but it does not appear to form definite compounds with them. With alkalies it unites readily; when the hydrated acid is heated to redness, water is expelled, and the anhydrous columbic acid remains.

Antimony.

Symb. Sb *Equiv.* 64.6

Ores.

1113. This metal is found *native* in Sweden, in France, and in the Hartz; but its principal ore is the *sulphuret* which is found massive and crystallized, and of which there are several varieties. The most common is the *radiated*, which is of a gray colour and brittle. This ore may be decomposed, and the pure metal obtained from it, by the following process:

Reduction of.

Mix three parts of the powdered sulphuret with two of crude tartar, one of nitre, and throw the mixture by spoonfuls into a red-hot crucible; then heat the mass to redness, and a button will be found at the bottom of the crucible, which is the metal as it commonly occurs in commerce.

1114. The metal thus obtained is not pure enough for chemical use, and for that should be procured by heating the sesquioxide with an equal weight of cream of tartar.

Properties.

1115. Antimony (sometimes called *regulus of antimony*), is of a silvery white colour, brittle, and crystalline in its ordinary texture. It fuses at about 810° and is volatile at a high heat. Its specific gravity is 6.702. Placed upon ignited charcoal, under a current of oxygen gas, antimony burns with great brilliancy.

Decomposes water.

The vapour of water, brought into contact with ignited antimony, is decomposed with so much rapidity as to produce a series of detonations.

Sesquioxide.

1116. *Sesquioxide of Antimony.* $2Sb+3O$, $\overset{\cdots}{\overline{Sb}}$, or Sb^2O^3, 129.2 2 eq. ant. + 24 3 eq. oxy. = 153.2 equiv. When sesquichloride of antimony, made by boiling the native sulphuret in hydrochloric acid (755), is poured into water, a white curdy precipitate subsides, formerly called *powder of Algaroth*, which consists of sesquioxide of antimony combined with undecomposed sesquichloride. On decomposing the latter by digestion with carbonate of potassa and then washing with water, the sesquioxide is obtained in a state of purity. It may also be procured by adding carbonate of potassa or soda to a solution of tartar emetic, and by sublimation during the combustion of antimony. When slowly sublimed it condenses in fine needles of silvery whiteness. It occurs as a mineral, the oxide of antimony of mineralogists, the primary form of which is a right rhombic prism, isomorphous with the crystals of arsenious acid lately observed by Wöhler.* (1049.)

Properties. 1117. It is a white powder, acquiring a yellow tint by heat. Sp. gr. 5.566. It is volatile and may be sublimed; heated in the air it absorbs oxygen, and antimonious acid is generated.

1118. It is the only oxide which forms regular salts with acids, and is the base of *emetic tartar*, the tartrate of antimony and potash.

Solubility of its salts. Most of its salts are either insoluble in water, or, like chloride of antimony, are decomposed by it, owing to the affinity of that fluid, for the acid being greater than that of the acid for sesquioxide of antimony. This oxide is therefore a feeble base, and indeed possesses the property of uniting with alkalies. To the foregoing remark, however, tartrate of antimony and potassa, is an exception, for it dissolves readily in water without change. By excess of tartaric or hydrochloric acids, the insoluble salts of antimony may be rendered soluble in water.

Detected. 1119. The presence of antimony in solution is easily detected by hydrosulphuric acid. This gas occasions an orange-coloured precipitate, hydrated sesquisulphuret of antimony, which is soluble in pure potassa, and is dissolved with disengagement of hydrosulphuric acid gas by hot hydrochloric acid, forming a solution from which the white oxychloride (*powder of Algaroth*) is precipitated by water.

In trying the effect of reagents on solutions of sesquioxide of antimony, it is convenient to employ tartar emetic, from its property of dissolving in pure water without decomposition. T. 357.

It may be detected when present even in small quantity by decomposing antimoniuretted hydrogen, in the apparatus (fig. 179, p. 274.)†

Antimonious acid, 1120. *Antimonious Acid*, $2Sb+4O$, $\dddot{Sb}$, or Sb^2O^4, 129.2 2 eq. antim. + 32 4 eq. oxy. = 161.2 equiv. When metallic antimony is digested in strong nitric acid, the metal is oxidized at the expense of the acid, and hydrated antimonic acid is formed; on exposing this substance to a red heat, it gives out water and oxygen gas, and is converted into antimonious acid. It is also generated when the oxide is exposed to heat in open vessels.

Properties. 1121. This acid is formed in the process of preparing the *Pulvis Antimonialis* of the Pharmacopœia. Antimonious acid is white while cold, but yellow when heated, is very infusible, and fixed in the fire, two characters by which it is readily distinguished from the

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* *Ann. de Chim. et de Phys.* li. 201.

† For the method of detecting antimony in mixed fluids, &c., see Turner, p. 357, and Christison on Poisons, 354.

sesquioxide. It is insoluble in water, and likewise in acids after being heated to redness. It combines in definite proportions with alkalies, and its salts are called *antimonites*. Antimonious acid is precipitated from these salts by acids as a hydrate.

Antimonic acid.

1122. *Antimonic Acid*, 2Sb+5O, $\overset{\therefore\cdot}{\underline{\mathrm{Sb}}}$, or Sb^2O^5, 129.2 2 eq. antim. + 40 5 eq. oxy. = 169.2 equiv., sometimes called *peroxide* of antimony, is obtained as a white hydrate, by digesting the metal in strong nitric acid, or by dissolving it in nitro-hydrochloric acid, concentrating by heat and throwing the solution into water. When recently precipitated it reddens litmus, and may be dissolved in water by means of hydrochloric or tartaric acid. It does not enter into definite combination with acids, but with alkalies forms salts, which are called *antimoniates*. When hydrated antimonic acid is exposed to a temperature of 500° or 600° F., the water is evolved, and the anhydrous acid of a yellow colour remains; exposed to a red heat, it parts with oxygen, and is converted into antimonious acid.

Chlorides.

1123. *Chlorides of Antimony*, 2Sb+3Cl or Sb^2Cl^3, 129.2 2 eq. antim. + 106.26 3 eq. chlor. = 235.46 equiv. When antimony in powder is thrown into a jar of chlorine gas, combustion ensues, and the *sesquichloride* of antimony is generated, (616.) The same compound may be formed by distilling a mixture of antimony with about twice and a half its weight of corrosive sublimate, when the volatile sesquichloride of antimony passes over into the recipient, and metallic mercury remains in the retort. At common temperatures it is a soft solid, thence called *butter* of antimony, which is liquefied by gentle heat, and crystallizes on cooling. It deliquesces on exposure to the air.*

Sesquisulphuret.

1124. *Sesquisulphuret of Antimony*, 2Sb+3S, or Sb^2S^3, 129.2 2 eq. antim. + 48.3 3 eq. sulph. = 177.5 equiv. This is by far the most abundant ore of antimony, and is hence employed in making the preparations of antimony. Though generally compact or earthy, it sometimes occurs in acicular crystals and in rhombic prisms. Its sp. gr. is 4.62, colour red-gray, and its lustre metallic. When heated in close vessels, it enters into fusion without any other change.

Artificial.

1125. It may be formed artificially by fusing together antimony and sulphur, or by transmitting a current of hydrosulphuric acid gas through a solution of tartar emetic: in this case it falls as a hydrate of an orange-red colour, and does not acquire its dark colour till its water is expelled by heat.†

Oxysulphuret.

1126. *Oxysulphuret of Antimony*, $2Sb^2S^3+Sb^2O^3$, 355 2 eq. sesquisulph. + 153.2 1 eq. sesquiox. = 508.2 equiv., occurs in the mineral kingdom, as the *red antimony* of mineralogists. The pharmaceutic preparations, known as *glass*, *liver* and *crocus* of antimony,

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* *Bichloride of Antimony*, 2Sb+4Cl, or Sb^2Cl^4, 129.2 2 eq. antim. + 141.68 4 eq. chlor. = 270.88 equiv.

Perchloride of Antimony, 2Sb+5Cl, or Sb^2Cl^5, 129.2 2 eq. antim. + 177.1 5 eq. chlor. = 306.3 equiv.

† *Oxychloride of Antimony*, $2Sb^2Cl3+9Sb^2O3$, 470.92 2 eq. sesquichlor. + 1378.8 9 eq. sesquioxide. = 1649.72 equiv., is obtained when an acid solution of the sesquichloride is thrown into a large quantity of water and the precipitate allowed to subside. It has been lately examined by Johnson, see *Edin. Philos. Jour.* No. 25, and *Lond. and Edin. Philos. Mag.* No. 40.

are of a similar nature, which are made by roasting the native sulphuret, so as to form sulphurous acid and sesquioxide of antimony, and then vitrefying the oxide together with undecomposed ore, by means of a strong heat. The product will of course differ according as more or less of the sulphuret escapes oxidation during the process.

Kermes mineral.

1127. When sesquisulphuret of antimony is boiled in a solution of potassa or soda, a liquid is obtained, from which on cooling an orange-red matter called *kermes mineral* is deposited; and on neutralizing the cold solution with an acid, an additional quantity of a similar substance, the *golden sulphuret** of the Pharmacopœia, subsides. These compounds may also be obtained by igniting sesquisulphuret of antimony with an alkali or alkaline carbonate, and treating the product with hot water; or by boiling the mineral in a solution of carbonate of soda or potassa.†

Alloys.

1128. Antimony forms brittle alloys with the malleable metals. Gold alloyed with $\frac{1}{1920}$ its weight of antimony, is perfectly brittle; and even the fumes of antimony in the vicinity of melted gold are sufficient to destroy its ductility. With potassium and sodium it forms white brittle compounds, destructible by the action of air and water.

Type metal.

An alloy with lead in the proportion of 3 lead to 1 antimony, and a small addition of copper, is used for *printers' types.* With lead only, a white and rather brittle compound is formed, used for the plates upon which music is engraved. With iron it forms a hard whitish alloy, formerly called *martial regulus,* which may be obtained by fusing two parts of sulphuret of antimony with one of iron filings; a scoria consisting chiefly of sulphuret of iron is formed; and the fused alloy beneath usually presents a stellated appearance in consequence of its crystallization. This star was much admired by the alchymists, who considered it a mysterious guide to transmutation. With tin, antimony constitutes a kind of *pewter,* a term, however, which has also been applied to some other alloys, especially that of lead and tin. The finest pewter consists of about 12 parts of tin and 1 of antimony, with a small addition of copper. A good white metal, used for teapots, is composed of 100 tin, 8 antimony, 2 bismuth, and 2 copper.

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* Antimonii sulphuretum precipitatum, U. S. P.

† Great difference of opinion has long existed as to the nature of kermes. See Turner, 359.

The finest kermes is obtained, according to Cluzel, from a mixture of 4 parts of sulphuret of antimony, 90 of crystallized carbonate of soda, and 1000 of water. These materials are boiled for half or three-quarters of an hour; the hot solution is filtered into a warm vessel, in order that it may cool slowly; and after 24 hours, the deposite is collected on a filter, moderately washed with cold water, and dried at a temperature of 70° or 80° F.

Bisulphuret of Antimony, $2Sb+4S$, or Sb_2S4, 129.2 2 eq. antim. + 64.4 4 eq. sulph. = 193.6 equiv.

Persulphuret of Antimony, $2Sb+5S$, or Sb^2S5, 129.2 2 eq. antim. + 80.5 5 eq. sulph. = 209.7 equiv.

Uranium.

Symb. U *Eq.* 217

Uranium. 1129. This metal was discovered by Klaproth in 1789,* in a mineral called *pitch-blende*, which consists of protoxide of uranium and oxide of iron.

Process. The metal is procured by heating the ore to redness, digesting its powder in pure nitric acid diluted with 3 or 4 parts of water; lead and copper are separated by hydrosulphuric acid gas; the solution is concentrated and set aside when nitrate of sesquioxide of uranium crystallizes in prisms of a lemon yellow colour.

Properties. 1130. The properties of uranium are not well known; its sp. gr. is 9.†

Protoxide. 1131. *Protoxide of Uranium*, $U+O$, $\dot{U}$, or Uo, 217 1 eq. uran. $+$ 8 1 eq. oxy. $=$ 225 equiv., is of a dark green colour, and is obtained by decomposing the nitrate of the sesquioxide by heat. It is exceedingly infusible, unites with acids, forming salts of a green colour, and is readily oxidized by nitric acid.

Use. The protoxide is employed in the arts for giving a black colour to porcelain.

Sesquioxide. 1132. *Sesquioxide of Uranium*, $2U+3O$, $\overset{\cdots}{U}$, or U^2O^3, 434 2 eq. uran. $+$ 24 3 eq. oxy. $=$ 458 equiv., is of a yellow colour, and most of its salts have the same. It combines with acids, and with alkaline bases. From the former it is precipitated as a yellow hydrate by the pure alkalies.

Cerium.

Symb. Ce *Eq.* 46

Cerium; ores. 1133. This metal was obtained by Hisinger and Berzelius, from a mineral found at Bastnas in Sweden, to which they have given the name of *Cerite*.‡ It is also contained in *Allanite*, a mineral from Greenland, first distinguished as a peculiar species by Allan, of Edinburgh. It contains, according to Thomson's analysis, about 40 per cent. of oxide of cerium.

This oxide is extremely difficult of reduction. Children succeeded in fusing it by the aid of his powerful Voltaic apparatus, and when intensely heated it burned with a vivid flame, and was partly volatilized.

Vauquelin's experiments. 1134. The attempts of Vauquelin to reduce the oxide of cerium produced only a small metallic globule, not larger than a pin's head. This globule was not acted upon by any of the simple acids; but it was dissolved, though slowly, by nitro-hydrochloric acid.

Protoxide. 1135. *Protoxide of Cerium*, $Ce+O$, $\dot{Ce}$, or CeO, 46 1 eq. cerium, $+$ 8 1 eq. oxy. $=$ 54 equiv. This oxide is a white powder, insoluble in water, forming salts with acids, all of which, if soluble,

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* Named after the new planet, discovered in that year and called Uranus.

† Buchholz, in *Mem. Acad. Sci. of Stockholm*, 1822.

‡ The name *Cerium* was given to this metal from the planet *Ceres*, discovered about the same period. See Nicholson's *Jour*. xii. 105.

have an acid reaction. Heated in open vessels, it absorbs oxygen, and is converted into the sesquioxide. It is precipitated as a white hydrate by pure alkalies; as a white carbonate by alkaline carbonates, but is redissolved by the precipitant in excess; and as a white oxalate by oxalate of ammonia.

Sesquioxide.

1136. *Sesquioxide of Cerium*, $2Ce+3O$, $\underline{\overset{\cdots}{\mathrm{Ce}}}$, or Ce^2O^3, 92 2 eq. cerium, $+$ 24 3 eq. oxy. $=$ 116 equiv., has a fawn red colour; it is dissolved by several of the acids, but is a weaker base than the protoxide. Digested in hydrochloric acid, chlorine is disengaged and a protochloride results. It is most readily extracted from cerite by a process of Laugier.*

Bismuth.

Symb. Bi *Eq.* 71

Native.

1137. This metal is found native; combined with oxygen; and with arsenic and sulphur. *Native Bismuth* occurs crystallized in octohëdra and cubes, and in addition to arsenic generally contains cobalt.

Properties.

1138. Bismuth has a reddish white colour, and is composed of broad brilliant plates adhering to each other. Its sp. gr. is 9.822, but is increased by hammering. It breaks, however, under the hammer, and hence cannot be considered as malleable; nor can it be drawn out into wire. The bismuth of commerce is not quite pure.

1139. Bismuth is one of the most fusible metals, melting at 476° F., and it forms more readily than most other metals, distinct crystals by slow cooling.

Process for obtaining crystals.

It may be obtained in regular crystals, by fusing a quantity of it in a crucible, and allowing it to cool till a crust is formed on the surface; the extremity of the crucible may then be broken off, and the fluid metal beneath be allowed to escape. The under surface of the crust will be found beautifully crystallized.

Oxide.

1140. When bismuth is exposed to heat and air it oxidizes. If the heat be increased by directing a current of oxygen upon the metal, it burns with much brilliancy, and produces abundant yellow fumes of protoxide. It is readily oxidized and dissolved by nitric acid.

Protoxide.

1141. *Protoxide of Bismuth*, $Bi+O$, $\dot{\mathrm{Bi}}$, or BiO, 71 1 eq. bism. $+$ 8 1 eq. oxy. $=$ 79 equiv. This compound is readily prepared by heating to redness the nitrate or subnitrate of protoxide of bismuth. Its colour is yellow; at a full red heat it is fused into a brown liquid, which on cooling becomes a yellow transparent glass of sp. gr. 8.211. At intense temperatures it is sublimed. It unites with acids, and most of its salts are white.

Magistery.

1142. When nitrate of protoxide of bismuth, either in solution or in crystals, is put into water, a copious precipitate, the subnitrate, of a beautifully white colour, subsides, which was formerly called

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* For which see Turner's *Chem.* 362.

the *magistery of bismuth* and *pearl white*. From its whiteness it is sometimes employed as a paint for improving the complexion.[*]

White oxide.

If the nitrate with which it is made contains no excess of acid, and a large quantity of water is employed, nearly the whole of the bismuth is separated as a subnitrate, *White oxide of the Pharmacopœia*. By this character bismuth may be both distinguished and separated from other metals.

Sesquioxide.

1143. *Sesquioxide of Bismuth*, $2Bi+3O$, $\overset{\cdots}{\underline{Bi}}$, or Bi^2O^3, 142 2 eq. bism. + 24 3 eq. oxy. = 166 equiv. This oxide is generated when hydrate of potassa is fused at a moderate heat with protoxide of bismuth; but the best mode of preparation is first to prepare the protoxide by igniting the subnitrate, and then gently heating it for some time in a solution of chloride of potassa or soda. After washing with water, any unchanged protoxide is dissolved by a solution made with 1 part of nitric acid (quite free from nitrous acid) and 9 of water.

Properties.

1144. As thus prepared, sesquioxide of bismuth is a heavy powder of a brown colour, with little disposition to unite either with acids or alkalies. Heated with sulphuric or phosphoric acid, it gives off oxygen gas, and with hydrochloric acid, chlorine is evolved, and the protochloride produced.[†]

Chloride.

1145. *Chloride of Bismuth*, $Bi+Cl$, or $BiCl$, 71 1 eq. bism. + 35.42 1 eq. chlor. = 106.42 equiv. When bismuth in fine powder is introduced into chlorine gas, it takes fire, burns with a pale blue light, and is converted into a chloride, formerly termed *butter* of bismuth. It may be prepared conveniently by heating two parts of corrosive sublimate with one of bismuth, and afterwards expelling the excess of the former, together with the metallic mercury by heat.

Properties.

1146. Chloride of bismuth is of a grayish-white colour, opaque, and of a granular texture. It fuses at a temperature a little above that at which the metal itself is liquefied, and bears a red heat in close vessels without subliming.

1147. Bismuth also combines with bromine, and with sulphur, the sulphuret is found native.

Titanium.[‡]

Symb. Ti *Eq.* 24.3

Discovery.

1148. Titanium, in the metallic state, was discovered by Wollaston in 1822, in the slag at the bottom of an iron smelting-furnace in South Wales.[§] It has been since found in several other places in Europe. It has the form of small smooth cubes, having a red colour exceedingly similar to that of copper. The cubes are hard enough to scratch rock crystal, and cannot be fused by the highest temperature which can be raised by the blow-pipe. The sp. gr. is

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[*] If a small portion of hydrochloric acid be mixed with the nitric, and the precipitate be washed with but a small quantity of cold water, it will appear in minute scales, constituting the *pearl-powder* of perfumers; but it is an inconvenient pigment, owing to the facility with which it is blackened by hydrosulphuric acid.

[†] *An. de Ch. et de Ph.* li. 267.

[‡] Named by Klaproth after the *Titans* of ancient fable.

[§] *Philos. Trans.* 1823.

5.3.* It does not appear, however, to be absolutely free from iron. Wollaston found that when suspended by a fine thread a magnet drew it about 20 degrees from the perpendicular. He succeeded in detecting the presence of iron in it, and calculated the amount of that metal at $\frac{1}{250}$ part of the weight of the titanium.†

Prepared.

1149. *Metallic Titanium* may be obtained by putting fragments of recently made chloride of titanium and ammonia into a glass tube half an inch wide and two or three feet long, transmitting through it a current of perfectly dry ammonia, and, when atmospheric air is entirely displaced, applying heat until the glass softens. Complete decomposition ensues, nitrogen gas is disengaged, hydrochlorate of ammonia sublimes, and metallic titanium is left in the state of a deep blue-coloured powder. If exposed to the air while warm, is apt to take fire.

Oxide. Prepared.

1150. *Oxide of Titanium*, (probably) $Ti+O$, or TiO, 24.3 1 eq. titan. + 8 1 eq. oxy. = 32.3 equiv., is prepared by exposing titanic acid to a strong heat in a black lead crucible; the exterior of the mass obtained consists of metallic titanium, the interior is supposed to be the oxide. It may be formed in the moist way by acting upon a solution of titanic acid in hydrochloric acid by zinc or iron. The titanic acid is thrown down as a purple powder, but cannot be collected.

Titanic acid.

1151. *Titanic Acid*, or *Peroxide of Titanium*, $Ti+2O$, $\ddot{Ti}$, or TiO^2, 24.3 1 eq. titan. + 16 2 eq. oxy. = 40.3 equiv., occurs nearly pure in the minerals *anatase* and *rutile;* it exists also in several other minerals.

Process.

It may be obtained from rutile, or titaniferous iron exposed in a porcelain tube to a very strong red heat and a current of hydrosulphuric acid gas, which gives rise to water and sulphuret of iron. When the water ceases to appear, the mass is removed and digested in hydrochloric acid to remove the iron, and the titanic acid is separated from adhering sulphur by heat.‡

Properties.

1152. Titanic acid is quite white, exceedingly infusible and difficult of reduction; after being once ignited it ceases to be soluble in acids, except in the hydrofluoric. In its chemical relations it is analogous to silicic acid, being a feeble acid, but combining with metallic oxides. In the state of hydrate, it has a singular tendency to pass through the pores of a filter when washed with pure water; but the presence of a little acid, alkali, or a salt, prevents this inconvenience.

Solubility, &c.

1153. If previously ignited with carbonate of potassa, titanic acid is soluble in dilute hydrochloric acid; but it is retained in solution by so feeble an attraction, that it is precipitated merely by boiling. It is likewise thrown down by the pure and carbonated alkalies, both fixed and volatile. A solution of gall-nuts causes an orange-red colour, which is very characteristic of titanic acid. When a rod of zinc is suspended in the solution, a purple-coloured powder, probably the oxide, is precipitated, which is gradually converted into titanic acid.

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* From the extreme infusibility of the cubes of metallic titanium, Wollaston infers that they have not been formed by crystallization in cooling from a state of fusion; but from the reduction of the oxide dissolved in the slag around them.

† *Phil. Trans.* p. 200. Thomson's *First Princip.* 2. 80.

‡ Rose, *An. de Ch. et de Ph.* xxiii. and xxxviii. 131.

Bichloride.

1154. *Bichloride of Titanium.* $Ti+2Cl$, or $TiCl^2$, 24.3 1 eq. titan. + 70.84 2 eq. chlor. = 95.14 equiv. This substance was discovered in the year 1824 by transmitting dry chlorine gas over metallic titanium at a red heat.

Properties.

1155. At common temperatures it is a transparent colourless fluid of considerable specific gravity, boils violently at a temperature a little above 212°, and condenses again without change. Dumas has shown that the density of its vapour may be estimated at 6.615. In open vessels it is attacked by the moisture of the atmosphere, and emits dense white fumes of a pungent odour similar to that of chlorine, but not so offensive. On adding a few drops of water to a few drops of the liquid, combination ensues with almost explosive violence, from the evolution of intense heat; and if the water is not in excess a solid hydrate is obtained. On exposure, and on adding water, the greater part is dissolved.

Tellurium.

Symb. Te *Equiv.* 64.2

Discovery.

1156. Tellurium is a rare metal, found in the gold mines of Transylvania, and in Connecticut, U. S.,[*] in small quantity. Its existence was inferred by Müller in the year 1782, and fully established in 1798 by Klaproth, who gave it the name of *tellurium*, from *tellus, the earth,* suggested by the source from which he drew the name of uranium.[†] It occurs in the metallic state, chiefly in combination with gold and silver.

Properties.

1157. Tellurium is of a bright gray colour, brittle, easily fusible, and very volatile. Its specific gravity is 6.17.

Oxide.

1158. It is oxidized when heated in contact with the air; and burns with a sky-blue flame, edged with green. Upon charcoal, before the blow-pipe, it inflames with a violence resembling detonation; exhibits a vivid flame; and entirely flies off in a gray smoke, having a peculiarly nauseous smell.[‡] This smoke, when condensed, and examined in quantity, is found to be white with a tint of yellow. It is fusible by a strong heat, and volatile at still higher temperature.

Tellurous acid.

1159. *Tellurous Acid.* $Te+2O$, $\ddot{Te}$, or TeO^2, 64.2 1 eq. tellur. + 16 2 eq. oxy. = 80.2 equiv. This compound, also called *oxide of tellurium,* is generated by the action of nitric acid on tellurium, by which acid it is dissolved; but the solution possesses such little permanence that mere affusion of water precipitates part of it, and the rest is obtained by evaporating to dryness. In this state, it is a white granular anhydrous powder, which slowly reddens moist litmus paper.

Properties.

1160. Its aqueous solution reddens litmus paper; it becomes turbid at 68°, and the acid which falls is no longer soluble in acids. In these properties tellurous acid closely resembles the titanic and several other feeble acids, which have a soluble hydrated state easily convertible into an insoluble anhydrous one. Its salts are precipitated black by hydrosulphuric acid, bisulphuret of tellurium being formed.[§]

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[*] *Amer. Jour.* i. 406. [†] *Contributions*, iii.

[‡] Ascribed by Berzelius to the presence of selenium.

[§] *Hydrotelluric Acid.* $Te+H$, or TeH, 64.2 1 eq. tellur. + 1 1 eq. hyd. = 65.2

Chap IV.

Copper.

Symb. Cu *Equiv.* 31.6

Ores of copper; Native copper.

1161. This metal was known in the early ages of the world, and was the principal ingredient in domestic utensils, and in the instruments of war, previous to the discovery of malleable iron.* It is found native, and in various states of combination. Native copper is by no means uncommon, being found more or less in most copper mines. It occurs in a variety of forms; massive, dendritic, granular, and crystallized in cubes, octohedra, &c. It is found in Cornwall, Siberia, and other parts of Europe. Large masses have been found in various parts of America; one of which, about 30 miles from Lake Superior, described by Schoolcraft, weighs by estimation 2000 lbs.† The copper of commerce is extracted chiefly from the native sulphuret; especially from copper pyrites, a double sulphuret of iron and copper.

Metal obtained pure.

1162. The metal may be obtained by dissolving the copper of commerce in hydrochloric acid; the solution is diluted and a plate of iron immersed, upon which the copper is precipitated. It may be fused into a button, after having been previously washed in dilute sulphuric acid to separate a little iron that adheres to it.

Properties.

1163. Copper has a fine red colour, and much brilliancy; it is very malleable and ductile, and has a peculiar smell when warmed or rubbed. It melts at a cherry-red or dull white heat, 1996° F. Its sp. gr. varies, being increased by hammering; when fused, its density is 8.895. Under a flame urged by oxygen gas, it takes fire, and burus with a beautiful green light.

Action of air.

1164. Copper is oxidized by air. This may be shown by heating one end of a polished bar of copper, which will exhibit various shades of colour, according to the intensity of the heat.

Combustion of copper.

It burns with great splendour before the compound blow-pipe, upon charcoal.

Exp.

The white-hot globule being thrown from the charcoal into a tall jar or wide tube filled with water, it will pass in full ignition, through a column of the fluid two feet high, and will remain for some time ignited on the bottom, which should be protected by a layer of sand.‡

Effect of heat.

A plate of copper, exposed for some time to heat, becomes covered with protoxide, which breaks off in scales when the copper is hammered.

Equivalent.

1165. From the experiments of Berzelius, eight parts of oxygen unite with 31.6 parts of copper to constitute the black oxide, and therefore if this oxide be formed of an atom of oxygen united with an atom of copper the eq. of this metal will be 31.6. This is adopted

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equiv. By acting on an alloy of tellurium with zinc or tin, by hydrochloric acid, Davy discovered this gas in 1809. It has the properties of a feeble acid.

Telluric Acid, $Te+3O$, $\dddot{Te}$, or TeO^3, 64.2 1 eq. tellur. + 24 3 eq. oxy. = 88.2 equiv. For other compounds of tellurium see Turner, 368. See also Berzelius on *Tellurium*, in *Ann. des Mines*, v. 381, and *Amer. Jour.* xxviii. 137.

[*] The word *copper* is derived from the island of Cyprus, where it was first wrought by the Greeks.

[†] Stromeyer has lately discovered it in several specimens of meteoric iron, but in a quantity not exceeding $\frac{2}{1000}$ of the mass. See other localities in Cleaveland's *Mineralogy*, p. 554, and J. D. Dana's *System*.

[‡] Silliman.

by many chemists, others regard it as a binoxide, and the red as the protoxide, and take twice 31.6, or 63.2, as the eq. of copper.

Red oxide.

1166. *Red, or Dioxide of Copper*, $2Cu+O$, or Cu^2O, 63.2 2 eq. copper + 8 1 eq. oxy. = 71.2 equiv., occurs native in the form of octohedral crystals, and is found of peculiar beauty in the mines of Cornwall. It may be prepared artificially by heating, in a covered crucible, a mixture of 31.6 parts of copper filings with 39.6 of the black oxide; or, still better, by arranging thin copper plates one above the other, with interposed strata of the black oxide, and exposing them to a red heat carefully protected from the air. Another method is by boiling a solution of acetate of protoxide of copper with sugar, when the dioxide subsides as a red powder; and another is to fuse at a low red heat the dichloride of copper with about an equal weight of carbonate or bicarbonate of soda, subsequently dissolving the sea-salt by water, and drying the red powder.*

Process.

In this case, by an interchange of elements,

Theory.

1 eq. dichloride of copper $2Cu+Cl$ yield 1 eq. red oxide . . $2Cu+O$
and 1 eq. soda . . $Na+O$ and 1 eq. chloride of sodium $Na+Cl$

Properties.

1167. The red or dioxide of copper has a density of 6.093, and in colour is very similar to copper. At a red heat it absorbs oxygen, and is converted into the protoxide. Dilute acids act on it very slowly; resolving it into metal and a protoxide.

Action of acids.

1168. With strong nitric acid it is oxidized, binoxide of nitrogen escapes, and a nitrate of the black oxide is formed. Strong hydrochloric acid forms with it a colourless solution. The red oxide of copper is soluble in ammonia, and the solution is quite colourless; but it becomes blue with surprising rapidity by free exposure to air, owing to the formation of the black oxide.

Exp.

Put a small quantity of this oxide into a small bottle, nearly full of water of ammonia, and shake it frequently, the solution will have a rich blue colour. If a quantity of copper filings be added and the bottle well closed so as completely to exclude the air, the solution will become colourless in a few days. If the cork be withdrawn, the blue colour will again return as oxygen is absorbed.

Black.

1169. *Black or Protoxide.* $Cu+O$, $\dot{Cu}$, or CuO, 31.6 1 eq. cop. + 8 1 eq. oxy. = 39.6 equiv. This oxide of copper occurs native, by the spontaneous oxidation of other ores of copper; it is the *copper black* of mineralogy.

Artificial.

1170. It may be prepared artificially by calcining metallic copper, by precipitation from the salts of copper by means of pure potassa, and by heating nitrate of copper to redness.

Properties.

1171. It varies in colour from a dark brown to a bluish-black, according to the mode of formation, and its density is 6.401. It undergoes no change by heat alone, but is readily reduced to the metallic state by heat and combustible matter. It is insoluble in water. It combines with nearly all the acids, and most of its salts have a green or blue tint. With ammonia, it forms a deep blue solution, by which it is distinguished from all other substances.

Malaguti's process.

* The following process is recommended by Malaguti: 100 parts of sulphate of copper and 57 of carbonate of soda, both in crystals, are fused with a gentle heat; and the mass left, when all water is expelled, is pulverized and mixed with 25 parts of copper filings. The mixture is pressed into a crucible and exposed for twenty minutes to a white heat. The result is again pulverized and washed. *Ann. de Chim. et de Phys.* liv. 216.

Salts recognised.

1172. Its salts are distinguished from most substances by their colour, and are easily recognised by reagents. Pure ammonia throws down the disulphate when carefully added; but an excess of the alkali instantly redissolves the precipitate, and forms a deep blue solution. Alkaline carbonates cause a bluish-green precipitate. It is precipitated as a dark brown sulphuret by hydrosulphuric acid, and as a reddish-brown ferrocyanuret by ferrocyanuret of potassium.

Antidote.

1173. It is thrown down of a yellowish white colour by albumen, and Orfila has proved that this compound is inert, so that albumen is an antidote to poisoning by copper.[*]

Metal separated.

1174. Copper is separated in the metallic state by a rod of iron or zinc. The copper thus obtained, after being digested in a dilute solution of hydrochloric acid, is almost chemically pure.

Detected.

1175. The best mode of detecting copper, when supposed to be present in mixed fluids, is by hydrosulphuric acid. The sulphuret, after being collected, and heated to redness in order to char organic matter, should be placed on a piece of porcelain, and be digested in a few drops of nitric acid. Sulphate of protoxide of copper is formed, which, when evaporated to dryness, strikes the characteristic deep blue tint on the addition of ammonia.[†]

Dichloride.

1176. *Dichloride of Copper.* $2Cu+Cl$, or Cu^2Cl, 63.2 2 eq. copper + 35.42 1 eq. chlor. = 98.62 equiv. When copper filings are introduced into an atmosphere of chlorine gas, the metal takes fire spontaneously, and both the chlorides are generated. The *dichloride* may be conveniently prepared by heating copper filings with twice their weight of corrosive sublimate. It is slowly deposited in crystalline grains, when the green solution of protochloride of copper is kept in a corked bottle in contact with metallic copper.

Properties.

1177. The dichloride of copper is fusible at a heat just below redness, and bears a red heat in close vessels without subliming. It is insoluble in water, but dissolves in hydrochloric acid. Its colour varies with the mode of preparation, being white, yellow, or dark brown.[‡]

Sulphurets.

1178. *Sulphurets of Copper.* The *disulphuret,* $2Cu+S$, or Cu^2S, 63.2 2 eq. copper + 16.1 1 eq. sulph. = 79.3 equiv., is a natural production, the *copper glance* of mineralogists, and in combination with protosulphuret of iron, it is a constituent of variegated copper ore.[§]

Disulphuret formed.

1179. It is formed by heating copper filings with a third of their weight of sulphur; when the sulphur is raised a little above its melt-

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[*] *Superoxide of Copper.* $Cu+2O$, $\ddot{Cu}$, or CuO^2, 31.6 1 eq. cop. + 16 2 eq. oxy. = 47.6 equiv.

[†] The action of ammonia may be taken advantage of in cleaning (or colouring, as it is termed by jewellers) gold trinkets, such as chains, &c. which are often made of a very inferior alloy. Artists make use of weak nitric acid, or of the materials from which the acid is produced, and which often destroys the finer kinds of workmanship by dissolving the copper of the alloy to some depth on the surface; the gold not being acted upon, the trinket appears as if newly gilded. Boiling in ammonia is a safe substitute for this process, and the operation may be performed by any person without the assistance of the artist. Brewster's *Jour.* i. 75; *Bost. Jour.* ii. 206.

[‡] *Protochloride of Copper.* $Cu+Cl$, 31.6 1 eq. copper + 35.42 1 eq. chlor. = 67.02 equiv.

[†] For an outline of the process of reducing the ores of copper, see Brande, ii. 67, and Vivian, in *Ann. Philos.* N. S. v. 113.

ing point, combustion suddenly pervades the whole mass. The experiment succeeds equally well *in vacuo* or in azote. U. 370. Copper leaf burns in gaseous sulphur as brilliantly as iron wire in oxygen gas.*

Alloys.

1180. Many of the *alloys* of copper are important. With gold it forms a fine yellow ductile compound, used for coin and ornamental work. With silver it forms a white compound, used for plate and coin.† Lead and copper require a high red heat for union; the alloy is gray and brittle.

Of the alloys of copper with the metals already described the most important are brass and bell-metal. It forms white compounds with potassium and sodium; a reddish alloy with manganese; and a gray one with iron.

Brass.

1181. *Brass* is an alloy of copper and zinc. The metals are usually united by mixing granulated copper with calamine (1004) and charcoal: the mixture is exposed to heat sufficient to reduce the calamine and melt the alloy, which is then cast into plates. The relative proportions of the two metals vary in the different kinds of brass; the best brass consists of four parts copper to one of zinc. This alloy is malleable and ductile when cold; and its colour and little liability to rust, recommend it in preference to copper for many purposes of the arts.‡

Tutenag, pinchbeck, &c.

1182. *Tutenag* is said to be an alloy of copper, zinc, and a little iron; and *Tombac*, *Dutch gold*, *Similor*, *Prince Rupert's metal* and *Pinchbeck*, are alloys, containing more copper than exists in brass, and consequently made by fusing various proportions of copper with brass. According to Wiegleb, *Manheim gold* consists of three parts of copper and one of zinc. A little tin is sometimes added, which, though it may improve the colour, impairs the malleability of the alloy.§

Bell-metal and bronze.

1183. *Bell-metal* and *bronze* are alloys of copper and tin; they are harder and more fusible, but less malleable than copper. The best bell-metal is composed of three parts copper and one of tin; the Indian gong, celebrated for the richness of its tones, contains copper and tin in this proportion. A little zinc is added to small shrill bells. Bronze consists of from 8 to 12 of tin with 100 of copper.

Alloys definite compounds.

1184. Dalton finds that into all the alloys of copper which are characterized by useful properties, the ingredients enter in atomic proportions; and it is probable that by attention to these proportions, the manufacture of the artificial alloys may be greatly improved.

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* Berzelius, *Ann de Chim.* See also Vauquelin on *Sulphurets of Copper*, lxxx. 255.

† See *Gold* and *Silver*.

‡ According to Sage, a very beautiful brass may be made by mixing 50 grains of oxide of copper, 100 of calamine, 400 of black flux, and 30 of charcoal powder; melt these in a crucible till the blue flame is no longer seen round the cover; and, when cold, a button of brass is found at the bottom, of a golden colour, and weighing one sixth more than the pure copper obtained from the above quantity of oxide.

§ An alloy, which, from the resemblance it has in colour to gold, is called *Mosaic gold*, has been lately prepared from equal parts of copper and zinc melted at the lowest temperature at which copper will fuse.

Speculum metal is an alloy of copper and tin, with a little arsenic; about 6 copper, 2 tin, 1 arsenic. On this subject the reader is referred to Edwards's experiments. Nicholson's *Jour.* 4to. iii.

1185. Vessels of copper used for culinary purposes are usually coated with tin, to prevent the food being contaminated with copper. Their interior surface is first cleaned, then rubbed over with sal-ammoniac to prevent oxidation; the vessel is heated, a little pitch or rosin spread over the surface, and a bit of tin rubbed over it, which instantly unites with and covers the copper.*

Lead.

Symb. Pb *Equiv.* 103.6

Ores. 1186. Lead appears to have been known in the earliest ages of the world. The natural compounds of this metal are very numerous. The most important is the sulphuret, or *galena*, from which the pure metal is chiefly procured. Lead is also found combined with various acids, with oxygen, chlorine, &c.

To obtain pure lead. 1187. To obtain lead perfectly pure, Berzelius dissolved it in nitric acid, and crystallized the salt several times, till the mother liquor, on adding carbonate of ammonia, gave no traces of copper. The pure nitrate of lead, mixed with charcoal, was strongly heated in a Hessian crucible; and the lead, which separated, was kept for some time in fusion, in order to free it entirely from charcoal. The lead, thus obtained, when re-dissolved in nitric acid, gave no trace of any other metal.

Properties. 1188. Its colour is bluish-white; it is soft, flexible, malleable and ductile. It melts at about 612° and by slow cooling may be obtained in octohedral crystals. Its sp. gr. is 11.352. At high temperatures it absorbs oxygen, and when in fusion a gray film is formed on its surface, which is a mixture of metallic lead and protoxide; by increasing the heat it is dissipated in fumes of the protoxide.

Action of water, 1189. Lead undergoes no change in distilled water in close vessels, but in open vessels is oxidized; the oxide combines also with carbonic acid present in the air. The presence of saline matter in the water retards the oxidation, and some salts, even in minute quantity, prevent it altogether. Many kinds of spring water, owing to the salts which they contain, do not corrode lead.†

Of acids. 1190. Lead is not attacked by hydrochloric, or the vegetable acids, though their presence often accelerates the absorption of oxygen. The only proper solvent for lead is nitric acid; it oxidizes it and forms a salt of the protoxide.

Protoxide. 1191. *Protoxide of Lead.* $Pb+O$, $\dot{P}b$, or PbO, 103.6 1 eq. lead + 8 1 eq. oxy. = 111.6 equiv., is prepared on a large scale by collecting the gray film which forms on the surface of melted lead, and exposing it to heat and air until it acquires a uniform yellow colour. In this state it is the *massicot* of commerce; and when partially fused

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[*] The oxidation of copper plates is a matter of very great importance in the arts, and in the case of great and expensive works where few impressions of an engraving are taken and the plates laid aside for a considerable length of time, a serious injury to the plates is sustained by the necessity of cleaning them from oxide, when they are to be again used. This may be prevented by varnishing the plates with common lac varnish, which can easily be removed, when requisite, by spirits of wine. Brewster's *Jour.* i. 76; *Bost. Jour.* ii. 206.

For method of analysis of these alloys, see Brande, xi. 74; and for other details Thomson's *System—Inorganic Bodies*, i. 601; Dumas' *Traité de Chim.* iii. 505.

[†] See this subject discussed in Christison's *Treatise on Poisons.*

the term *litharge* is applied to it. As thus procured it is always mixed with red oxide. It may be obtained pure by adding ammonia to a cold solution of nitrate of protoxide of lead until it is faintly alkaline, washing the precipitated subnitrate with cold water, and, when dry, heating it to redness for an hour in a platinum crucible. An open fire should be used, and great care taken to prevent combustible matter in any form from contact with the oxide.

Properties.

1192. Protoxide of lead is red while hot, but has a rich lemon-yellow colour when cold, is insoluble in water, fuses at a bright red heat, and is fixed and unchangeable in the fire. Its sp. gr. is 9.4214. The fused protoxide has a highly foliated texture, and is very tough, so as to be pulverized with difficulty. By transmitted light it is yellow; but by reflected light it appears green in some parts and yellow in others. Heated with combustible matters, the protoxide parts with oxygen and is reduced. It unites with acids, and is the base of all the salts of lead, most of which are of a white colour.

White lead.

1193. Protoxide of lead is precipitated from its solutions by pure alkalies, as a white hydrate, which is redissolved by potassa in excess; as a white carbonate, which is the well known pigment *white lead*, by alkaline carbonates; as a white sulphate by soluble sulphates; as a dark brown sulphuret by hydrosulphuric acid; and as yellow iodide of lead by hydriodic acid or iodide of potassium.*

Test of Lead.

The best method of detecting the presence of lead in wine or other suspected mixed fluids is by means of hydrosulphuric acid.† (Fig. 166.)

Union of Pb with earthy bodies.

1194. Protoxide of lead unites readily with earthy substances, forming with them a transparent colourless glass, and is much employed for glazing earthenware and porcelain. It enters in large quantity into the composition of flint glass,‡ which it renders more fusible, transparent, and uniform.

Separated.

1195. Lead is separated from its salts in the metallic state by iron or zinc. The best way of demonstrating this fact is by dissolving in a tall jar or bottle 1 part of acetate of protoxide of lead in 24 of water, and suspending a piece of zinc in the solution by means of a thread. The lead is deposited upon the zinc in a peculiar arborescent form, giving rise to the appearance called *arbor Saturni.*§

Red oxide, or minium.

1196. *Red Oxide of Lead.* $3Pb+4O$, or $2PbO+PbO^2$, 310.8 3 eq. lead + 32 4 eq. oxy., or 223.2 2 eq. protox. + 119.6 1 eq. perox. = 342.8 equiv. This compound, the *minium* of commerce, is employed as a pigment, and in the manufacture of flint glass.

Poisonous.

* With regard to the poisonous property of the salts of lead, the carbonate is by far the most virulent poison. Any salt of lead which is easily convertible into the carbonate, as for instance the subacetate, is also poisonous. Acetate of protoxide of lead, mixed with vinegar to prevent the formation of any carbonate, may be freely and safely administered in medical practice. (Dr A. T. Thomson.)

† The sulphuret of lead, after being collected on a filter and washed, is to be digested in nitric acid diluted with twice its weight of water, until the dark colour of the sulphuret disappears. The solution of the nitrate should then be brought to perfect dryness on a watch-glass, in order to expel the excess of nitric acid, and the residue be redissolved in a small quantity of cold water. On dropping a particle of iodide of potassium into a portion of this liquid, yellow iodide of lead will instantly appear.

‡ Hence flint glass retorts are less suitable for some chemical processes than those of green glass without lead; the latter are also less fusible. W.

§ *Dinoxide of Lead.* $2Pb+O$, or Pb^2O, 207.2 2 eq. lead + 8 1 eq. oxy. = 215.2 equiv.

Chap. IV.

It is formed by oxidizing lead by heat and air without allowing it to fuse, and then exposing it in open vessels to a temperature of 600° or 700°, while a current of air plays upon its surface. It slowly absorbs oxygen and is converted into minium.

This oxide does not unite with acids. When heated to redness it gives off pure oxygen gas, and is reconverted into the protoxide. When digested in nitric acid it is resolved into protoxide and peroxide of lead, the former of which unites with the acid, while the latter remains as an insoluble powder. From the facility with which this change is effected even by acetic acid, most chemists consider red lead not so much as a definite compound of lead and oxygen, but as a salt composed of the protoxide and peroxide.[*]

Peroxide. 1197. *Peroxide of Lead.* $Pb+2O$, $\ddot{Pb}$, or PbO^2, 103.6 1 eq. lead + 16 2 eq. oxy. = 119.6 equiv. This oxide may be obtained by the action of nitric acid on minium, as just mentioned; by fusing protoxide of lead with chlorate of potassa, at a temperature short of redness, and removing the chloride of potassium by solution in water; and by transmitting a current of chlorine gas through a solution of acetate of the protoxide of lead. The chloride formed is removed by washing with warm water.

Properties. 1198. Peroxide of lead is of a puce colour, is insoluble in water, and is resolved by strong ox-acids, such as the sulphuric and nitric, into a salt of the protoxide and oxygen gas. With hydrochloric acid it yields chlorine gas and chloride of lead. At a red heat it emits oxygen gas and is converted into the protoxide.

Chloride. 1199. *Chloride of Lead.* $Pb+Cl$, or $PbCl$, 103.6 1 eq. lead + 35.42 1 eq. chlor. = 139.02 equiv. This compound, sometimes called *horn lead*, is slowly formed by the action of chlorine gas on thin plates of lead, and may be obtained more easily by adding hydrochloric acid or a solution of sea-salt to acetate or nitrate of oxide of lead dissolved in water. This chloride dissolves to a considerable extent in hot water, especially when acidulated with hydrochloric acid, and separates on cooling in small acicular anhydrous crystals of a white colour. It fuses at a temperature below redness, and forms as it cools a semi-transparent mass, which has a density of 5.133.[†]

Alloys. 1200. *Alloys of Lead.* The most important are those with tin. Common *pewter* consists of about 80 parts of tin and 20 of lead. Solders. *Fine solder* consists of 2 parts of tin and 1 of lead; it fuses at about 360°, and is much employed in tinning copper. *Coarse solder* contains one fourth of tin, fuses at about 500°, and is used by plumbers. *Pot metal* is an alloy of lead and copper.

1201. If lead be heated so as to boil and smoke, it soon dissolves pieces of copper thrown into it; the mixture, when cold, is brittle. The union of the two metals is remarkably slight; for, upon exposing the mass to a heat no greater than that in which lead melts, the lead almost entirely runs off by itself. This process is called *eliquation*. Eliquation. The coarser sorts of lead, which owe their brittleness and gra-

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[*] This was long considered as a sesquioxide, an error corrected by Dalton, *New System of Chem.* ii. 41. T.

[†] For other compounds see Turner's *Elements*, 376.

nulated texture to an admixture of copper, throw it up to the surface on being melted by a moderate heat.*

Section VII.—*Metals, the oxides of which are reduced to the metallic state by a red heat.*

Mercury. 1202. *Mercury or Quicksilver*, Hg. 202 eq.,† is the only one of the metals that retains a fluid form at the ordinary temperature of the atmosphere.

Ore. The principal ore of this metal is the sulphuret, or *native cinnabar*, from which the mercury is separated by distillation with quicklime or iron filings.

Boiling point. 1203. Mercury is a brilliant white metal, having much of the colour of silver, whence the terms *hydrargyrum*, *argentum vivum*, and *quicksilver*. It has been known from very remote ages. According to Crichton it boils and becomes vapour at 656° F., 680° according to Petit and Dulong, 670° Brande, and 662° T.

It also rises in vapour in small portions at the common temperature of the atmosphere, particularly in a vacuum.

Vapour. 1204. When the temperature of mercury is considerably increased above its boiling point, the vapour acquires great expansive force, and the power of bursting the strongest vessels. Gay-Lussac has calculated that the vapour of mercury is 12.01 more dense than oxygen gas, and that the liquid metal in becoming gaseous, increases in volume 961 times.

Freezing. 1205. When the temperature of mercury is reduced to about —39° or 40° F., it becomes solid and malleable.

By congelation it acquires an increase of sp. gr.; and, therefore, unlike other metals, the congealed portion sinks to the bottom of a fluid mass of mercury. Its sp. gr. at 47° above 0 F. being 13.568, it is increased by congelation, to 15.612.

Mercury, if quite pure, is not tarnished in the cold by exposure to air and moisture; but if it contain other metals, the amalgam of those metals oxidizes readily, and collects a film upon its surface.

Adulteration, how detected. 1206. Mercury is sometimes adulterated with the alloy of lead and bismuth, a fraud easily detected by the want of its due fluidity, and by its not being perfectly volatile, but leaving a residuum when boiled in a platinum or iron spoon.‡

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* Lead combines with Iodine, Fluorine, &c., for which see Turner, Brande, Thomson and others.

† Turner, *Phil. Trans.*, 1833, part ii.

‡ Mercury which is chemically impure will soon acquire adhesive films on its surface, even when cleansed of mechanical impurities, and with a rapidity dependent on the agitation of the metal or extension of surface. These interfere chemically when the metal is to be used in forming combinations, and mechanically in its uses in the trough in electro-magnetic experiments, and in the construction of barometers and thermometers.

Purified. The purification of mercury from metals by distillation should be performed in an iron retort, a portion of clean iron and copper filings having been introduced with the mercury, which should be condensed and received in clean water. This process, however, is not wholly unobjectionable, as both zinc and arsenic will pass over, and these metals are often present. A very useful method is to put from half an inch to an inch in depth of mercury, into a large earthenware pan, and to pour over it sulphuric acid diluted with twice its weight of water. The substances should be left together for a week or two, being frequently agitated. The metal and acid are then to

Chap. IV.

Action of acids. 1207. The only acids that act on mercury are the sulphuric and nitric, the former requires the aid of heat and sulphurous acid is disengaged (530); the latter acts at all temperatures and binoxide of nitrogen is evolved (455).

Protoxide. 1208. *Protoxide of Mercury*, $Hg+O$, $\dot{Hg}$, or HgO, 202 1 eq. merc. + 8 1 eq. oxy. = 210 equiv. This oxide which is a black powder, insoluble in water, is best prepared by the process recommended by Donovan.* This consists in mixing calomel briskly in a mortar with pure potassa in excess, so as to effect its decomposition as rapidly as possible: the protoxide is then washed with cold water, and dried spontaneously in a dark place. These precautions are rendered necessary by the tendency of the protoxide to resolve itself into the peroxide and metallic mercury, a change which is easily effected by heat, by the direct solar rays, and even by daylight. It is on this account very difficult to procure protoxide of mercury in a state of absolute purity.

Properties. 1209. It is a black powder, insoluble in water, uniting with acids, but a weak alkaline base. The alkalies precipitate it from solutions of its salts as the black protoxide.

It is thrown down as a white carbonate by alkaline carbonates, but soon becomes dark from loss of its carbonic acid; as calomel by hydrochloric acid or any soluble chloride, and as black protosulphuret by hydrosulphuric acid; this last is the best test of its presence.

Peroxide, or red precipitate. 1210. *Peroxide of Mercury*, $Hg+2O$, $\ddot{Hg}$, or HgO^2, 202 1 eq. merc. + 16 2 eq. oxy. = 218 equiv. This oxide may be formed either by the combined agency of heat and air, or by dissolving mercury in nitric acid, and exposing the nitrate so formed to a temperature just sufficient for expelling the whole of the nitric acid.† It is commonly known by the name of *red precipitate*.‡

Process. 1211. When prepared by heat the process may be conducted by introducing into a flat-bottom matrass, (Fig. 182,) about 4 ounces of mercury, and placing it in a sand-bath, heated to the boiling point of the metal. In about a month's time nearly the whole is converted into oxide. Air is freely admitted by the tube, while its length prevents the escape of mercurial vapour, which condenses and falls back into the body of the vessel; the remaining portion of running mercury may be driven off by exposing it in a basin to a heat just below redness.

182.

Properties. 1212. Peroxide of mercury, thus prepared, is commonly in the form of shining crystalline scales of a nearly black colour while hot,

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be separated, the latter preserved for a similar operation in future, and the former washed, dried and cleansed mechanically, by squeezing through shamois leather, by agitation with damp loaf sugar, passing through a paper funnel, &c.—See Faraday's *Chem. Manip.* sect. xx.

* *Ann. of Phil.* xiv.

† The peroxide prepared from the nitrate almost always contains a trace of nitric acid, which may be detected by heating it in a clean glass tube by means of a spirit-lamp; a yellow ring, formed of subnitrate of peroxide of mercury, collects within the tube just above the part which is heated. (Clarke.)

‡ *Hydrargyri oxidum rubrum* of the Pharmacop. In the manufacture of this compound at Apothecaries' Hall (Lond.) 100 lbs. of mercury are boiled with 48 lbs. of nitric acid (sp. gr. 1.48) and by proper evaporation and application of a dull red heat, 112 lbs. of the *hydrargyri nitrico oxidum* are obtained. B.

but red when cold: when very finely levigated, the peroxide has an orange colour. It is soluble to a small extent in water, forming a solution which has an acrid metallic taste, and is poisonous. When heated to redness, it is converted into metallic mercury and oxygen. Long exposure to light has a similar effect.[*]

Action of water, &c.

1213. Some of the neutral salts of this oxide, such as the nitrate and sulphate, are converted by water, especially at a boiling temperature, into insoluble yellow subsalts, leaving a strongly acid solution, in which a little of the original salt is dissolved. The oxide is separated from all acids as a red, or when hydratic as a yellow precipitate, by the pure and carbonated fixed alkalies. Ammonia and its carbonate cause a white precipitate, which is a double salt, consisting of one equivalent of the acid, one equivalent of the peroxide, and one equivalent of ammonia. The oxide is readily reduced to the metallic state by metallic copper.

Protochloride, or calomel.

1214. *Protochloride of Mercury*, $Hg+Cl$, or $HgCl$, 202 1 eq. merc. + 35.42 1 eq. chlor. = 237.42 equiv. This compound, commonly termed *calomel*, is first mentioned by Crollius, early in the seventeenth century.[†]

Obtained.

1215. It is always generated when chlorine comes in contact with mercury at common temperatures; and also by the contact of metallic mercury and the bichloride. It may be made by precipitation, by mixing nitrate of protoxide of mercury in solution with hydrochloric acid or any soluble chloride. It is more commonly prepared by sublimation. This is conveniently done by mixing 272.84 parts or one equivalent of the bichloride with 202 parts or one equivalent of mercury, until the metallic globules entirely disappear, and then subliming. When first prepared it is always mixed with some corrosive sublimate, and, therefore, should be reduced to powder and well washed, before being employed for chemical or medical purposes.[‡]

Properties.

1216. When obtained by sublimation it is in semi-transparent crystalline cakes; but as formed by precipitation, it is a white powder. Its density is 7.2. At a heat short of redness, but higher than the subliming point of the bichloride, it rises in vapour without previous fusion; but during the sublimation a portion is always

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[*] Guibourt.

[†] The first directions for its preparation are given by Beguin, in the *Tyrocinium Chemicum*, published in 1608. He calls it *draco miligatus*. Several other fanciful names have been applied to it, such as *aquila mitigata, manna metallorum, panchymagogum minerale, sublimatum dulce, mercurius dulcis, &c.*

Old custom.

[‡] It was formerly the custom to submit calomel to very numerous sublimations, under the idea of rendering it *mild;* but these often tended to the production of corrosive sublimate; and the calomel of the first sublimation, especially if a little excess of mercury be found in it, is often more pure than that afforded by subsequent operations. The following are the directions given in the *Lond. Pharmacop.*

"Take of oxymuriate of mercury, 1 lb.
———— purified mercury, *by weight*, 9 oz.

Rub them together until the metallic globules disappear; then sublime: take out the sublimed mass, reduce it to powder, and sublime it in the same manner twice more successively; bring it to the state of a very fine powder; throw this into a large vessel, full of water; then stir it, and, after a short interval, pour the supernatant turbid solution into another vessel, and set it by, that the powder may subside. Lastly, having poured away the water, dry the powder."

It will be observed that in these processes the operation consists in reducing the bichloride to the state of protochloride by the addition of mercury.

resolved into mercury and the bichloride. It is yellow while warm, but recovers its whiteness on cooling. It is distinguished from the bichloride by not being poisonous, by having no taste, and by being exceedingly insoluble in water. Acids have little effect upon it; but pure alkalies decompose it, separating the black protoxide of mercury.

Bichloride, or corrosive sublimate.

1217. *Bichloride of Mercury*, $Hg+2Cl$, or $HgCl^2$, 202 1 eq. merc. + 70.84 2 eq. chlor. = 272.84 equiv. When mercury is heated in chlorine gas, it takes fire, and burns with a pale red flame, forming the well known medicinal preparation and virulent poison *corrosive sublimate*, or bichloride of mercury. It is prepared for medical purposes by subliming a mixture of bisulphate of the peroxide of mercury with chloride of sodium or sea-salt.* The exact quantities required for mutual decomposition are 298.2 parts or one equivalent of the bisulphate, to 117.44 parts or two equivalents of the chloride. Thus,

Theory.

1 eq. Bisulphate of Mercury.			2 eq. Chloride of Sodium.		
Sulphuric Acid .	80.2 or 2 eq.	$2SO^3$	Chlorine . .	70.84 or 2 eq.	$2Cl$.
Perox. of Merc. .	218 or 1 eq.	HgO^2	Sodium . .	46.6 or 2 eq.	$2Na$
	298.2	HgO^2+2SO^3		117.44	$2\,(Na+Cl)$

and by mutual interchange of elements they produce

1 eq. Bichloride of Mercury.			2 eq. Sulphate of Soda.		
Mercury . . .	202 or 1 eq.	Hg.	Soda . . .	62.6 or 2 eq.	$2NaO$
Chlorine . . .	70.84 or 2 eq.	$2Cl$	Sulph. Acid .	80.2 or 2 eq.	$2SO^3$
	272.84	$Hg+2Cl$		142.8	$2\,(NaO+SO^3)$

The products have exactly the same weight (272.84 + 142.8 = 415.64) as the compounds (298.2 + 117.44 = 415.64) from which they were prepared.

Characters.

1218. Bichloride of mercury is usually seen in the form of a perfectly white semi-transparent mass, exhibiting the appearance of imperfect crystallization. It is sometimes procured in quadrangular prisms. Its sp. gr. is 5.2, its taste is acrid and nauseous, leaving a peculiar metallic and astringent flavour upon the tongue. It dissolves in 20 parts of water at 60°, and but twice its weight at 212°. It is more soluble in alcohol than in water. When heated, it readily sublimes in the form of a dense white vapour, strongly affecting the nose and mouth. It dissolves without decomposition in hydrochloric, nitric, and sulphuric acids: the alkalies and several of the metals decompose it.

Action of light,

1219. Its aqueous solution is gradually decomposed by light, calomel being deposited.

Of alkalies,

The pure and carbonated fixed alkalies throw down the peroxide of mercury from a solution of corrosive sublimate; ammonia on the

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Process.

* The following is the process followed at Apothecaries Hall, (Lond.) 50 lbs. of mercury are boiled with 70 lbs. of sulphuric acid, to dryness, in a cast-iron vessel; 62 lbs. of the dry salt are triturated with 40 1-2 lbs. of mercury, until the globules disappear, and 34 lbs of common salt are then added. This mixture is submitted to heat in earthen vessels, and from 95 to 100 lbs. of calomel are the result. It is to be washed in large quantities of distilled water, after having been ground to a fine and impalpable powder.

White precipitate.

contrary, causes the deposition of a white matter which is commonly known as *white precipitate.**

Detection of mercury,

1220. The presence of mercury in a fluid, supposed to contain corrosive sublimate, may be detected by concentrating and digesting it with an excess of pure potassa. Peroxide of mercury, which subsides, is then sublimed in a small glass tube by means of a spirit-lamp, and obtained in the form of metallic globules. When the bichloride is mixed with organic substances, Christison recommends that the liquid, without previous filtration, be agitated with a fourth of its volume of ether, which separates the poison from the aqueous part and rises to the surface. The ethereal solution is then evaporated on a watch-glass, the residue dissolved in water, and the mercury precipitated in the metallic state by protochloride of tin at a boiling temperature.†

Sylvester's method.

1221. A very elegant method of detecting the presence of mercury is to place a drop of the suspected liquid on polished gold, and to touch the moistened surface with a piece of iron wire or the point of a penknife, when the part touched instantly becomes white, owing to the formation of an amalgam of gold. This process was originally suggested by Sylvester, and has since been simplified by Paris.‡

Action of albumen.

1222. Many animal and vegetable solutions convert bichloride of mercury into calomel. Some substances effect this change slowly; while others, and especially albumen, produce it in an instant.

Exp.

Into a solution of corrosive sublimate drop a solution of albumen, made by mixing a portion of white of egg with water, a white flocculent precipitate subsides, which Orfila has shown to be a compound of calomel and albumen, and which he has proved experimentally to be inert.§ Consequently, a solution of the white of eggs is an an antidote to poisoning by corrosive sublimate.

Protiodide.

1223. *Protiodide of Mercury*, $Hg+I$, or HgI, 202 1 eq. merc. + 126.3 1 eq. iod. = 328.3 equiv., is obtained by mixing nitrate of protoxide of mercury in solution, with iodide of potassium; when the latter is added to the mixed nitrates of the protoxide and peroxide of mercury, the latter in excess, the *sesquiodide* falls.

Biniodide.

1224. *Biniodide of Mercury*, $Hg+2I$, or HgI^2, 202 1 eq. merc. + 252.6 2 eq. iod. = 454.6 equiv. This compound is formed by mixing nitrate of the peroxide or bichloride of mercury with iodide of potassium in solution, and falls as a rich red-coloured powder of a tint which vies in beauty with that of vermilion, though unfortu-

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* This substance has been recently examined.* It was found that a slight excess of ammonia being added, just one half the chlorine of the corrosive sublimate was separated, the other half remaining in the solution with the ammonia. The precipitate, nevertheless, did not contain calomel. It was found to be composed of

Mercury . .	78.6	Ammonia . .	6.77
Chlorine . .	13.85	Hygrometric water loss and oxygen,	.78

Its atomic constitution would appear from this analysis to contain the compound radical which is the base of the amides.

† If, as is probable, most of the poison is already converted into calomel, and thereby rendered insoluble, as many vegetable fibres should be picked out as possible, and the whole at once digested with protochloride of tin. The organic substances are then dissolved in a hot solution of caustic potassa, and the insoluble parts washed and sublimed to separate the mercury.†

‡ *Medical Jurisprudence*, by Paris and Fonblanque. § *Toxicologie*, vol. i.

* Kane in *Trans. Irish Acad.* xvii. † Christison on *Poisons.*

nately, the colour is less permanent. Though insoluble in water, it dissolves freely in an excess of either of its precipitants. If taken up in a hot solution of nitrate of peroxide of mercury, the biniodide crystallizes out on cooling in scales of a beautiful red tint. The same crystals separate from a solution in iodide of potassium; but if the liquid be concentrated, a double iodide of mercury and potassium subsides.

Effect of heat.

1225. The biniodide, when exposed to a moderate heat, gradually becomes yellow; and the particles, though previously in powder, acquire a crystalline appearance. At about 400° it forms a yellow liquid which slowly sublimes in small transparent scales, or in large rhombic tables, when a considerable quantity is sublimed. The crystals retain their yellow colour at 60° if kept very tranquil; but if the temperature be below a certain point, or they are rubbed or touched, they quickly become red.* This phenomenon is entirely due to a change in molecular arrangement: the different colours so often witnessed in the same substances at different temperatures, as in peroxide of mercury and the protoxides of lead and zinc, appear to be phenomena of the same nature.†

Sulphurets.

1226. *Protosulphuret of Mercury*, $Hg+S$, or HgS, 202 1 eq. merc. + 16.1 1 eq. sulph. = 218.1 equiv., may be prepared by transmitting a current of hydrosulphuric acid gas through a dilute solution of nitrate of protoxide of mercury, or through water in which calomel is suspended. It is a black-coloured substance, which is oxidized by digestion in strong nitric acid. When exposed to heat it is resolved into the bisulphuret and metallic mercury.

Bisulphuret, or cinnabar.

1227. *Bisulphuret of Mercury*, $Hg+2S$, or HgS^2, 202 1 eq. merc. + 32.2 2 eq. sulph. = 234.2 equiv., is formed by fusing sulphur with about six times its weight of mercury, and subliming in close vessels. When procured by this process it has a red colour, and is known by the name of *factitious cinnabar*.‡ Its tint is greatly improved by being reduced to powder, in which state it forms the beautiful pigment *vermilion*. It may be obtained in the moist way by pouring a solution of corrosive sublimate into an excess of hydrosulphate of ammonia. A black precipitate subsides, which acquires the usual red colour of cinnabar when sublimed.

1228. Cinnabar is not altered by exposure to air or moisture; when heated to dull redness in an open vessel, the sulphur forms sulphurous acid, and the mercury escapes in vapour. It is decomposed by distillation with fixed alkalies, lime, and baryta, and by

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* This appears to have been first noticed by Hayes, who has given an economical process for preparing the compound in *Amer. Jour.* xvi. 174.

† *Sesquiodide of Mercury*, $2Hg+3I$, or Hg^2I^3, 404 2 eq. merc. + 378.9 3 eq. iod. = 782.9 equiv.

Protobromide of Mercury, $Hg+Br$, or $HgBr$, 202 1 eq. merc. + 78.4 1 eq. brom. = 280.4 equiv.

Bibromide of Mercury, $Hg+2Br$. or $HgBr^2$, 202 1 eq. merc. + 156.8 2 eq. brom. =358.8 equiv.

Process.

‡ In the manufacture of cinnabar 8 parts of mercury are mixed in an iron pot with one of sulphur, and made to combine by a moderate heat, and constant stirring; this compound is then transferred to a glass subliming vessel, (on a small scale a Florence flask answers perfectly,) and heated to redness in a sand-bath; a quantity of mercury and of sulphur evaporate, and a sublimate forms which is removed, and rubbed or levigated into a very fine powder.

several of the metals. When adulterated with red lead it is not entirely volatile.

Native cinnabar. 1229. *Native Cinnabar* is the principal ore of mercury; it occurs massive and crystallized of various colours, sometimes appearing steel-gray, at others bright red. Native mercury and native amalgam of silver sometimes accompany it.

Ethiops. 1230. When equal parts of sulphur and mercury are triturated together until metallic globules cease to be visible, the dark coloured mass called *ethiops mineral* results, which Brande has proved to be a mixture of sulphur and bisulphuret of mercury.*

Amalgams. 1231. Mercury combines with most of the other metals, and forms a class of compounds which have been called *amalgams*. These are generally brittle or soft. One part of potassium with 70 of mercury produces a hard brittle compound. If mercury be added to the liquid alloy of potassium and sodium, an instant solidification ensues, and heat enough to inflame the latter metal is evolved. The amalgams of gold and silver are employed in gilding and silvering.

An amalgam of 2 parts of mercury, 1 of bismuth, and 1 of lead, is fluid, and when kept for some time, deposits cubic crystals of bismuth.†

Oxidation of metals promoted by mercury. 1232. By combination with mercury, metals that are not easily oxidized, acquire a facility of entering into union with oxygen. Thus gold and silver, when combined with mercury, are oxidized by ignition in contact with air. This fact furnishes a striking illustration of the effect of overcoming the aggregative affinity of bodies in promoting chemical union.

1233. When mercury is negatively electrized in a solution of ammonia, or when an amalgam of potassium and mercury is placed upon moistened hydrochlorate of ammonia, the metal increases in volume, and becomes of the consistency of butter, an appearance which has sometimes been called the *metallization of ammonia*. It has suggested some hypotheses concerning the nature of ammonia and the metals (731).‡

Silver.

Symb. Ag *Equiv.* 108

Silver. 1234. Silver is found *native*, and in a variety of combinations; it was known to the ancients. Native silver occurs crystallized in octohedral or cubic crystals, arborescent and capillary. It is seldom pure, but contains small portions of other metals, which affect its colour and ductility. It is chiefly found in primitive countries. In Peru and Mexico are the richest known mines of native silver.

Pure, process for. 1235. Pure silver may be obtained from goldsmiths', or standard silver, by dissolving it in nitric acid and precipitating by means of a

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* *Jour. of Sci.* vol. xviii. p. 294.

Ioduretted Bichloride of Mercury. $20\text{HgCl}^2+\text{I}$, 5456.8 20 eq. bichlor. + 126.3 1 eq. iodine = 5583.1 equiv.

Iodobichloride of Mercury. $40\text{HgCl}^2+\text{HgI}^2$, 10913.6 40 eq. bichlor. + 454.6 1 eq. biniodide = 11368.2 equiv.

† For the method of making an amalgam of copper see Aikin's *Dict.*, art. *Mercury*, p. 92; Thomson's *Chem. of Inorg. Bodies*, i. 626.

‡ Upon this subject the student may consult Gay-Lussac and Thenard (*Recherches Phys. Chim.* vol. i.), and Berzelius (*Lehrbuch* 1).

clean piece of copper, washing with pure water, and then digesting in ammonia, to remove the copper.

Another. 1236. A better process is to decompose chloride of silver by means of carbonate of potassa.

For this purpose precipitate a solution of nitrate of oxide of silver with chloride of sodium, wash the precipitate with water, and dry it. Then put twice its weight of carbonate of potassa into a clean Hessian or black lead crucible, heat it to redness, and throw the chloride by successive portions into the fused alkali. Effervescence takes place from the evolution of carbonic acid and oxygen gases, chloride of potassium is generated, and metallic silver subsides to the bottom. The pure metal may be granulated by pouring it while fused from a height of seven or eight feet into a vessel of water.*

Characters. 1237. Silver has a pure white colour, and considerable brilliancy. Its sp. gr. is 10.51 (hammered). It is so malleable and ductile, that it may be extended into leaves not exceeding a ten thousandth of an inch in thickness, and drawn into wire finer than a human hair.

Properties. 1238. It melts at a bright red heat, 1873° F., and when in fusion appears extremely brilliant. It resists the action of air and moisture, and does not oxidize;† the *tarnish* of silver is occasioned by sulphurous vapours; it takes place very slowly upon the pure metal, but more rapidly upon the alloy with copper used for plate, and was found by Proust to consist of sulphuret of silver.

Effect of water, &c. 1239. Pure water has no effect upon the metal; but if the water contain vegetable or animal matter, it often slightly blackens its surface in consequence of the presence of sulphur. If an electric explosion be passed through fine silver wire, it burns into a black powder, which is an oxide of silver. In the Voltaic circle it burns with a fine green light, and throws off abundant fumes of oxide. Exposed to an intense white heat, it boils and evaporates. If suddenly cooled, it crystallizes during congelation, often shooting out like a cauliflower, and throwing small particles of the metal out of the crucible.

Cupellation. 1240. Silver is not unfrequently obtained in considerable quantities from argentiferous sulphuret of lead, which is reduced in the usual way and then *cupelled;* the oxide of lead thus procured is afterwards reduced by charcoal.‡

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* Thomson found it difficult to obtain silver free from copper, even when reduced from the chloride, but accomplished the object by first washing the chloride with diluted nitric acid, which removed the copper. *First Principles*, ii. 436.

† When fused in open vessels it absorbs oxygen amounting sometimes to twentytwo times its volume, but parts with it in the act of becoming solid. T.

‡ The principle of its separation from lead is founded on the different oxidability of lead and silver, and on the ready fusibility of litharge. The lead obtained from those kinds of galena which are rich in sulphuret of silver is kept at a red heat in a flat furnace, with a draught of air constantly playing on its surface; the lead is thus rapidly oxidized; and as the oxide, at the moment of its formation, is fused, and runs off through an aperture in the side of the furnace, the production of litharge goes on uninterruptedly until all the lead is removed. The button of silver is again fused in a smaller furnace, resting on a porous earthen dish, made with bone-ashes, called a *test* or *cupel*, the porosity of which is so great, that it absorbs any remaining portions of litharge which may be formed on the silver.

The cupel is easily prepared by driving pounded bone ashes into a small brass mould, by means of a pestle (Fig. 183), struck forcibly by a wooden mallet. It must then be removed cautiously, placed on a piece of paper and dried. The mould is open above and below. In the process the cupel is placed in a *muffle* (Fig. 184), which is made of the clay used for crucibles, arched above and closed at every side except in front, so that it may be exposed to a high temperature, and air be at the same time admitted. The cupel in which is the

Fig.183.

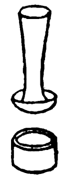
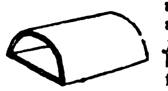


Fig. 184.



Amalgamation.

Some of the silver ores, especially the sulphurets, are reduced by amalgamation. These ores, when washed and ground, are mixed with a portion of common salt and roasted; then powdered and mixed by agitation with mercury, and the amalgam thus formed is distilled.*

Action of acids.

1241. The only pure acids that act upon silver, are the sulphuric and nitric, the latter is its proper solvent, forming with its oxide a salt, which, after fusion, is known as *lunar caustic.*

Oxide.

1242. *Oxide of Silver*, $Ag+O$, $\dot{Ag}$, or AgO, 108 1 eq. silver + 8 1 eq. oxy. = 116 equiv., may be procured by mixing a solution of pure baryta with nitrate of oxide of silver dissolved in water. It is of a brown colour, insoluble in water, and is completely reduced by a red heat.

Action of alkalies, &c.

1243. Silver is separated from its solution in nitric acid by pure alkalies and alkaline earths as the brown oxide, which is redissolved by ammonia in excess; by alkaline carbonates as a white carbonate, soluble in an excess of carbonate of ammonia; as a dark brown sulphuret by hydrosulphuric acid; and as a white curdy chloride of silver, which is turned violet by light and is very soluble in ammonia, by hydrochloric acid or any soluble chloride. By the last character, silver may be both distinguished and separated from other metallic bodies.

Arbor Dianæ,

1244. Silver is precipitated in the metallic state by most other metals. When mercury is employed the precipitation is very slow, and produces a peculiar symmetrical arrangement, called the *arbor*

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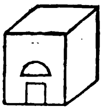
lead and silver, is placed in the muffle, in the *cupelling furnace.* (Fig. 185.) This furnace has an opening in one of its sides to receive the muffle.

Fig. 185.



This is an important process and much used by refiners and assayers in the analysis of alloyed silver. Supposing that an alloy of silver and copper is to be *assayed*, or analyzed, by cupellation, the following is the mode of proceeding.

A clean piece of the metal, weighing about 30 grains, is laminated, and accurately weighed in a very sensible balance. It is then wrapped up in the requisite quantity of sheet lead, (pure and reduced from litharge,) and placed upon a small *cupel*, or shallow crucible, made of bone earth, which has been previously heated. The whole is then placed under the muffle, heated to bright redness; the metals melt, and by the action of the air which plays over the hot surface, the lead and copper are oxidized and absorbed by the cupel, and a button of pure silver ultimately remains, the completion of the process being judged of by the cessation of the oxidation and motion upon the surface of the globule, and by the very brilliant appearance assumed by the silver when the oxidation of its alloy ceases. The button of pure metal is then suffered to cool gradually, and its loss of weight will be equivalent to the weight of the alloy, which has been separated by oxidation.

To perform this process with accuracy, many precautions are requisite, and nothing but practice can teach these, so as to enable the operator to gain certain results. A muffle 10 inches in length, 5 broad, and about 4½ high, answers for most operations. It should never be exposed suddenly to a strong heat, as it is very apt to be cracked; the fire should also be raised very gradually, at first with little more than may prevent it from going out. The fuel is introduced from an opening above, and care must be taken not to allow any of it to fall directly upon the muffle. The bottom should rest on a fire brick, and its sides be at least 2 inches from the walls of the furnace.

* The old process of *eliquation* is now scarcely used; it consisted in fusing alloys of copper and silver with lead; this triple alloy was cast into round masses which were set in a proper furnace upon an inclined plane of iron with a small channel grooved out, and heated red-hot, during which the lead melted out, and in consequence of its attraction for silver, carrried that metal with it, the copper being left behind in a reddish-black spongy mass.*

* Aikin's *Dict.* art. *Silver.*

Chap IV. *Dianæ.* It was first remarked by Lemery. To obtain this crystallization in its most perfect state, the solution should contain a little mercury, and the mercury put into it should be alloyed with a little silver.

How made. Make an amalgam, without heat, of four drachms of silver leaf with two drachms of mercury. Dissolve the amalgam in four ounces or a sufficient quantity of pure nitric acid of a moderate strength; dilute this solution in about a pound and a half of distilled water; agitate the mixture, and preserve it for use in a glass bottle with a ground stopper. When this preparation is to be used, the quantity of one ounce is put into a phial, and the size of a pea of amalgam of gold, or silver, as soft as butter, is to be added; after which the vessel must be left at rest. Soon afterwards, small filaments appear to issue out of the ball of amalgam, which increase and shoot out branches in the form of shrubs. U. 703. According to Proust all that is required is to throw mercury into nitrate of silver very much diluted.

Fulminating silver. 1245. When oxide of silver, recently precipitated by baryta or lime-water, and separated from adhering moisture by bibulous paper, is left in contact for ten or twelve hours with a strong solution of ammonia, the greater part of it is dissolved; but a black powder remains which detonates violently from heat or percussion. This substance, which was discovered by Berthollet,* appears to be a compound of ammonia and oxide of silver; for the products of its detonation are metallic silver, water, and nitrogen gas.

Process. Precipitate nitrate of silver by lime-water, and thoroughly edulcorate and dry the precipitate. Let this be afterward put into a vessel of the purest liquid ammonia, in which it may remain for ten or twelve hours. It will then assume the form of a black powder, from which the fluid is to be decanted, and the black substance left to dry in the air.

This is the celebrated compound termed *fulminating silver*, which explodes with the gentlest heat, and even with the slightest friction.

Caution. 1246. It should be made in very small quantity at a time, and dried spontaneously in the air.† When once prepared, no attempt must be made to enclose it in a bottle, and it must be left undisturbed in the vessel in which it was dried. Great caution is necessary in the preparation of this substance, for in making experiments on it several fatal accidents have been produced by indiscretion in its use. It even explodes, when moist, on the gentlest friction.‡

The liquid when gently heated, affords a still more dangerous compound. Another detonating compound, less dangerous, may be prepared by dissolving silver in nitric acid, and adding the solution to alcohol. It is this which is used in the little balls known by the name of *torpedoes.*§

Chloride. 1247. *Chloride of Silver*, $Ag+Cl$, or $AgCl$, 108 1 eq. silver $+$ 35.42 1 eq. chlor. $=$ 143.42 equiv., occurs in nature and is the *horn silver* of mineralogists. It is generated when silver is heated in chlorine gas, and may be prepared conveniently by mixing hydrochloric acid, or any soluble chloride, with a solution of nitrate of oxide of silver.

Effect of light. As formed by precipitation it is quite white; but by exposure to the

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* *Ann. de Chim.* i.

† The student cannot be too careful in preparing this dangerous substance, which has caused several fatal accidents. See Bruce's *Min. Jour.*, i.; and for details Silliman's *Chem.*, ii. 336.

‡ See Count Rumford's papers, *Phil. Trans.*, 1798.

§ For processes see Silliman's *Chem.*, ii.

direct solar rays it becomes violet, and almost black, in the course of a few minutes; and a similar effect is slowly produced by diffused day-light.* According to Berthollet, the dark colour is owing to separation of oxide of silver.†

Of acids.

1248. It is insoluble in water, and is dissolved very sparingly by the strongest acids; but it is soluble in ammonia. Hyposulphurous acid likewise dissolves it. At about 500° it fuses, and forms a semi-transparent horny mass on cooling, which has a density of 5.524. It bears any degree of heat, or even the combined action of pure charcoal and heat, without decomposition; but hydrogen gas decomposes it readily.

Action of ammonia.

1249. Chloride of silver is very soluble in ammonia, by which it is usefully distinguished from some other chlorides, which, like it, are white, and formed by precipitation.‡

Uses.

1250. As chloride of silver is insoluble in water, and very readily formed, it is often employed in analysis, as a means of ascertaining the proportion of chlorine present in various compounds.§

Sulphuret.

1251. *Sulphuret of Silver.* $Ag+S$, or AgS, 108 1 eq. silver + 16.1 1 eq. sulph. = 124.1 equiv. Silver has a strong affinity for sulphur. This metal tarnishes rapidly when exposed to an atmosphere containing hydrosulphuric acid gas, owing to the formation of a sulphuret. On transmitting a current of this gas through a solution of lunar caustic, a dark brown precipitate subsides, which is a sulphuret of silver. The *silver glance* of mineralogists is a similar compound, and the same sulphuret may be prepared by heating thin plates of silver with alternate layers of sulphur. This sulphuret is remarkable for being soft and even malleable.‖

Alloys.

1252. *Alloys of Silver.* Silver unites with most other metals, and suffers greatly in malleability and ductility by their presence. When silver and steel are fused together, an alloy is formed, which appears perfect while in fusion, but globules of silver exude from it on cooling, which shows the weak attraction of the metals. At a very high temperature the greater part of the silver evaporates, but a portion equal to about 1 in 500 remains, forming a perfect alloy, admirably adapted to the formation of cutting instruments.¶

1253. Silver readily combines with zinc and tin, forming brittle alloys. The alloy of silver with copper is of the most importance, as it constitutes plate and coin. By the addition of a small proportion of copper to silver, the metal is rendered harder and more sonorous,

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* Advantage has been taken of this in obtaining copies of paintings, engravings, &c., see Talbot on *Photogenic Drawing*, in *Lond. and Edin. Philos. Jour.* xiv. 197.

† *Stat. Chim.* vol. i. p. 195.

‡ We should be cautious in applying heat to the ammoniacal solution, as it sometimes forms a fulminating precipitate.

Circumstances to be attended to.

§ In these cases some excess of the precipitant should be used, and the precipitate allowed to subside previous to separating it upon the filter; if the supernatant liquor become perfectly clear, the whole of the silver has fallen; if it remain opalescent, a portion is probably retained. When the precipitate remains long suspended, its deposition may be accelerated by warmth, or by adding a little nitric acid. The chloride in these cases should be perfectly dried in a silver crucible, up to incipient fusion. B. ii. 180.

‖ *Iodide of Silver.* $Ag+I$, or AgI, 108 1 eq. silver + 126.3 1 eq. iodine = 234.3 equiv.

¶ Stoddart and Faraday, on the *Alloys of Steel*. *Quart. Jour.* ix.; *Bost. Jour.* i. 130.

while its colour is scarcely impaired. With lead the alloy is gray and brittle, as also with antimony, bismuth, cobalt, and arsenic.*

1254. Amalgam of silver is sometimes employed for *plating;* it is applied to the surface of copper, and the mercury being evaporated by heat, the remaining silver is burnished. The better kind of plating, however is performed by the application of a plate of silver to the surface of the copper, which is afterwards beaten or drawn out.

Silvering for dials.

1255. A mixture of chloride of silver, chalk, and pearlash, is employed for silvering brass; the metal is rendered very clean, and the above mixture moistened with water rubbed upon its surface. In this way thermometer scales and clock dials are usually silvered.

Gold.

Symb. Au *Equiv.* 199.2

Native gold.

1256. Gold occurs in nature in a metallic state, alloyed with a little silver or copper, and in this state is called *native gold.* Its colour is various shades of yellow; its forms are massive, ramose, and crystallized in cubes and octohedra. Large quantities of this metal are collected in alluvial soils and in the beds of certain rivers, more especially those of the west coast of Africa and Peru, Brazil and Mexico. It is found in various parts of Europe, in the Uralian mountains, and in North America.†

Separation or quartation.

1257. Gold is generally separated by amalgamation and cupellation. The best mode is by fusing the gold with so much silver, that the former may constitute one fourth of the mass; nitric acid will then dissolve all the silver and leave the gold. This process is termed *quartation.*

Method of obtaining pure gold.

1258. Gold may be obtained pure by dissolving standard gold in nitro-hydrochloric acid,‡ evaporating the solution to dryness, re-dissolving the dry mass in distilled water, filtering, and adding to it a solution of sulphate of protoxide of iron; a black powder falls, which, after having been washed with dilute hydrochloric acid and distilled water, affords on fusion a button of pure gold.

Characters.

1259. Gold is of a deep yellow colour. It melts at a bright red heat, 2016° Daniell, and when in fusion appears of a brilliant green colour. Its specific gravity varies a little according to the mechanical processes which it has undergone; but it may be stated on the average at 19.257.

Malleability.

1260. Gold is so malleable that it may be extended into leaves which do not exceed $\frac{1}{282000}$ of an inch in thickness. It is also very

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* The *standard silver* of Great Britain consists of $11\frac{2}{20}$ of pure silver, and $\frac{18}{20}$ copper. A pound troy therefore is composed of 11 oz. 2 dwts. pure silver, and 18 dwts. of copper, and it is coined into 66 shillings. B.

The standard silver of the United States is such that of 1000 parts by weight, 900 are pure and 100 alloy; the alloy being of copper. The dollar weighs 412½ grs., the dime 41¼ grs.

† For an account of the gold mines of North Carolina see *Amer. Jour. of Sci.* iv. 5. The gold received at the United States' mint from N. Carolina, in 1836, amounted to 148,100 dollars in value, and that from all the workings in United States to 467,000 dollars.

‡ Composed of two measures hydrochloric and one of nitric acid.

ductile and considerably tenacious; for a wire only $\frac{78}{1000}$ of an inch in diameter will sustain a weight of 150 lbs.

Effect of electricity, 1261. It shows no tendency to unite to oxygen even when exposed to its action in a state of fusion; but if an electric discharge be passed through a very fine wire of gold, a purple powder is produced, which has been considered as an oxide. **Of chlorine.** Chlorine appears to be the active agent in dissolving gold.

Protoxide. 1262. *Protoxide of Gold*, Au+O, $\dot{\text{Au}}$, or AuO, 199.2 1 eq. gold + 8 1 eq. oxy. = 207.2 equiv., is obtained by the action of a cold solution of potassa on the protochloride. It is precipitated of a green colour. It undergoes spontaneous change into metallic gold and teroxide. The purple oxide formed by the combustion of gold is supposed to be the *binoxide.**

Teroxide. 1263. *Teroxide of Gold*, Au+3O, $\dddot{\text{Au}}$, or AuO^3, 199.2 1 eq. gold. + 24 3 eq. oxy. = 223.2 equiv., the only well known oxide of gold, may be prepared by the following process:

Process. Dissolve 1 part of gold in the usual way, render it quite neutral by evaporation, and redissolve in 12 parts of water: to the solution add 1 part of carbonate of potassa dissolved in twice its weight of water, and digest at about 170°. Carbonic acid gradually escapes, and the hydrated teroxide of a brownish-red colour subsides. After being well washed it is dissolved in colourless nitric acid of sp. gr. 1.4, and the solution decomposed by admixture with water.

The hydrated teroxide is thus obtained quite pure, and is rendered anhydrous by a temperature of 212° F.

Properties. 1264. Teroxide of gold is yellow in the state of hydrate, and nearly black when anhydrous, is insoluble in water, and completely decomposed by solar light or a red heat. It combines with alkaline bases, such as potassa and baryta, apparently forming regular salts, in which it acts the part of a weak acid. **Aurates.** This property, induced Pelletier to propose for it the name of *auric acid*, its compounds with alkalies being called *aurates.*†

Action of Ammonia. 1265. When recently precipitated teroxide of gold is kept in strong ammonia for about a day, a detonating compound of a deep olive colour is generated. According to the analysis of Dumas, its elements are in the ratio of one equivalent of gold, two of nitrogen, six of hydrogen, and three of oxygen. With regard to the mode in which these elements are arranged, different opinions may be formed. It appears most simple to consider it as a diaurate of ammonia, expressed by the formula $2(3\text{H}+\text{N})+\text{AuO}^3$. T. 387.

Fulminating gold. 1266. The compound known as *Fulminating Gold*, is similar to the above, and is obtained by digesting terchloride of gold with an excess of ammonia.

Process for. To obtain this compound add a solution of ammonia in water, or the pure liquid ammonia, to the diluted chloride; a precipitate will appear, which will be re-dissolved if too much alkali be used. Let the liquor be filtered and wash the sediment which remains on the filter with several portions of warm water. Dry it by exposure to the air, without any artificial heat, and preserve it in a wide mouthed bottle, in small packets of paper, closed, not with a glass stopper, but merely by a cork.

A small portion of this powder, less than a grain in weight, being

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* *Binoxide of Gold.* Au+2O, or AuO^2, 199.2 1 eq. gold + 16 2 eq. oxy. = 215.2 equiv.

† *An. de Ch. et de Ph.* xv.

placed on the point of a knife and held over a lamp, detonates violently. The precise temperature which is required is not known, but it appears to be about 290° F. At the moment of explosion, a transient flash is observed. Two or three grains, exploded on a pretty strong sheet of copper, will force a hole through it. Neither electricity nor a spark from the flint and steel are sufficient to occasion its detonation; but the slightest friction explodes it, and serious accidents have happened from this cause.

Chlorides.

1267. *Chlorides of Gold.* The terchloride is obtained in ruby-red crystals by concentrating the solution of gold. It is soluble in alcohol and ether, the latter removing it from the aqueous solution. It loses chlorine at about 400° F., and is changed into a mixture of *protochloride** and terchloride, soluble in water.

Terchloride,

1268. *Terchloride of Gold*, $Au+3Cl$, or $AuCl^3$, 199.2 1 eq. gold + 106.26 3 eq. chlor. = 305.46 equiv., is the usual and most convenient form of obtaining a solution of gold. On adding to the solution sulphate of protoxide of iron, a brown precipitate ensues, which is gold in very fine division, and the solution contains tersulphate of sesquioxide, and sesquichloride of iron. The action is such that

6 eq. sulphate of protoxide of iron . . .	$6(\dot{Fe}+\dddot{S})$
and 1 eq. terchloride of gold	$Au+3Cl$

yield

2 eq. tersulphate of sesquioxide of iron . .	$2(\underline{\ddot{Fe}}+3\dddot{S})$
1 eq. sesquichloride of iron	$2Fe+3Cl$
and 1 eq. gold	Au

Pure gold from.

1269. The precipitate, washed with dilute hydrochloric acid to separate adhering iron, is gold in a state of perfect purity. A similar reduction is effected by most of the metals. When a piece of charcoal is immersed in a solution of gold, and exposed to the direct solar rays, its surface acquires a coating of metallic gold, and ribands may be gilded by moistening them with a dilute solution of gold, and exposing them to a current of hydrogen or phosphuretted hydrogen gas.

Ethereal solution.

1270. When a strong aqueous solution of gold is shaken in a phial with an equal volume of pure ether, two fluids result, the lighter of which is an ethereal solution of gold. From this liquid flakes of metal are deposited on standing, especially by exposure to light, and substances moistened with it receive a coating of metallic gold.†

Action of tin.

1271. When protochloride of tin is added to a dilute aqueous solution of gold, a purple-coloured precipitate, called the *purple of Cassius*, is thrown down; and the same substance may be prepared by fusing together 150 parts of silver, 20 of gold, and 35.1 of tin, and acting on the alloy with nitric acid, which dissolves out the silver and leaves a purple residue, containing the tin and gold which were employed. To prevent the oxidation of the tin during fusion, the three metals should be projected into a red-hot black-lead crucible, which contains a little melted borax.

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* *Protochloride of Gold.* $Au+Cl$, or $AuCl$, 199.2 1 eq. gold + 35.42 1 eq. chlor. = 234.62 equiv.

† See an Essay on Combustion by Mrs Fulhame, and a paper by Rumford in the *Phil. Trans.* for 1798.

Purple of Cassius. Uses.

1272. When the powder of Cassius is fused with vitreous substances, such as flint-glass, or a mixture of sand and borax, it forms with them a purple enamel, which is employed in giving pink colours to porcelain. The essential cause of the colour is probably a compound of the purple or supposed binoxide of gold with earthy matters, similar to the enamel formed by glass and oxide of silver.*

With potassium, &c.

1273. *Alloys of Gold.*† The alloy of gold and iron is malleable and ductile, and harder than gold, its colour dull white, and its specific gravity 16.885. The metals expand by union.

With zinc.

1274. With zinc the compound is brittle and brass-coloured. Specific gravity 16.937. The metals contract a little in uniting. The fumes of zinc in a furnace containing fused gold, make it brittle.

With tin.

1275. Tin forms a whitish alloy, brittle when thick, but flexible in thin pieces. Specific gravity 17.307. There is considerable contraction. The old chemists called tin *diabolus metallorum*, from its property of rendering gold brittle, but Bingley's experiments quoted by Hatchett, show that $\frac{1}{80}$ of tin does not render gold brittle.

With lead.

1276. The alloy of lead is very brittle when that metal only constitues $\frac{1}{1920}$ of the alloy; even the fumes of lead destroy the ductility of gold. The sp. gravity is 18.080; and 1000 parts become 1005.

With copper.

1277. With copper (standard gold) the alloy is perfectly ductile and malleable, but harder than pure gold, and resists wear better than any other alloy except that with silver. Its specific gravity is 17.157.‡

1278. Arsenic and antimony, when alloyed in very small proportions with gold, destroy its colour and render it quite brittle.

Analysis of alloys of gold.

1279. The analysis of most of the alloys of gold is performed by cupellation. The triple alloy of gold, silver, and copper, may be analyzed by digesting it in nitric acid, which takes up the silver and copper, and leaves the gold in the form of a black powder, which may be fused into a button and weighed. The silver may be thrown down in the state of chloride by solution of common salt, and the copper precipitated by iron.

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* *Iodides of Gold* are formed by the action of iodide of potassium on the terchloride of gold.

Protiodide of Gold. Au+I, or AuI, 199.2 1 eq. gold + 126.3 1 eq. iod. = 325.5 equiv.

Teriodide of Gold. Au+3I, or AuI^3, 199.2 1 eq. gold + 378.9 3 eq. iod. = 576.1 equiv.*

† A very curious series of experiments upon the alloys of gold has been published in the *Phil. Trans.* for 1803, by Hatchett. See also Thomson's *Inorg. Chem.*, i 654.

‡ The standard gold of the United States contains in 1000 parts by weight 900 of pure metal and 100 alloy composed of copper and silver, the latter not exceeding one half of the whole alloy. The legal weight of the American eagle is 258 grs The legal standard of the British sovereign is 22 carats = 916⅔ thousandths. Forty pounds Troy are made into 1869 sovereigns, the weight of each = 123.2744 grs. The value of the sovereign in gold of United States, should be 4.8665. Numerous examinations of British gold at the U. S. mint show that the actual quality of the gold does not average more than 915½, or the average weight more than 122.88 grs. The examination of 104,960 sovereigns (the Smithsonian legacy) at the mint, produced an average of 4.84$\frac{3}{10}$ per sovereign.

* See Johnston's experiments in *Phil. Mag. and Ann.* ix. 266.

Tersulphuret of Gold. Au+3S, or AuS^3, 199.2 1 eq gold + 48.3 3 eq. sulph. = 247.5 equiv.

Assay.

1280. The assay of gold is more complicated than that of silver, in consequence of the high attraction which it has for copper, and which prevents its complete separation by mere cupellation. An alloy, therefore, of copper with gold, is combined with a certain quantity of silver, previous to cupellation; this is then cupelled with lead in the usual way, and the silver is afterwards separated by the action of nitric acid.[*]

Water gilding.

1281. Mercury and gold combine with great ease, and produce a white amalgam much used in gilding. For this purpose the amalgam is applied to the surface of the silver; the mercury is then driven off by heat, and the gold remains adhering to the silver, and is burnished. This process is called *water gilding*.

1282. In gilding porcelain, *gold powder* is generally employed, obtained by the decomposition of the chloride; it is applied with a pencil, and burnished after it has been exposed to the heat of the porcelain furnace.

Carats.

1283. The degree of purity of gold is expressed by the number of parts of that metal, contained in the 24 parts of any mixture. Thus gold, which in 24 such parts (termed *carats*,) contains 22 of the pure metal is said to be 22 carats fine. Absolutely pure gold, using the same language, is 24 carats fine; and gold alloyed with an equal weight of another metal, 12 carats fine.[†]

Platinum.

Symb. Pt *Equiv.* 98.8

Ores.

1284. This valuable metal occurs in Brazil, Peru, and other parts of South America in rounded or flattened grains mingled with several other metals. In 1826 it was discovered by Bousingault in a sienitic rock in the province of Antioquia, in South America, and since then it has been found in larger quantity in the Uralian mountains.[‡]

Characters.

1285. It is a white metal, much resembling silver, and is the heaviest metal known; after forging its density being about 21.25, and in the state of wire 21.5. It is malleable, and may be drawn into wire the diameter of which does not exceed the two thousandth part of an inch. It is soft, and has the valuable property of welding. It is a less perfect conductor of heat than several other metals.[§]

Action of heat and air.

1286. It is unaltered by the joint action of heat and air; but small wires of it are fused and burn in the Voltaic circuit, and before the oxyhydrogen blow-pipe. No pure acids attack it. Its solvents are chlorine, or solutions that supply chlorine, as nitrohydrochloric acid.

Spongy platinum.

1287. Spongy platinum has been discovered by Döbereiner to have

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[*] The real quantity of gold or silver taken for an assay is very small; from 18 to 36 grains, for instance, for silver, and from 6 to 12 for gold; whatever the quantity may be it is called the *assay pound*. The silver assay pound is divided into 12 ounces, and each ounce into 20 pennyweights. The gold assay pound is subdivided into 24 carats, and each carat into 4 assay grains. Aiken's *Dict.*, art. *Assay*.

[†] Many curious facts relating to the properties of gold, and its uses in the arts, will be found in Lewis's *Phil. Com. of the Arts*.

[‡] *Edin. Jour. of Sci.*, v. 323.

[§] For many important details respecting platinum, see Wollaston's paper in *Phil. Trans.*, 1829, and Brande's *Manual*, ii. 208.

the remarkable property of causing the union of oxygen and hydrogen gases (387); and Dulong and Thenard have shown that the same effect takes place, though in a lower degree, with platinum foil and wire.*

Faraday's observations. 1288. According to Faraday† the gases must be pure and the platinum free from foreign matters, pure water excepted, which is effected by fusing pure potassa on its surface, washing, then dipping the platinum in hot oil of vitriol, and again washing with pure water.

Action of. 1289. In this state platinum foil acts so rapidly at common temperatures on oxygen and hydrogen gases mixed in the ratio of 1 to 2, that it often becomes red-hot and kindles the mixture. Handling the platinum, wiping it with a towel, or exposing it to the atmosphere for a few days, suffices to soil the surface of the metal, and thereby diminish or prevent its action.

Theory of. 1290. These phenomena are supposed to result from the concurring influence of two forces, the self-repulsive energy of similar gaseous particles, and the adhesive attraction exerted between them and the platinum. Each gas, repulsive to itself and not repelled by the platinum, comes into the most intimate contact with that metal, and both gases are so condensed upon its surface, that they are brought within the sphere of their mutual attraction and combine.

Protoxide. 1291. *Protoxide of Platinum*, $Pt+O$, $\dot{Pt}$, or PtO, 98.8 1 eq. plat. + 8 1 eq. oxy. = 106.8 equiv., is prepared by digesting protochloride of platinum in a solution of pure potassa, avoiding a large excess of the alkali, since it dissolves a portion of the oxide, and thereby acquires a green colour. In this state it is a hydrate which loses first its water and then oxygen when heated, and dissolves slowly in acids, yielding solutions of a brownish-green tint.

Binoxide. 1292. *Binoxide of Platinum.* $Pt+2O$, $\ddot{Pt}$, or PtO^2, 98.8 1 eq. plat. + 16 2 eq. oxy. = 114.8 equiv. This oxide is prepared with difficulty. Berzelius recommends that it should be prepared by exactly decomposing sulphate of binoxide of platinum with nitrate of baryta, and adding pure soda to the filtered solution, so as to precipitate about half of the oxide; since otherwise, a sub-salt would subside. The oxide falls in the form of a bulky hydrate, of a yellowish-brown colour; it resembles rust of iron when dry, and is nearly black when rendered anhydrous.‡

Protochloride. 1293. *Protochloride of Platinum.* $Pt+Cl$, or $PtCl$, 98.8 1 eq. plat. + 35.42 1 eq. chlor. = 134.22 equiv. When the bichloride is heated to 450°, half of its chlorine is expelled, and the protochloride of a greenish-gray colour remains. It is insoluble in water, sulphuric acid, and nitric acid; but hydrochloric acid partially dissolves it, yielding a red solution. At a red-heat its chlorine is driven off, and metallic platinum is left. It is dissolved by a solution of the bichloride.

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[*] *Ann. de Chim. et de Phys.*, xxiii. and xxiv.

[†] *Phil. Trans.* 1834, part i.

[‡] Sesquioxide. *Sesquioxide of Platinum.* $2Pt+3O$, or Pt^2O^3, 197.6 2 eq. plat. + 24 3 eq oxy. = 221.6 equiv. This oxide, of a gray colour, is prepared according to its discoverer, E. Davy, by heating fulminating platinum with nitrous acid; but the nature of the compound so formed has not yet been decisively determined. *Phil. Trans.*, 1820.

Bichloride. 1294. *Bichloride of Platinum.* $Pt+2Cl$, or $PtCl^2$, 98.8 1 eq. plat. + 70.84 2 eq. chlor. = 169.64 equiv. This chloride is obtained by evaporating the solution of platinum in nitro-hydrochloric acid to dryness at a very gentle heat, when it remains as a red hydrate, which becomes brown when its water is expelled. It is deliquescent, and very soluble in water, alcohol, and ether; its solution, if free from the chlorides of palladium and iridium, being of a pure yellow colour. Its ethereal solution is decomposed by light, metallic platinum being deposited.

Solutions recognized. 1295. A solution of platinum is recognized by the following characters. When to an alcoholic or concentrated aqueous solution of the bichloride, a solution of chloride of potassium is added, a crystalline double chloride of a pale yellow colour subsides, which is insoluble in alcohol, and sparingly soluble in water; at a red heat it yields chlorine gas, and the residue consists of metallic platinum and chloride of potassium. With a solution of hydrochlorate of ammonia a similar yellow salt falls, which when ignited leaves pure platinum in the form of a delicate spongy mass, the power of which in kindling an explosive mixture of oxygen and hydrogen gases has already been mentioned* (1287).

Biniodide. 1296. *Biniodide of Platinum,* $Pt+2I$, or PtI^2, 98.8 1 eq. plat. + 252.6 2 eq. iod. = 351.4 equiv., prepared by the action of iodide of potassium on a rather dilute solution of bichloride of platinum. At first the liquid acquires an orange-red and then a claret colour, without any precipitation; but when the solution is boiled, a black precipitate subsides, which should be washed with hot water and dried at a heat not exceeding 212°. This biniodide is a black powder, sometimes crystalline, is tasteless and inodorous, insoluble in water, and may be boiled in water without change. By alcohol it is sparingly dissolved, especially when heated. Acids act feebly upon it; but it is decomposed by alkalies; and begins to lose iodine at 270°.†

Protosulphuret. 1297. *Protosulphuret of Platinum,* $Pt+S$, or PtS, 98.8 1 eq. plat. + 16.1 1 eq. sulph. = 114.9 equiv., is formed by heating the ammoniacal chloride with half its weight of sulphur, until all the sal ammoniac and excess of sulphur are expelled.

Bisulphuret. 1298. *Bisulphuret of Platinum,* $Pt+2S$, or PtS^2, 98.8 1 eq. plat. + 32.2 2 eq. sulph. = 131 equiv., is formed by dropping a solution of bichloride of platinum into a solution of sulphuret of potassium, or by transmitting hydrosulphuric acid gas into a solution of the double chloride of platinum and sodium. It should be dried *in vacuo.*

Fulminating. 1299. Fulminating platinum may be prepared by the action of ammonia in slight excess on a solution of sulphate of protoxide of platinum. When boiled in potassa, washed and dried, it was found by E. Davy to explode at about 420° with a very loud report.‡ One grain laid on a thin sheet of copper and exploded produces a report

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Protiodide. * *Protiodide of Platinum,* $Pt+I$, or PtI, 98.8 1 eq. plat. + 126.3 1 eq. iod. = 225.1 equiv., prepared by digesting the protochloride of platinum in a rather strong solution of iodide of potassium, when the protiodide gradually appears in the form a black powder, which is insoluble in water and alcohol. It is unchanged by the sulphuric, nitric, and hydrochloric acids, decomposed by the alkalies, and at a red heat gives off its iodine.

† *An. de Ch. et de Ph.*, li. 118.

‡ *Phil. Trans.* 1817.

louder than that of a pistol, and the copper is deeply indented. It is incapable of being exploded by percussion.

Associated metals. 1300. *Palladium, Rhodium, Osmium, and Iridium.* These metals are found associated in the ore of platinum, and have been procured but in small quantity.

Palladium, 1301. *Palladium,* Pd, 53.3 eq., was discovered by Wollaston; it resembles platinum in colour and lustre; it is ductile and malleable; its sp. gr. is 11.3 to 11.8.

Properties. 1302. In fusibility it is intermediate between gold and platinum, and is dissipated in sparks when intensely heated by the oxyhydrogen blow-pipe. At a red heat in oxygen gas, its surface acquires a fine blue colour, owing to superficial oxidation; but the increase of weight is so slight as not to be appreciated.

Action of acids. 1303. Palladium is oxidized and dissolved by nitric acid, and even the sulphuric and hydrochloric acids act upon it by the aid of heat; but its proper solvent is nitro-hydrochloric acid. Its protoxide forms beautiful red-coloured salts, from which metallic palladium is precipitated by sulphate of protoxide of iron, and by all the metals described in the foregoing sections, excepting silver, gold, and platinum.

Rhodium obtained, 1304. *Rhodium,* R, 52.2 eq., was discovered by Wollaston at the time he was occupied with the discovery of palladium. He obtained it in the form of a black powder, which requires the strongest heat that can be produced in a wind furnace for fusion, and when fused has a white colour and metallic lustre.

Properties, 1305. It is brittle, is extremely hard, and has a specific gravity of about 11. It attracts oxygen at a red heat, a mixture of peroxide and protoxide being formed. It is not attacked by any of the acids when in its pure state, but if alloyed with other metals, such as copper or lead, it is dissolved by nitro-hydrochloric acid, a circumstance which accounts for its presence in the solution of crude platinum.

Oxidized. 1306. It is oxidized by being ignited either with nitre, or bisulphate of potassa. When heated with the latter, sulphurous acid gas is evolved, and a double sulphate of peroxide of rhodium and potassa is generated, which dissolves readily in hot water, and yields a yellow solution. The presence of rhodium in platinum, iridium, and osmium may thus be detected, and by repeated fusion a perfect separation be accomplished.* Most of its salts are either red or yellow.

Osmium and Iridium. 1307. *Osmium and Iridium.* Os, 99.7 eq. These metals were discovered by Tennant in the year 1803,† and the discovery of iridium was made about the same time by Descotils in France. Wollaston detected them as an alloy in the black powder accompanying the ore of platinum. Osmium acquires a metallic lustre by friction; its sp. gr. is 7 to 10. It takes fire when heated in the open air, and is readily oxidized and dissolved by fuming nitric acid.

Osmic acid. 1308. The highest stage of oxidation of Os. is the volatile compound *Osmic Acid,* $Os+4O$, or OsO^4, 99.7 1 eq. osmium $+$ 32 4 eq. oxy. $=$ 131.7 equiv., which is the product of the oxidation of osmium by

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* Berzelius.

† *Phil. Trans.* 1804.

acids, by combustion, or by fusion with nitre or alkalies. Its vapour is very acrid, exciting cough, irritating the eyes, and producing a copious flow of saliva; its odour is disagreeable and pungent, somewhat like that of chlorine, hence the name osmium from οσμῆ, *odour*. With infusion of gall nuts it gives a purple solution, which afterwards acquires a deep blue tint, a delicate test of the acid.

Iridium. 1309. *Iridium* is a brittle metal, apt to fall to powder when burnished, but with care may be polished and then resembles platinum. It is the most infusible of all metals; sp. gr. 15.8629; equiv. 98.8. It forms with oxygen 4 oxides, and with chlorine 4 chlorides.

1310. These metals combine with oxygen, chlorine, and sulphur, for an account of the compounds the student is referred to Turner's *Elements*, and Brande's *Manual*.

Latanium, 1311. *Latanium.* In submitting the cerite of Bastnaes to examination Mosander has very recently obtained this new metal, and which was named from its being, as it were, *hidden* by the cerium. It was prepared by calcining the nitrate of cerium mixed with nitrate of latanium. The oxide of cerium loses its solubility in weak acids; and the oxide of latanium, which is a very strong base, may be separated by nitric acid, mixed with 100 parts of water.

Oxide of, 1312. The oxide is of a brick-red colour, owing to the presence of oxide of cerium; it is converted by hot water into a white hydrate which restores the blue colour of litmus paper; it is rapidly dissolved by dilute acids, and when used in excess is converted into a sub-salt.

Salts of. 1313. Its salts have an astringent taste, without any mixture of sweetness; and the crystals are of a rose-red colour. The atomic weight of latanium is smaller than that of cerium.*

CHAPTER V.

Section 1. *Salts.*

Application of the term salt. 1314. The term salt has been applied to a very extensive range of compounds, where acids are combined with oxides, or other compounds having similar properties. The oxide or other substance united with the acid is called a *base* or *salifiable base.* Each acid, with few exceptions, is capable of uniting with every alkaline base, and frequently in two or more proportions.

Orders. 1315. The class of salts has been divided into four orders (330), and many of their characters have been already described.†

Order 1st. Oxysalts.

Oxysalts, what. 1316. Of the common salts, a large proportion contain oxygen both in the acid and in the base, thus in the phosphate of soda it is associated with phosphorus in the phosphoric acid, and with sodium in the soda, and hence such are termed *oxysalts*.

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* *Lond. and Edin. Phil. Mag.*, May, 1839.

† Graham has been led to the conclusion that all salts are neutral in their constitution, with the exception of certain classes. See Turner, 408. Thomson has divided the salts into nine classes. See *Chem. of Inorg. Bodies*, vol. ii. 378.

1317. Those salts which consist of the same acid united with different salifiable bases, possess certain characters in common, and may be considered as constituting one family.

Double salts.

The combination of salts with one another gives rise to compounds which were formerly called *triple* salts; but the term *double* salt, proposed by Berzelius, gives a more correct idea of their nature and constitution. These salts may be composed of one acid and two bases, of two acids and one base, and of two different acids and two different bases. Most of the double salts hitherto examined consist of the same acid and two different bases.

Remarkable law.

1318. All the powerful alkaline bases, excepting ammonia, are the protoxides of an electro-positive metal, such as potassium, barium or iron; so that if M represent an eq. of any one of those metals $M+O$, or MO is the strongest alkaline base, and often the only one which that metal can form. A single eq. of acid neutralizes MO, forming with it a neutral salt. Thus, indicating an equivalent of sulphuric and nitric acid by the signs SO^3 and NO^5, all the neutral sulphates and nitrates of protoxides are indicated by $MO+SO^3$ and $MO+NO^5$. There is, therefore, in the neutral protosalts of each family, a constant ratio in the oxygen of the base and acid, resulting from the composition of each acid, that ratio for sulphates being as 1 to 3, and for nitrates as 1 to 5. If the metal M of a neutral sulphate pass into a higher grade of oxidation, becoming a binoxide MO^2, then will that binoxide be disposed to unite with two eq. of acid, and form a bisalt, MO^2+2SO^3, in which the oxygen of the base and acid is still as 1 to 3; and if the metal yield a sesquioxide, M^2O^3, then, if sufficient acid be supplied, the resulting salt will consist of $M^2O^3+3SO^3$, the ratio of 1 to 3 being preserved.*

Sulphates.

Sulphates detected

1319. The acid of the sulphates is readily detected by chloride of barium (551). An insoluble sulphate may be detected by mixing it, in fine powder, with three times its weight of carbonate of potassa or soda, and exposing the mixture to a red heat for half an hour, in a platinum crucible. Double decomposition ensues; and on digesting the residue in water, filtering the solution, neutralizing the free alkali by pure hydrochloric, nitric, or acetic acid, and adding chloride of barium, the insoluble sulphate of that base is precipitated.

Natural, Artificial, Solubility, Decomposed.

1320. Many sulphates exist in nature, and those of lime and baryta are the most abundant. They may all be formed by the action of sulphuric acid on the metals, their oxides or their carbonates, or by double decomposition. They vary in solubility in water; most of them are decomposed by a white heat with the escape of one part of the sulphuric acid, while the other part is resolved into sulphurous acid and oxygen. They are decomposed by carbonaceous matter with the aid of heat, carbonic acid being formed and a sulphuret of the metal.

Composition of neutral sulphates expressed.

1321. The composition of neutral protosulphates is expressed by the formula $MO+SO^3$; the acid containing three times as much

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* This curious law relative to oxy-salts, which is very general, was first noticed by Gay Lussac (*Mem. d'Arcueil*, ii.), and Berzelius has found it to hold in earthy minerals, and employed it as a guide in studying their composition. T.

oxygen as the base; and if both were deprived of it a metallic protosulphuret would result, M+S.*

Sulphate of potassa,

1322. *Sulphate of Potassa.* $KO+SO^3$, 47.15 1 eq. base + 40.1 1 eq. acid = 87.25 equiv. The *sal de duobus* of the old chemists, *potassæ sulphas* of the Pharmacop. This salt is the result of several chemical operations in the arts; and is procured abundantly by neutralizing with carbonate of potassa the residue of the operation for preparing nitric acid (471).

Properties,

1323. Its taste is saline and bitter. Its crystals belong to the right prismatic system; they are unchanged by exposure to the air, but decrepitate when heated. Soluble in sixteen times their weight of water at 60°, and five of boiling water.

Effect of heat and carbon,

1324. Intensely heated with one fifth its weight of powdered charcoal, it produces sulphuret of potassium.

About two parts of sulphate of potassa and one of lampblack intimately mixed in fine powder, heated to redness in a coated phial, with great care to exclude the air during cooling, afford a compound which takes fire on exposure to the air. It appears to contain a compound of potassium which powerfully attracts oxygen, and thus excites heat enough to inflame the charcoal and sulphur. Gay Lussac attributes the combustibility of common pyrophorus to this compound.

Bisulphate formed,

1325. *Bisulphate of Potassa.* $KO+2SO^3$, eq. 127.35; with 1 eq. water 136.35. This salt is formed by adding $\dddot{S}$ to a hot solution of $KO+SO^3$, or by boiling it with half its weight of $\dddot{S}$ in a platinum crucible, till none of the acid escapes when the heat approaches redness. It is obtained in crystals from a concentrated solution at high temperatures, as in the cold the neutral sulphate is formed. The form is a right rhombic prism, generally tabular. According to Graham they contain 1 eq. water (basic), the bisulphate being a double sulphate of water and potassa.

Properties.

1326. It has a sour taste, and is more soluble than the neutral sulphate, requiring only twice its weight of water at 60°, and less than an equal weight at 212°.

Old names.

1327. It is formed in the process for nitric acid (471), and is called *sal enixum*—formerly *arcanum duplicatum* and *panacea Holsatica.* It is used for cleaning coin and other works in metal.

Sulphate of soda.

1328. *Sulphate of Soda—Glauber's Salt.* $NaO+SO^3$, 31.3 1 eq. base + 40.1 1 eq. acid = 71.4 equiv.; in crystals with 10 eq. water, 161.4 eq. This salt occurs in the earth and in the waters of certain springs. It may be obtained by saturating sulphuric acid with carbonate of soda. Large quantities are obtained as the residuum in the processes for hydrochloric acid and chlorine (610, 629).

Properties.

1329. Its crystals belong to the right prismatic system, containing ten eq. of water, which is lost by efflorescence on exposure to the air; by heat they undergo the watery fusion. The taste is bitter, cooling, and saline. 100 parts of water at 32° dissolve 12 parts of the crystals; at 64.5° 48 parts; at 77° 100 parts; at 91.5° 322 parts.

Class of sulphates according to Graham.

* In accordance with the views of Graham (22), the sulphates may be divided into three classes: 1st, anhydrous sulphates without the eq. of constitutional water; 2d, those in which it is an essential part; 3d, double salts, produced from the second by the eq. of constitutional water being replaced by an eq. of a sulphate of the first class. T.

Uses.

1330. Sulphate of soda is sometimes decomposed for the purpose of obtaining soda, by igniting it with chalk and charcoal.[*] Its principal use is in pharmacy and in the manufacture of glass.

Sulphate of lithia,

1331. *Sulphate of Lithia.* $LO+SO^3$, 14.44 1 eq. base + 40.1 1 eq. acid = 54.54 eq. in crystals with 9 1 eq. water. This salt is very soluble in water, fuses by heat more readily than the sulphates of the other alkalies, and crystallizes in flat prisms resembling sulphate of soda, but not efflorescent. Taste saline.

Of ammonia,

1332. *Sulphate of Oxide of Ammonium—Sulphate of Ammonia.* H^4NO+SO^3, 26.15 1 eq. base + 40.1 1 eq. acid = 66.25 eq., in crystals with 9 or 1 eq. water = 75.25. It is obtained by neutralizing sulphuric acid with carbonate of ammonia; or by decomposing hydrochlorate of ammonia by sulphuric acid.

Use.

1333. It is important as a source of the hydrochlorate of ammonia which is obtained from a mixture of common salt and sulphate of ammonia by sublimation; by this process sulphate of soda is also formed.[†] It is contained in the soot from coal.

Properties.

1334. It crystallizes in long flattened six sided prisms; dissolves in two parts of water at 60°, and in an equal weight of boiling water. In a warm dry air it effloresces, losing 1 eq. of water. Sharply heated it fuses and is decomposed, yielding nitrogen gas, water, and sulphate of oxide of ammonium.

Native.

1335. *Native Sulphate of Ammonia* is sometimes found in volcanic countries; it has been procured from fissures in the earth near certain small lakes in Tuscany, and is known by the name of *Mascagnine.*[‡]

Sulphate of Baryta.

1336. *Sulphate of Baryta—heavy spar.* $BaO+SO^3$, 76.7 1 eq. base + 40.1 1 eq. acid = 116.8 eq. This is an abundant natural product, insoluble in hot and cold water, and precipitated when sulphuric acid or any soluble sulphate is added to any soluble salt of baryta (551). So extremely delicate is baryta as a test of sulphuric acid, that it shows the presence of 1 part of sulphate of soda in 400,000 of water.[§]

Use as a test.

Occurs in nature.

1337. Heavy spar occurs associated with metallic ores, especially those of lead, massive and crystallized. The form of the crystals is variable, being sometimes prismatic and sometimes tabular, deducible from a right rhombic prism. Its density is about 4.4. It is easily formed by double decomposition.

Bologna phosphorus.

1338. When native sulphate of baryta is heated it decrepitates, and, at a high temperature, fuses into an opaque white enamel; it was employed in the manufacture of *jasper ware*, by Wedgwood. When heated to redness, it acquires the property of phosphorescence. This was first ascertained by Vincenzo Cascariolo, of Bologna, whence the term *Bologna phosphorus* is applied to it.[||]

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[*] For a full account of the processes for decomposing this salt see Aiken's *Dict.* art. *Mur. Soda*, and Brande's *Manual*, i. 426.

[†] In the arts it is obtained by treating sulphate of lime with the carbonate of ammonia procured from animal matter by distillation.

[‡] From the name of its discoverer.

[§] Sulphate of baryta is sometimes very obstinate in subsiding from water, and will not only long remain suspended, but even pass through filtering paper; heat and a little excess of acid generally facilitate its deposition. B.

[||] To prepare this substance the native sulphate, powdered after being ignited, is to

This kind of phosphorus, after being exposed for a few minutes to the sun's rays, shines in the dark sufficiently to render visible the dial of a watch. This property is lost by repeated use, in consequence of the oxygenation of the sulphur; but it may be restored by a second calcination.*

Methods of obtaining pure baryta from native sulphate.

1339. As the native sulphate is a common and abundant compound, several processes have been contrived for obtaining from it pure baryta.

This may be effected by reducing the crystallized sulphate to a fine powder, and heating it red-hot for half an hour in a silver crucible with three parts of carbonate of potassa, the fused mass is then boiled repeatedly in water, till it no longer affords anything soluble in that liquid; the insoluble residue, consisting chiefly of carbonate of baryta, may be digested in dilute nitric acid, by which nitrate of baryta is formed, and which will yield the pure earth by exposure to heat.

Henry's process.

The following method has been recommended by Henry. The sulphate of baryta is to be finely powdered, mixed with three or four times its weight of carbonate of potassa, and boiled with a proper quantity of water for a considerable time, in an iron kettle, stirring it, and breaking down the hard lumps, into which it is apt to run, by an iron pestle. It is then to be washed with boiling water, as long as this acquires any taste. On the addition of *dilute* hydrochloric acid, a violent effervescence will ensue, and a considerable portion of the earth, probably along with some metals, will be dissolved. To the saturated solution, add solution of pure baryta in water, as long as it disturbs the transparency of the liquor. This will throw down any metals that may be present; and the excess of baryta may afterwards be precipitated in the state of a carbonate by a stream of carbonic acid. Decompose the hydrochloric solution by any alkaline carbonate; let the precipitated earth be well washed with distilled water; and if the pure baryta is to be obtained from it, let it be treated as directed page 238.

Another.

Another method consists in exposing to a red heat, in an earthen crucible, a mixture of six parts of finely powdered sulphate of baryta, with one of powdered charcoal, for half an hour. This converts the sulphate into sulphuret which is to be dissolved in hot water, the solution filtered and mixed with solution of carbonate of soda as long as it occasions a precipitate, which when washed and dried, is carbonate of baryta. Or, by adding hydrochloric acid to the liquid sulphuret, sulphur is thrown down, hydrosulphuric acid gas evolved, and hydro chlorate of baryta formed, which may be filtered off, and if required, decomposed by carbonate of potassa. Or the sulphuret, as it comes out of the crucible, may be thrown into *dilute* nitric acid, by which hydrosulphuric acid gas is evolved, and a nitrate of baryta formed, which may be separated from the remaining impurities by copious washings with hot water.

Sulphate of strontia.

1340. *Sulphate of Strontia.* $SrO+SO^3$, 51.8 1 eq. base + 40.1 1 eq. acid = 91.9 equiv. This salt occurs native. It is nearly insoluble, 1 part requiring for solution 4000 parts of cold, and 3840 of hot water. Heated with charcoal, its acid is decomposed and sulphuret of strontium is formed, which affords nitrate of strontia by the action of nitric acid. This process, equally practicable upon sulphate of baryta (884), is adopted to obtain strontia.

Nature.

1341. *Native Sulphate of Strontia* is sometimes of a blue tint, and has hence been called *celestine.* Sometimes it is colourless and transparent. It occurs of great beauty in Sicily associated with sul-

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be formed into a paste with mucilage of gum arabic, and divided into cylinders or pieces of one fourth of an inch in thickness. These, after being dried in a moderate heat, are to be exposed to the temperature of a wind furnace, placed in the midst of the charcoal. When the fuel is half consumed, it must be replenished, and suffered to burn out. The pieces will be found, retaining their original shapes, among the ashes. from which they may be separated by the blast of a pair of bellows. They must be preserved in a well-stopped phial. H. 1. 534.

* The artificial sulphate of baryta is used as a pigment, under the name of *permanent white.* It is very useful for marking phials and jars in the laboratory.

phur, in anhydrous prismatic crystals. Magnificent crystals have been met with on Strontian Island in Lake Erie.*

Sulphate of lime,

1342. *Sulphate of Lime.* $CaO+SO^3$, 28.5 1 eq. base + 40.1 1 eq. acid = 68.6 eq.; as *gypsum* with 18 or 2 eq. of water = 86.6. This salt is easily formed by mixing in solution a salt of lime with any soluble sulphate (61, exp. 2). It occurs abundantly as a natural production. The mineral called *anhydrite* is anhydrous sulphate of lime, and all the varieties of *gypsum* are composed of the same salt united with water. The pure crystallized specimens are called *selenite*, and the white compact variety is known as *alabaster*.

Anhydrite, Gypsum. Alabaster,

Crystalline forms, &c.

1343. The crystals of anhydrite belong to the right prismatic system, and are isomorphous with the sulphates of baryta and strontia, while the forms of gypsum are oblique prismatic. They contain 2 eq. water, one only of which is considered by Graham to be water of crystallization, the other being constitutional. The former is readily lost by exposing pounded gypsum to a temperature of 212° *in vacuo*, and the whole water is expelled by a temperature below 300°. Thus dried, it constitutes the well known plaster of Paris, which, when mixed with a proper proportion of water, rapidly becomes dry and solid, owing to the reproduction of gypsum.†

Plaster of Paris.

Contained in water.

1344. Nearly all spring and river waters contain this salt, and in those waters which are termed *hard* it is abundant. It gives them a slightly nauseous taste.

Exp.

Pour a quantity of hard water into two glasses, solution of baryta dropped into one will detect the sulphuric acid, and a solution of oxalic acid dropped into the other, will detect the lime.

Solubility.

1345. Sulphate of lime has hardly any taste. It is more soluble than sulphate of baryta or strontia, requiring for solution about 500 parts of cold, and 450 of boiling water.

Epsom salt,

1346. *Sulphate of Magnesia—Epsom Salt.* $MgO+SO^3HO$, 20.7 1 eq. base + 40.1 1 eq. acid + 9 aq. 1 eq. = 69.8; in crystals with 54 6 eq. water = 123.8 eq. This salt is usually obtained from sea-water, the residue of which, after the separation of common salt, is known by the name of *bittern*, and contains sulphate and hydrochlorate of magnesia; the latter is decomposed by sulphuric acid; a portion of the hydrochlorate often remains in the sulphate and renders it deliquescent: it is also occasionally obtained from saline springs; and sometimes by the action of sulphuric acid on magnesian limestone. It was procured from the springs of Epsom, in England, and hence called *Epsom salt*. It has been found native, constituting the *bitter salt* and *hair salt* of mineralogists: it not unfrequently occurs as a fine capillary incrustation upon the damp walls of cellars and new buildings.‡

How obtained.

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* Discovered by Delafield, see *Amer. Jour.* iv. 279.

† It is remarkable that gypsum which has lost only 1 eq. water, as well as that which is dried by a heat exceeding 270° will not act in a similar manner. In the latter case the powder is a perfect anhydrite. (*Phil. Mag*. vi. 417.) Raw gypsum, according to Emmet, finely pulverized, is capable of undergoing immediate and perfect solidification when mixed with certain solutions of potassa. See *Amer. Jour.* xxiii. 209.

‡ The sulphate of magnesia of commerce is occasionally adulterated with small crystals of sulphate of soda; the fraud is detected by the inferior weight of the preci-

Taste and crystalline form.

1347. Sulphate of magnesia may be made by neutralizing dilute sulphuric acid with carbonate of magnesia. It has a saline, bitter, and nauseous taste, and crystallizes in small quadrangular prisms, which effloresce slightly in a dry air. It is obtained also in larger crystals, the principal form of which is a right rhombic prism.

Solubility.

1348. The crystals are soluble in an equal weight of water at 60°, and in three fourths their weight of boiling water. They undergo the watery fusion, and the anhydrous salt is deprived of a portion of its acid at a white heat. Dried at 212° it retains 2 eq. of water, but one of these is expelled at 270°, while the other is retained till the temperature rises to 460°.*

Sulphate of alumina,

1349. *Sulphate of Alumina.* $Al^2O^3+SO^3$, 51.4 1 eq. base + 40.1 1 eq. acid = 91.5; in crystals with 81 9 eq. water = 172.5.

Tersulphate. $Al^2O^3+3SO^3$, 51.4 acid + 120.3 3 eq. base = 171.7 eq.; in crystals with 162 18 eq. water = 333.7 eq.

Tersulphate.

The *tersulphate* is prepared by saturating dilute sulphuric acid with hydrated alumina, and evaporating. It crystallizes in thin flexible plates of a pearly lustre, containing 18 eq. of water and soluble in twice their weight of water.

Hydrated sulphate.

1350. The *hydrated* disulphate is known to mineralogists under the name of *aluminite*.†

Sulphates of iron,

1351. *Sulphate of Protoxide of Iron.* $FeO+SO^3HO$, 36 1 eq. base + 40.1 1 eq. acid + 9 aq. 1 eq. = 85. 1; in crystals with 45 5 eq. water = 130.1. Sulphuric acid with the protoxide of iron forms *sulphate of the protoxide*, *green vitriol*, or *copperas*.‡ It is prepared in large quantities for commercial purposes, by exposing the native protosulphuret of iron to air and moisture, the iron being converted into an oxide, and the sulphur into sulphuric acid by attracting oxygen.

Copperas.

Process.

On the small scale it may be prepared by mixing 6 parts of iron with 10 of $\ddot{S}$ and 60 of water, evaporating the solution in a glass or earthen vessel, after the effervescence has ceased, and continuing the heat, till a rod dipped into it presents appearances of crystallization, when taken out and held in the air. The solution may then be filtered, and green crystals of the sulphate will be formed as it cools.

Properties.

1352. This salt has a strong styptic taste. When pure it does not change vegetable blue colours, though generally stated to do so, the reddening effect being only produced when some of the iron

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pitate, occasioned by adding carbonate of potassa; 100 parts of pure crystallized sulphate of magnesia furnishing a precipitate of about 40 parts of dry carbonate. B.

Much of the sulphate found in the shops contains some hydrochlorate of magnesia, which renders it deliquescent, and consequently, it requires to be preserved in close and covered jars. It is often adulterated with Glauber's salt, which is made to resemble Epsom salt, by stirring it briskly, when it is about to crystallize. It may be detected by precipitating the magnesia by pure ammonia, aiding by heat; filtering and evaporating the filtered fluid to dryness by a heat sufficient to volatilize the sulphate of ammonia; if it contains Glauber's salt the soda will remain fixed. Or it may be detected by no precipitation ensuing, on adding carbonate of potassa to the solution. Hydrochlorate of lime is detected by the oxalic acid. Thomson's *Lond. Disp.* 407.

* On the manufacture of this salt from magnesite see *Amer. Jour.* iv. 22, and xiv. 10.

† *Sulphate of Protox. Manganese.* $MnO+SO^3HO$, 35.7 1 eq. base + 40.1 1 eq. acid + 9 aq. 1 eq. = 84.8 eq.

‡ *Native Green Vitriol* is frequently found associated with iron pyrites, being produced by its decomposition; it occurs in some coal mines.

passes into a higher state of oxidation. This is prevented by a few drops of sulphuric acid in excess, and the resulting crystals have a distinctly blue colour. The common green tint is a delicate test of the presence of sesquioxide of iron.*

Crystalline form.

The crystals belong to the oblique prismatic system, and contain 6 eq. of water, one of which is retained, according to Graham, till the temperature rises to 535°. By operating carefully it may be rendered anhydrous without the loss of acid. It is soluble in two parts of cold, and in three fourths its weight of boiling water. This salt is employed in the manufacture of fuming sulphuric acid (540).

Effect of heat.

1353. When heated it fuses, and at a high temperature evolves a mixture of sulphurous and sulphuric acids, and the oxide remaining was formerly called *caput mortuum vitrioli*, or *colcothar*.

Colcothar.

Tersulphate.

1354. *Tersulphate of the Sesquioxide*, $Fe^2O^3+3SO^3$, 80 1 eq. base + 120.3 3 eq. acid = 200.3 eq., is formed by mixing a solution of the protosulphate with half as much $\dddot{S}$ as that salt contains, and adding to the mixture in a boiling state successive portions of nitric acid until $\ddddot{N}$ fumes cease to appear. The solution is then evaporated to dryness to expel the excess of $\overset{\cdot\cdot\cdot\cdot\cdot}{N}$, and the tersulphate remains as a white salt.

Solubility, &c.

1355. It dissolves in water, after being strongly heated; and at a red heat gives out all its acid, sesquioxide of iron remaining. Its solution in water is yellow.†

Sulphate of zinc.

1356. *Sulphate of Protoxide of Zinc—White Vitriol*, $ZnO + SO^3HO$, 40.3 1 eq. base + 40.1 1 eq. acid + 9aq. 1 eq. = 89.4; in crystals with 54 6 eq. water = 143.4. This salt is the residue of the process for obtaining hydrogen gas, (378.)‡ It is also made for the purposes of commerce, by roasting native sulphuret of zinc.

Crystalline form, solubility, &c.

1357. Its crystalline form is a flattened four sided prism of the right prismatic system, and isomorphous with Epsom salt. The crystals dissolve in 2½ parts of cold, and are still more soluble in boiling water. Its taste is strongly styptic. It reddens vegetable blue colours, though a neutral salt.

Impurities removed.

1358. This salt is almost always contaminated with iron, and often with copper and lead. Hence the yellow spots which are visible on it; and hence also the reason why its solution in water lets fall a dirty brown sediment. It may be purified by dissolving it in water, and putting into the solution a quantity of zinc filings; taking care to agitate occasionally. The zinc precipitates the foreign metals and takes their place. The solution is then to be filtered

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* Bonsdorff in *Pogg. Ann.*, xxxi. 81.

† The *disulphate of the sesquioxide* falls as a hydrate of an ochreous colour, when a solution of the protosulphate is kept in an open vessel.

Hydrozincic gas.

‡ Hydrogen gas holding zinc in solution, may be obtained by a process of Vauquelin. A mixture of the ore of zinc, (blende, or calamine) with charcoal, is to be put into a porcelain tube, which is to be placed horizontally in a furnace, and when red-hot, the vapour of water is to be driven over it. The gas produced is a mixture of carbonic acid, carburetted hydrogen, and a solution of zinc in hydrogen gas, which has been called *hydrozincic gas*. The zinc is deposited on the surface of the water, over which this gas is kept; but if burned when recently prepared, the gas exhibits, in consequence of this impregnation, a distinctly blue flame.

and the sulphate of zinc may be obtained from it in crystals by proper evaporation.[*]

1359. In the dose of a scruple or a drachm, sulphate of zinc is one of the most immediate emetics we possess; and it is to be inferred, that if larger doses are rejected, as is the fact, with equal rapidity, they will in general cause no more harm than the medicinal dose. In some instances, however, persons have suffered severely from overdoses of this salt, and a few have even perished. It has also been said to have proved fatal when applied externally.[†]

Sulphate of nickel. 1360. *Sulphate of Protoxide of Nickel,* $NiO+SO^3HO$, 37.5 base 1 eq. + 40.1 acid 1 eq. + 9aq. = 86.6, like most of the salts of nickel this of a green colour, and crystallizes from its solution in pure water in right rhombic prisms, similar to the sulphates of zinc and magnesia. If an excess of acid is present the crystals are square prisms, containing less water and more acid than the preceding.[‡] Soluble in about three times its weight of water at 60°.

Sulphate of cobalt. 1361. *Sulphate of Protoxide of Cobalt,* $CoO+SO^3HO$, 37.5 1 eq. base + 40.1 1 eq. acid + 9 aq. 1 eq. = 86.6, is obtained by digesting protoxide of cobalt in dilute $\dddot{S}$, evaporation and crystallization. The crystals are red, and isomorphous with $FeO+SO^3HO$.[§]

Sulphate of copper. 1362. *Sulphates of the Oxides of Copper.—Blue Vitriol,* $CuO+SO^3HO$, 39.6 1 eq. base + 40.1 1 eq. acid +9aq. 1 eq. = 88.7 eq. in crystals with 36 4 eq. water = 124.7. The sulphate of the black or protoxide of copper is made by roasting the native sulphuret, or by dissolving the protoxide in dilute $\dddot{S}$ and crystallizing by evaporation. It forms crystals of a blue colour, which contain 5 eq. of water, 4 of which are lost at 212° in dry air, but the fifth is retained till the temperature exceeds 430°. It is then a white powder, combining readily with water with development of heat. It is isomorphous with $MnO+SO^3HO$.

Process. 1363. In the large way the the copper is oxidized by igniting it in an oven; the scale of oxide is then beaten off and the copper is heated again till the whole is thus oxidized; the scales heated in the acid will partially dissolve without decomposing the latter.[||]

Disulphate, 1364. When pure potassa is added to a solution of this salt, in a quantity insufficient for separating the whole of the acid, the *disulphate,* of a pale bluish green colour, is thrown down.

Sulphate of protox. cop. and ammonia. 1365. By adding cautiously, a solution of ammonia to the sulphate, until the subsalt thrown down is nearly all dissolved, *sulphate of protoxide of copper and ammonia* is generated. The solution is a rich blue from which crystals are deposited by the addition of alcohol. It may be formed also by triturating carbonate of ammonia

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[*] Thomson's *Inorg. Chem.* ii, 610.

[†] Christison on *Poisons,* 375. For method of detecting in contents of the stomach see *ibid,* 374.

[‡] *Ann. Philos.* xxii. 439.

[§] Brooke in *Ann. Philos.* NS. vi. 120. They are insoluble in alcohol, but dissolve in about 24 parts of cold water.

[||] The composition of these scales is variable, they are often a pure protoxide, and when treated with hot $\dddot{S}$ become peroxide of copper, which dissolves and finely divided metallic copper subsides. Their texture is crystalline and they readily dissolve in ammonia, and give, in close vessels, a colourless solution. (Hayes.)

with crystals of sulphate of copper; carbonic acid is disengaged and the mass becomes moist, the water of the blue vitriol being liberated. This is the *cuprum ammoniatum* of the U. S. *Phar.* and contains $\dddot{S}$, $Cu+O$ and NH^3? It loses NH^3 by exposure to the air.

Sulphates of Mercury.

1366. *Sulphates of the Oxides of Mercury. Sulphate of the Protoxide* $HgO+SO^3$ 210 1 eq. base + 40.1 1 eq. acid = 250.1 eq., is obtained when two parts of mercury are gently heated in three parts of strong $\dddot{S}$, so as to cause effervesence (530).

Effect of heat.

1367. If a strong heat is employed so as to excite brisk effervescence, and the mixture is brought to dryness, a *bisulphate of the peroxide* results, both being anhydrous.*

Turpeth mineral.

This salt is employed in making corrosive sublimate (1217). When thrown into hot water, it is decomposed, and a yellow subsalt, formerly called *Turpeth mineral*,† subsides, according to Phillips it consists of 3 eq. of acid and 4 eq. of peroxide.

Sulphate of silver.

1368. *Sulphate of Oxide of Silver.* $AgO+SO^3$, 116 1 eq. base + 40.1 1 eq. acid = 156.1 eq. This salt is deposited when sulphate of soda is mixed with nitrate of silver. It is also formed by boiling silver with its weight of sulphuric acid.

Properties.

1369. It is white and easily fusible, requiring about 80 times its weight of hot water for solution, and the greater part is deposited in small needles on cooling.‡

1370. A compound acid, which may be called *nitro-sulphuric*, consisting of one part of nitre dissolved in about ten of $\dddot{S}$, dissolves silver at a temperature below 200°, and the solution admits of moderate dilution before sulphate of silver separates from it. This acid scarcely acts upon copper, lead, or iron, unless diluted with water; it is, therefore, useful in separating the silver from old plated articles: the precious metal may afterwards be separated either in the form of chloride, by adding common salt; or by diluting the acid and continuing the immersion of the pieces of copper which hav[illegible] lost their silvering, and which will now dissolve in the diluted acid and occasion the precipitation of metallic silver.§

Action of ammonia.

1371. Sulphate of oxide of silver forms with ammonia a double salt, which crystallizes in rectangular prisms, the solid angles and lateral edges being replaced by tangent planes. It consists of 1 eq. AgO, 1 acid, and 2 NH^3; it is formed by dissolving $AgO+SO^3$ in a hot concentrated solution of ammonia, from which, on cooling, the crystals are deposited. It is isomorphous with the double chromate and seleniate of oxide of silver and ammonia.‖

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* Donovan in *Ann. Philos.* xiv.

† Hydrarg. sulphas flavus of the U. S. *Pharm.*

Economical method of separating gold.

‡ Upon the large scale small portions of gold may be economically separated from large quantities of silver, by heating the finely granulated alloy in $\dddot{S}$; the gold remains in the form of a black powder, and the sulphate of silver may be decomposed by the action of metallic copper; the silver is precipitated in a pulverulent state, and, with a little borax or other vitrifiable flux, is fused, and cast into ingots; the sulphate of copper is easily obtained in the crystallized state by evaporating the residuary liquor. B. ii. 187.

§ Keir in *Phil. Trans.* lxxx.

‖ Mitscherlich in *Ann. de Chim. et de Phys.*, xxxviii. 62.

Double Sulphates.

Glauberite. 1372. *Sulphate of Soda and Lime.* NaO, SO^3+CaO, SO^3, 71.4 1 eq. sulph. sod. + 68.6 1 eq. sulp. lime = 140 eq. This salt, described by mineralogists under the name of *Glauberite*, is found in the salt mines of New Castile. It may be made by fusing together its constituents in the ratio of their equivalents.[*]

Alum, **Process for,** 1373. *Sulphate of Potassa and Alumina—Alum.* $KO, SO^3+Al^2O^3, 3SO^3$, 87.25 1 eq. sulph. potassa + 171.7 1 eq. tersulph. alu. = 258.95 eq.; do. with 216 or 24 eq. water = 474.95. Common alum is prepared by roasting and lixiviating certain clays containing iron pyrites; to the leys a proper quantity of sulphate of potassa is added, and the salt is obtained by crystallization. In Italy it is made from *alum stone* which occurs at Tolfa near Rome. It occurs in volcanic countries, being probably formed by the action of sulphurous acid vapours on felspathic rocks.[†]

Properties, 1374. Alum has a sweetish taste. It is soluble in five parts of water at 60°, and a little more than its own weight of boiling water.[‡]

Crystalline form, 1375. Alum crystallizes readily in octohedrons or in segments of octohedrons. When the crystals are heated, they froth up, parting with their water and forming anhydrous alum, *alumen exsiccatum* of the U. S. Pharmacop.

Pyrophorus, 1376. When alum is ignited with charcoal, a spontaneously inflammable compound results, which has long been known under the name of Homberg's Pyrophorus.

Process, It is made by mixing equal weights of alum and brown sugar, and stirring the mass over the fire in an iron ladle till quite dry. It is then reduced to powder and introduced into a phial coated with clay in a crucible filled with sand.[§] The whole is heated to redness, and when a blue flame appears at the neck of the phial, allow it to burn about five minutes, then remove it from the fire; stop the phial with a piece of soft clay, and when cool substitute a good cork, to exclude the air.

Hare's, Hare recommends the following method, which affords a pyrophorus that rarely fails. Take 3 parts of lampblack, 4 of calcined alum, and 8 of pearlashes; mix[illegible]em thoroughly, and heat them in an iron tube to a bright cherry red for one hour. On removal from the fire the tube should be carefully stopped. When well prepared and poured out upon a glass plate, and especially when breathed upon, the pyrophorus kindles with a series of small explosions. This pyrophorus should be removed from the tube with great caution, as it has been found to explode violently on the introduction of a rod for the purpose of loosening it.[‖]

Theory of its combustion, 1377. From some experiments by Gay-Lussac, it appears that the essential ingredient of Homberg's pyrophorus is sulphuret of

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[*] *Sulphate of Potassa and Magnesia*, KO, SO^3+MgO, SO^3, 87.25 1 eq. sulph. pot. + 60.8 1 eq. sulph. magnes. = 148.05 eq., is formed on mixing solutions of the two salts; the crystals belong to the oblique prismatic system.

Sulph. Ox. Ammon. and Magnes. H_4NO, SO_3+MgO, SO^3, 66.25 1 eq. sulph. ox. ammon. + 60.8 1 eq. sulph. mag. = 127.05 eq.; do. with 54 or 6 eq. of water = 181.05.

[†] Large quantities are manufactured in the United States from the purer clays, as that of Martha's Vineyard.

[‡] The variable solubility of alum as stated by different chemists, may have arisen from the want of care in selecting specimens for trial. Hayes informs me that we have several varieties of alum in commerce, which vary in solubility; he finds that the pure potash alum is not more soluble than has been stated by Ure, (1 in 16 water at 60°). W.

[§] I usually prefer a small cast iron bottle, or retort. W.

[‖] Silliman in *Amer. Jour. of Sci.*, x. 367.

potassium in a state of minute division. The charcoal and alumina act only by being mechanically interposed between its particles; but when the mass once kindles, the charcoal takes fire and continues the combustion. He finds that an excellent pyrophorus is made by mixing 27 parts of sulphate of potassa with 15 parts of calcined lampblack, and heating the mixture to redness in a common Hessian crucible, of course excluding the air at the same time.[*]

Uses.

1378. Alum is of extensive use in the arts, more especially in dyeing and calico-printing, in consequence of the attraction which alumina has for colouring matter.

Other alums.

1379. Alum, having the same form, composition, appearance, and taste as the salt just described, may be made with ammonia,[†] the sulphate of which replaces sulphate of potassa. It is met with occasionally as a natural product, and may be prepared by evaporating a solution of sulphate of ammonia with tersulphate of alumina.

A *soda alum* may also be prepared, similar in form and composition to the preceding alums, except that it contains twentysix equivalents of water.[‡] This salt is disposed to effloresce in the air.[§]

Iron alum.

1380. *Iron Alum.* By mixing sulphate of potassa with tersulphate of sesquioxide of iron, and crystallizing by spontaneous evaporation, crystals are obtained similar to common alum, in form, *colour*, taste, and composition. This salt has often a pink tint, but is sometimes quite colourless. A similar double salt, quite colourless, may be made with ammonia instead of potassa. In both these alums the alumina is simply replaced by an equivalent quantity of oxide of iron.

Chrome alum.

1381. *Chrome Alums.* The tersulphate of sesquioxide of chromium forms with the sulphates of potassa and ammonia double salts which are exactly similar in form and composition to the preceding varieties of alum. They appear black by reflected, but ruby-red by transmitted light.

Manganese alum.

1382. *Manganese Alum.* Mitscherlich obtained this salt by mixing a solution of tersulphate of sesquioxide of manganese with sulphate of potassa, and evaporating to the consistence of syrup by a very gentle heat.[||]

Characteristic properties of alum.

1383. The salts to which the term alum is applied, are characterized by two common properties; they all crystallize in the octohedral system, and they are all constituted as represented by the formula $ROSO^3+R^2O^33SO^3+24Aq.$; where RO represents an eq. of potassa, or oxide of ammonium, and R^2O^3 any one of the isomorphous sesquioxides of aluminium, iron, manganese, and chromium. As remarked by Berzelius, the formula and crystalline form serve to determine the genus alum, and the oxidized bases its species.[¶] T. and L. 667.

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[*] *An. de Ch. et de Ph.*, xxxvii. 415.

[†] $H^4NO, SO^3+Al^2O^3, 3SO^3$, 66.25 1 eq. sulph. ox. ammon. + 171.7 1 eq. tersulph. alumina = 237.95 eq.; do. with 216 or 24 eq. water = 453.95.

[‡] Berzelius.

[§] $NaO, SO^3+Al^2O^3\ 3SO^3$, 71.4 1 eq. sulph. soda + 171.7 1 eq. tersulph. alumina = 243.1, eq.; do. with 234 or 26 eq. water = 477.1.

[||] KO, SO^3+MnO, SO^3, 87.25 1 eq. sulph. potassa + 75.8 1 eq. sulph. protox. mang. = 163.05 eq.; do with 54 or 6 eq. water = 217.05.

[¶] For *Sulphates of Protoxide of Iron and Alumina* and remarks on *Anhydrous Sulphates with Ammonia*, see Turner and Liebig's *Chem.*, 667.

Sulphites.

Sulphites. 1384. The salts of sulphurous acid have not hitherto been minutely examined. The sulphites of potassa, soda, and ammonia, made by neutralizing those alkalies with sulphurous acid, are soluble in water, but most of the other sulphites are of sparing solubility. The sulphites of baryta, strontia, and lime are very insoluble.

The stronger acids decompose all the sulphites with effervescence, owing to the escape of sulphurous acid, which may easily be recognised by its odour. Nitric acid, by yielding oxygen, converts the sulphites into sulphates.

Effect of heat. 1385. When the sulphites of the fixed alkalies and alkaline earths are strongly heated in close vessels, a sulphate is generated, and a portion of sulphur sublimed. In open vessels at a high temperature they absorb oxygen, and are converted into sulphates; and a similar change takes place even in the cold, especially when they are in solution.

The *hyposulphates* and *hyposulphites* are of little practical importance.*

Nitrates.

Nitrates. 1386. The nitrates may be prepared by the action of nitric acid on metals, on the salifiable bases themselves, or on carbonates. As nitric acid forms soluble salts with all alkaline bases, the acid of the nitrates cannot be precipitated by any reagent. They are readily distinguished from other salts, however, by the characters already described. (484.)

Effect of heat, &c. 1387. All the nitrates are decomposed without exception by a high temperature; but the changes which ensue are modified by the nature of the oxide. Nitrate of oxide of palladium is decomposed at a moderate temperature. Nitrate of protoxide of lead requires a red heat, by which it is resolved into oxygen and nitrous acid. In some instances the changes are more complicated.

Oxidize. 1388. As the nitrates are easily decomposed by heat alone, they must necessarily suffer decomposition by the united agency of heat and combustible matter. The nitrates on this account are much employed as oxidizing agents, and frequently act with greater efficacy even than nitro-hydrochloric acid.

The efficiency of nitre, which is the nitrate usually employed for the purpose, depends not only on the affinity of the combustible for oxygen, but likewise on that of the oxidized body for potassa. The process for oxidizing substances by means of nitre is called *deflagration*, and is generally performed by mixing the inflammable body with an equal weight of the nitrate, and projecting the mixture in small portions at a time into a red-hot crucible. Deflagration.

All the neutral nitrates of the fixed alkalies and alkaline earths, together with most of the neutral nitrates of the common metals, are composed of one equivalent of nitric acid, and one equivalent of a protoxide. Consequently, the oxygen of the oxide and acid in all such salts must be in the ratio of 1 to 5, the general formula being $MO+NO^5$.

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* For their characters see T. & L. *Elem.* 307, and Heeren in *Ann. de Chim. et Phys*, xl. 30.

The only nitrates found native are those of potassa, soda, lime, and magnesia.

Nitrate of potassa.

1389. *Nitrate of Potassa—Nitre*, $KO+NO^5$, 47.15 1 eq. base + 54.15 1 eq. acid = 101.3 eq. This salt is an abundant natural product, and is principally brought to this country from the East Indies, where it is produced by lixiviation of certain soils.*

The rough nitre is in broken crystals, of a brown colour, and more or less deliquescent: exclusive of other impurities, it often contains a very considerable proportion of common salt, which reacting upon the nitre, induces the production of nitrate of soda and chloride of potassium.

Artificial production of nitre.

1390. In Germany and France it is artificially produced in what are termed nitre-beds.† Thenard has described the French process at length.

It consists in lixiviating old plaster rubbish,‡ which when rich in nitre, affords about five per cent. Refuse animal and vegetable matter which has putrefied in contact with calcareous soils produces nitrate of lime, which affords nitre by mixture with subcarbonate of potassa. In the same way it is abundantly produced in some parts of Spain. Exudations containing saltpetre are not uncommon upon new walls, where it appears to arise from the decomposition of animal matter contained in the mortar. It was long ago shown by Glauber, that a vault plastered over with a mixture of lime, wood-ashes, and cows' dung, soon becomes covered with efflorescent nitre, and that after some months, the materials yield, on lixiviation, a considerable proportion of that salt.

Properties.

1391. Nitre crystallizes in six-sided prisms, it dissolves in 7 parts of water at 60° and in its own weight at 212°. Its taste is cooling and peculiar. It contains no water of crystallization, but its crystals are never quite free from water lodged mechanically within them.

Effect of heat.

1392. When exposed to a white heat, nitre is decomposed into oxygen, (365) nitrogen, and dry potassa. By distilling it in an earthen retort, or in a gun-barrel, oxygen gas may be obtained in great abundance, one pound of nitre yielding about 12,000 cubic inches, of sufficient purity for common experiments, but not for purposes of accuracy. It fuses at a heat below redness, and congeals on cooling into cakes called *sal prunelle*.

If the temperature of nitre be so far increased as to allow a portion of oxygen to escape, the remaining salt, as Scheele first observed, remains neutral, and in this state it has been considered as forming a *nitrite of potassa*.

Decomposed by charcoal.

1393. It is decomposed by charcoal at a red heat, and if excess of charcoal be used the results are $\dot{C}$, $\ddot{C}$, N and $KO+CO$. It is also decomposed by sulphur with different results, according to the temperature and proportions employed.

Exp.

This may be shown by mixing two parts of powdered nitre with one of powdered charcoal, and setting fire to the mixture in an iron vessel under a chimney.§

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* In Kentucky and other parts of the U. S. the caverns in limestone afford abundant supplies of nitrate of lime from which nitre is obtained. The potassa is obtained from wood ashes. In some places 1 bushel of the earth yields from 3 to 10 lbs. of the salt. *Amer. Jour.* 1. 321.

† *Traité de Chim. Elem.* ii. 511.

‡ The greater part of the nitre made in France is thus obtained.

§ The residuum is known as *white flux*.

Chap V.

Exp. Mix powdered nitre and sulphur, and throw the mixture, by a little at a time, into a red-hot crucible. The sulphur will unite with the oxygen of the nitric acid, and form sulphuric acid; which, combining with the potassa, will afford sulphate of potassa. The production of the latter salt will be proved by dissolving the mass remaining in the crucible, and crystallizing, when a salt will be obtained exhibiting the characters of the sulphate.

Exp. Mix a portion of sulphur with one sixth or one eighth its weight of nitrate of potassa; put the mixture into a tin cup; and raise it, by a small stand, a few inches above the surface of water, contained in a flat shallow dish. Set fire to the mixture, and cover it with a bell-shaped receiver. In this case, also, sulphuric acid will be formed; but it will not combine, as before, with the alkali of the nitre, which alkali is present in sufficient quantity to absorb only a part of the acid produced. The greater part of the acid will be condensed on the inner surface of the glass bell, and by the water, which will thus become intensely acid. The operation may be repeated three or four times, using the same portion of water. When the water is partly expelled, by evaporation in a glass dish, concentrated sulphuric acid remains. H. 1. 520.

Combustion with phosphorus, &c. When phosphorus is thrown upon nitre, and inflamed, a vivid combustion ensues, and a phosphate of potassa is formed. Sulphur sprinkled upon hot nitre burns, and produces a mixture of sulphate and sulphite of potassa. This salt used formerly to be employed in medicine, under the name of *Glaser's polychrest salt.* Most of the metals, when in filings or powder, detonate and burn when thrown on red-hot nitre; some of the more inflammable metals produce in this way a considerable explosion.

Fulminating powder. 1394. A mixture of three parts of nitre, two of dry subcarbonate of potassa, and one of sulphur, forms *fulminating powder.** If a little of this compound be heated upon a metallic plate, it blackens, fuses, and explodes with much violence, in consequence of the rapid action of the sulphur upon the nitre.

Use of nitre in chemistry, 1395. Nitre is employed in chemistry as an oxidizing agent, and in the formation of nitric acid (471). It is employed in the East Indies for the preparation of cooling mixtures; an ounce of nitre dissolved in five ounces of water reduces its temperature 15°. It is highly antiseptic and much used in the preservation of animal substances.

In the arts. 1396. Its chief use in the arts is in making gunpowder, which consists of a very intimate mixture of nitre, sulphur, and charcoal.†

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* Or nitre 2 parts, neutral carbonate of potassa 2, sulphur 1, and sea-salt 6, all in fine powder. Ferussac's *Bulletin*, 1828.

Composition of gunpowders. † The proportions vary. For a description of the manufacture, &c., see Ure's *Dict. Arts and Manuf.* p. 620, from which the following table of composition of different gunpowders is taken.

	Nitre.	Charcoal.	Sulphur.
Royal Mills, Waltham Abbey, - - -	75	15	10
France, national establishment, - -	75	12.5	12.5
French, for sportsmen, - - - - -	78	12	10
" " mining, - - - - - -	65	15	20
U. S. of America, - - - - - -	75	12.5	12.5
Prussia, - - - - - - -	75	13.5	11.5
Russia, - - - - - - - -	73.78	13.59	12.63
Austria (musquet), - - - - -	72	17	16
Spain, - - - - - - - -	76.47	10.78	12.75
Sweden, - - - - - - -	76	15	9
Switzerland (a round powder), - - -	76	14	10
Chinese, - - - - - - -	75	14.4	9.9
Theoretical proportions, - - - - -	75	13.23	11.79

Products of explosion of gunpowder.

1397. Gunpowder explodes at 600° F. The violence of the explosion depending upon the sudden production of gaseous matter resulting from the action of the combustibles upon the nitre.* $\dot{C}$, $\ddot{C}$, N, and $\ddot{S}$ are the principal gaseous results.

Inflamed by friction.

1398. Gunpowder may be inflamed by a violent blow; if mixed with powdered glass, or any other harder substance, and struck with a heavy hammer upon an anvil, it almost always explodes.

Nitrate of soda,

1399. *Nitrate of Soda.* $NaO+NO^5$, 31.3 1 eq. base + 54.15 1 eq. acid = 85.45 eq. This salt, the *cubic nitre* of old writers, is analogous in chemical properties to the preceding. It crystallizes in oblique rhombic prisms; but more commonly in the form of an obtuse rhombohedron. It occurs in the soil of India, and covers large districts in Peru.

1400. Mixed with charcoal and sulphur it burns, but more slowly than nitre. It may be advantageously used in the manufacture of both $\dddot{S}$ and $\overset{\cdot\cdot\cdot\cdot\cdot}{N}$.

Of ammonia,

1401. *Nitrate of Oxide of Ammonium.* H^4NO+NO^5, 26.15, base + 54.15 acid = 80.3 eq. This salt may be procured by the direct union of ammonia with nitric acid; or more easily by saturating dilute $\overset{\cdot\cdot\cdot\cdot\cdot}{N}$ with carbonate of ammonia, and evaporating the solution. The state of the salt varies with the temperature at which the evaporation is carried on.† At 100° it is obtained in prismatic crystals isomorphous with nitre; at 212° it is fibrous, at 300° it forms a compact mass on cooling. The fibrous and compact varieties still contain water, the former 8.2 per cent., and the latter 5.7. All the varieties deliquesce and are very soluble.

Use.

1402. It is the source of $\dot{N}$ (446). When heated to 600 it explodes,‡ being resolved into water, $\ddddot{N}$, $\ddot{N}$, and N. The fibrous variety yields the largest quantity of $\dot{N}$; from one pound of the salt nearly three cubic feet of gas may be obtained.

Nitrate of baryta.

1403. *Nitrate of Baryta.* $BaO+NO^5$, 76.7 1 eq. base + 54.15 1 eq. acid = 130.85 eq. It may be obtained by dissolving carbonate of baryta in $\overset{\cdot\cdot\cdot\cdot\cdot}{N}$, evaporating to dryness, redissolving and crystallizing; it forms transparent anhydrous octohedrons, and is apt

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The *port fire* used for firing artillery is made of three parts of nitre, two of sulphur, and one of gunpowder, well mixed and rammed in cases.

Signallights.

Signal lights are generally composed of nitre and sulphur, with a small quantity of some metallic sulphuret, as that of arsenic or antimony. Mix 600 grains of nitre with 200 of sulphur and 100 of the yellow sulphuret of arsenic; put the mixture into a cone of paper, and touch it (out of doors or under a large chimney), with a red-hot iron; it will burn rapidly with a brilliant white light.

Mix 100 or 200 grains of sulphuret of antimony with the same proportions of nitre and sulphur; it will burn with a vivid light having a bluish tinge. For other compositions used in pyrotechny, see Ure's *Dict.* and Gray's *Oper. Chem.* 496.

Amount of expansion.

* The volume of gases produced from gunpowder is at 60°, 250 times, and at the moment of discharge 1000 times greater than that of the powder;* as each additional vol. of gas exerts a force equal to that of the atmosphere, 1000 × 15=15.000 lbs. on a square inch, which will project a bullet with a force of 2000 feet in a second. (Murray.) Ure estimates it theoretically at upwards of 2000 times *Dict.* 627.

† Davy's *Researches.*

‡ Hence it was formerly called *nitrum flammans.*

* Robbins' *Essay on Gunnery*, and Nicholson's *Jour.* iv. 258.

to decrepitate by heat unless previously reduced to powder. It requires 12 parts of water at 60° and 3 or 4 of boiling water for solution. It is used as a reagent,* and for preparing pure baryta.†

Nitrate of strontia.

1404. *Nitrate of Strontia.* $SrO + NO^6$, 51.8 1 eq. base + 54.15 1 eq. acid = 105.95 eq.; in prisms with 45 or 5 eq. water = 150.95 eq. This salt may be made from the sulphate or carbonate of strontia in the same manner as the preceding. It crystallizes in anhydrous octohedons; it sometimes contains 30 per cent. of water of crystallization and then assumes the form of the oblique prismatic system.‡

Nitrate of lime.

1405. *Nitrate of Lime.* $CaO + NO^5$, 28.5 1 eq. base + 54.15 1 eq. acid = 82.65 eq. Nitrate of lime is a deliquescent salt, soluble in 4 parts of water at 60°. It is found in old plaster and mortar, from the washings of which, nitre is procured by the addition of carbonate of potassa (1381). When moderately heated it fuses, and on cooling concretes into a semitransparent mass known as *Baldwin's phosphorus.*§

Nitrate of copper.

1406. *Nitrate of Protoxide of Copper,* $CuO + NO^5$ 39.6 1 eq. base + 54.15 acid = 93.75 eq., is obtained by the action of $\overset{\cdot\cdot\cdot\cdot\cdot}{N}$ on copper (455). It crystallizes in prisms of a deep blue colour, soluble in water and alcohol, and deliquescent. By exposure to a heat of 400°, a green insoluble subsalt is obtained.‖

Effect of heat.

1407. When this salt is heated to redness, it yields pure oxide of copper. It is sometimes used as an escharotic. It is decomposed by tin with the evolution of heat and $\ddot{N}$.

Exp.

Spread a drachm or two of the salt in coarse powder on a piece of tin-foil, several inches square, moisten it with a few drops of water, fold it up quickly, and lay it upon a plate; much heat will be evolved and the metal often takes fire.¶

1408. *Nitrates of the Oxides of Mercury—Nitrate of the Protoxide,* $HgO + NO^5$, 210 base 1 eq. + 54.15 1 eq. acid = 264.15; in crystals with 18 or 2 eq. water = 282.15 eq.

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* If a moderately strong solution of this salt be added to $\overset{\cdot\cdot\cdot\cdot\cdot}{N}$, a precipitation of nitrate of baryta takes place, in consequence of the insolubility of the nitrate in the acid; hence in using nitrate of baryta as a test of $\overset{\cdot\cdot\cdot}{S}$, the latter should be considerably diluted previous to its application. B.

Green fire.

† This salt is employed in pyrotechny to impart a green colour to flame. The *green fire* is composed of 13 parts sulphur, 77 nitrate of baryta, chlorate of potassa 5, arsenic 2, and charcoal 3. The nitrate should be well dried, powdered, and mixed with the other ingredients, the powdered chlorate being added afterwards, and mixed, with caution, on a sheet of paper, and with an ivory or wooden spatula.

Red fire.

‡ This salt is used in the *red fire* employed at the theatres, which consists of 40 parts dry nitrate of strontia, 13 sulphur, 5 chlorate of potassa, and 4 sulphuret of antimony. The chlorate and sulphuret should be separately powdered, and mixed on paper with the other ingredients; a very small quantity of powdered charcoal may also be added.

§ Birch's *Hist. of Roy. Soc.*, iii. 328.

‖ The neutral salt contains 3 eq. of constitutional water, and may be represented by the formula $CuO\ NO^5\ 3HO$; the subsalt is supposed to be similarly constituted, being a nitrate of water with 3 eq. of constitutional oxide of copper, and may be represented by the formula $HO\ NO^5\ 3CuO$. T. 673.

¶ *Nitrate of Protoxide of Lead* $PbO + NO^5$, 111.6 1 eq. base + 54.15 1 eq. acid = 165.75 eq., is formed by digesting litharge in dilute $\ddot{N}$.

Nitrate of the Peroxide, HgO^2+NO^5, 218 1 eq. base + 54.15 acid = 272.15.

Dinitrate, $2HgO^2+NO^5$, 436 2 eq. base + 54.15 acid = 490.15 eq.

Protonitrate of mercury.

The protonitrate is obtained by digesting mercury in $\overset{\cdot\cdot\cdot\cdot\cdot}{N}$, diluted with 3 or 4 parts of water, until the acid is saturated, and then allowing the solution to evaporate spontaneously in an open vessel. The solution always contains, at first, some nitrate of the peroxide; but if metallic mercury is left in the liquid, a pure protonitrate is gradually deposited.*

Pernitrate of mercury.

1409. When mercury is heated in an excess of strong $\overset{\cdot\cdot\cdot\cdot\cdot}{N}$, it is dissolved with brisk effervescence, owing to the escape of $\overset{\cdot\cdot}{N}$, and transparent prismatic crystals of the pernitrate are deposited as the solution cools. When put into hot water it is resolved into a soluble salt the composition of which is unknown, and into a yellow dinitrate of the peroxide;† this is the *nitrous turpeth* of old writers.‡

Nitrate of silver.

1410. *Nitrate of Oxide of Silver*, $AgO+NO^5$, 116 1 eq. base + 54.15 1 eq. acid = 170.15. Nitric acid diluted with three parts of water, readily dissolves silver, with the disengagement of $\overset{\cdot\cdot}{N}$. If the acid contain the least portion of hydrochloric, the solution will be turbid, and deposit a white powder; and if the silver contain copper, it will have a permanent greenish hue; or if gold, that metal will remain undissolved in the form of a black powder.§

The solution should be perfectly clear and colourless; it is caustic, and tinges animal substances of a deep yellow, which, by exposure to light, becomes a deep purple, or black stain, and is indelible, or peels off with the cuticle: it consists of reduced silver.

Crystals.

1411. It may be obtained in transparent tabular crystals, by evaporation. These crystals, which are anhydrous, undergo the igneous fusion at 426°, and yield a crystalline mass on cooling; but at 600° or 700°, complete decomposition ensues, the acid being resolved into O and $\overset{\cdot\cdot\cdot\cdot}{N}$, and metallic silver is left.

Lunar caustic.

1412. When heated in a silver crucible it fuses, and if cast into small cylinders, forms the *lapis infernalis*, or *lunar caustic* of

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* According to Mitscherlich, it is a sub-salt, in which the protoxide and acid are in the ratio of 208 to 36. The neutral protonitrate is said to be obtained in crystals, by dissolving the former salt in pure water, acidulated with $\overset{\cdot\cdot\cdot\cdot\cdot}{N}$, and evaporating spontaneously without the contact of metallic mercury or uncombined oxide. *Pog. Ann.* ix. 387.

† *Ann. de Ch. et Phys.* xix.

‡ In preparing these salts for different purposes, great attention should be paid to the strength of the acid employed, the temperature, and the relative proportions, as all these circumstances have an important influence upon the oxidation of the mercury and the nature of the resulting salt. R.

Nitro-sulphuric acid.

§ A very useful solvent of silver is formed by dissolving one part of nitre in about eight or ten parts by weight of concentrated sulphuric acid. This compound (which may be called *nitro-sulphuric acid*) when heated to between 100° and 200° F. dissolves one fifth or one sixth its weight of silver, with an extrication of nitrous gas; and leaves untouched, any copper, gold, lead, or iron, with which the silver may be combined. Hence it is a most useful agent in extracting silver from old plated goods. The silver may be recovered from the solution by adding common salt, and the chloride of silver formed may be decomposed by carbonate of soda.

Chap. V. pharmacy; the *argenti nitras* of the *Pharmacop.* In forming this preparation, care should be taken not to overheat the salt, and the moulds should be warmed. When pure it is white and transparent, and does not deliquesce on exposure to the air; but common lunar caustic is often dark and opaque, and dissolves imperfectly in water, owing to some of the nitrate being decomposed during its preparation. It is impure, also, containing nitrate of protoxide of copper, and traces of gold.

Solubility. 1413. The pure salt is soluble in its own weight of cold and in half its weight of hot water. It dissolves also in 4 times its weight of alcohol. Its aqueous solution, if preserved in clear glass vessels, undergoes little or no change even in the direct rays of the sun; but when exposed to light, especially to sunshine, in contact with paper, the skin, or any organic substance, a black stain is produced, owing to decomposition of the salt and reduction of its oxide to the metallic state. This change is so constant, that this salt constitutes an extremely delicate test of the presence of organic matter. Its solution is a delicate test also of chlorine and hydrochloric acid.

Effect of light.

Action of sulphur, &c. 1414. Sulphur, phosphorus, charcoal, hydrogen, and several of the metals, decompose this nitrate.

Exp. A few grains mixed with a little sulphur, and struck upon an anvil with a heavy hammer, produce a detonation; phosphorus occasions a violent explosion when about half a grain of it is placed upon a crystal of the nitrate, upon an anvil, and struck sharply with a hammer; and if heated with charcoal, it deflagrates, and the metal is reduced.

Exp. If a piece of silk dipped into a solution of nitrate of silver be exposed while moist to a current of hydrogen gas, it is first blackened, and afterwards becomes iridescent from the reduction of portions of the metal.*

Exp. A stick of clean phosphorus, introduced into a solution of nitrate of silver, soon becomes beautifully incrusted with the metal, which separates upon it in arborescent crystals. A plate of copper occasions a brilliant precipitation of silver, and the copper is oxidized and dissolved by the acid.

Arbor Dianæ. The precipitation of silver by mercury produces a peculiar arrangement, called the *arbor Dianæ* (1244.)

Indelible ink. 1415. Nitrate of silver is employed for writing upon linen under the name of *indelible* or *marking ink*,† and is an ingredient in many of the liquids which are sold for the purpose of changing the colour of hair; but, when thus employed, it should be very much diluted, and used with extreme caution.

1416. White paper, or white leather, when stained with a solution of nitrate of silver, in the proportion of ten parts of water to one of the salt, undergoes no change in the dark; but when exposed to the light of day, it gradually acquires colour, and passes through a succession of changes to black. The common sun-beams, passing through red glass, have very little effect upon it; yellow and green are more efficacious; but blue and violet produce the most decidedly powerful effects. Hence this property furnishes a method of copying paintings on glass, and transferring them to leather or paper.‡

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* See Mrs Fulhame's *Essay on Combustion*.

† 100 grs. of the nitrate may be dissolved in distilled water, and 2 or 3 drachms of mucilage be added. The preparatory liquid may be made with half an ounce of carbonate of soda dissolved in 2 or 3 ounces of water, adding half an ounce of mucilage. This ink is discharged by chlorine and ammonia.

‡ See description of the process by Wedgwood in Nicholson's *Jour*. iii. 167, and Talbot on Photogenic drawing, *Lond. and Edin. Phil. Mag*. xiv.

Silvering of ivory,

By a similar process, ivory may be covered with silver. Let a slip of ivory be immersed in a dilute solution of pure nitrate of silver, till the ivory has acquired a bright yellow colour. Then remove it into a tumbler filled with distilled water, and expose it to the direct light of the sun. After two or three hours' exposure, it will have become black; but on rubbing it a little, the surface will be changed into a bright metallic one, resembling a slip of pure silver. As the solution penetrates deep into the ivory, the bright surface when worn away, is replaced by a succession of others. H. 2. 124.

1417. *Nitrites.*—Our knowledge of the compounds of nitrous acid with alkaline bases is imperfect.

Chlorates.

1418. *Chlorates.*—The salts of chloric acid are very analogous to the nitrates. As the chlorates of the alkalies, alkaline earths, and most of the common metals, are composed of 1 eq. of chloric acid and 1 eq. of a protoxide, $MO+ClO^5$, it follows that the oxygen of the latter to that of the former is in the ratio of 1 to 5.

Decomposed by heat.

1419. The chlorates are decomposed by a red heat, nearly all of them being converted into metallic chlorides, with evolution of pure oxygen gas. They deflagrate with inflammable substances with greater violence than nitrates, yielding oxygen with such facility that an explosion is produced by slight causes.

Exp.

Mix a few grains of sulphur with three times its weight of chlorate of potassa, wrap the mixture in tin foil, and strike it forcibly upon an anvil.*

Solubility of chlorates.

1420. All the chlorates are soluble in water, and are distinguished by the action of strong hydrochloric and sulphuric acids, the former of which occasions the disengagement of chlorine and protoxide of chlorine (641), and the latter of peroxide of chlorine (652). T.

Chlorate of potassa.

1421. *Chlorate of Potassa.* This salt, formerly called *oxymuriate* or *hyper-oxymuriate of potassa*, is formed by passing chlorine through a solution of potassa. Chloride of potassium is one of the results, the other is the chlorate of potassa.

How obtained.

This salt is prepared, upon the large scale, by charging Woulfe's bottles (634 note), with solution of carbonate of potassa, and passing chlorine slowly through it:† the gas is absorbed, and the liquor effervesces chiefly from the escape of carbonic acid; when this has ceased, the liquor may be put aside in a cold dark place for about 24 hours, when it will be found to have deposited a considerable portion of the crystallized chlorate which may be taken out, drained, and purified by solution in hot water, which, during cooling again, deposits the salt in white crystalline scales. The liquor is generally of a pinkish hue, from the presence of manganese.‡

Crystals.

1422. The crystals are four and six sided scales, of a pearly lustre. Its forms, according to Brooke, belong to the oblique prismatic system. It is soluble in 16 times its weight of water at 60°, and in two and a half of boiling water. It is anhydrous, and when exposed to a temperature of 400° or 500°, fuses. By an increase of heat, nearly to redness, pure oxygen gas is disengaged (365–4).

Action upon inflammables.

1423. It acts very energetically upon many inflammables.

Exp.

Rub two grains into powder in a mortar, and add one grain of sulphur. Mix them very accurately, by gentle triture, and then, having collected the mixture

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* This experiment requires caution, and is made more safely by placing the mixture under a long bar of wood, fitted to a groove, which can be driven down by a smart blow. W.

† The tube which is immersed in the alkaline solution, should be at least half an inch in diameter, to prevent its being choaked by crystals that may form.

‡ See another process by Hayes in *Amer. Jour.*, xvii. 408.

to one part of the mortar, press the pestle down upon it suddenly, and forcibly. A loud detonation will ensue.

Exp. Mix five grains of the salt with half the quantity of powdered charcoal in a similar manner. On triturating the mixture strongly, it will inflame, especially with the addition of a grain or two of sulphur, but not with much noise.

Action of sulphuric acid. 1424. When sulphuric acid is poured upon mixtures of this salt and combustibles, instant ignition ensues in consequence of the evolution of peroxide of chlorine; and when sulphuric or nitric acids are poured upon similar mixtures under water by means of a long funnel, inflammation also ensues.

Exp. Mix a small quantity of sugar with half its weight of the salt, and on the mixture pour a little sulphuric acid.* A sudden and vehement inflammation will be produced.

Exp. Phosphorus may be inflamed under the surface of the water, by means of this salt. Put into a tall wine glass, one part of phosphorus with two of the salt; fill it nearly with water, and slowly pour in, by means of a glass tube, reaching to the bottom, three or four parts of sulphuric acid. The phosphorus takes fire, and burns vividly under the water. These experiments require caution lest the inflamed substances should be thrown into the eyes. Oil may also be thus inflamed on the surface of water, the experiment being made with the omission of the phosphorus, and the substitution of a little olive or linseed oil.

Caution. 1425. Chlorate of potassa should not be kept mixed with sulphur in considerable quantity, as the mixture may explode spontaneously.†

1426. A few grains of chlorate of potassa put into a tea-spoonful of hydrochloric acid, and then diluted with water, form an extemporaneous bleaching liquor.

Chlorate of baryta, 1427. *Chlorate of Baryta* is the compound employed in the formation of chloric acid (657.)

Process. The readiest mode of preparing it is, to digest for a few minutes a concentrated solution of chlorate of potassa with a slight excess of silicated hydrofluoric acid, the alkali is precipitated in the form of an insoluble double fluoride of silicon and potassium, while chloric acid remains in solution. The liquid after filtration is neutralized by carbonate of baryta, which throws down the excess of silicated hydrofluoric acid, and chlorate of baryta is left in solution.

Crystals. By evaporation it yields prismatic crystals, requiring for solution four times their weight of cold, and a still smaller quantity of hot water. They are composed of 76.7 parts 1 eq. of baryta, 75.42 1 eq. of chloric acid, and 9 or 1 eq. of water. T. 677.

Matches. * A mixture of this kind is the basis of matches, for the purpose of procuring instantaneous light. The bottle into which they are dipped, contains concentrated sulphuric acid which is prevented from escaping by a quantity of finely spun glass or the fibres of amianthus. 30 parts of powdered chlorate of potassa, 10 of powdered sulphur, 8 of sugar, 5 of gum arabic, and a little cinnabar. The sugar, gum, and salt are first rubbed together into a paste with sufficient water; the sulphur is then added, and the whole being well beaten together, small brimstone matches are dipped in, so as to retain a thin coat of the mixture upon their sulphuretted points.

A very convenient method of obtaining a flame, is to dip the end of a piece of paper in spirits of turpentine, drop upon it a few scales of the salt, and then a drop of sulphuric acid.

Percussion powder. One of the compounds occasionally employed in percussion gun-locks contains this salt; 10 parts of gunpowder are rubbed with water, and the soluble part poured off; the remaining paste is then mixed with 5½ parts of finely powdered chlorate of potassa, and a drop of it put into each of the small copper caps adapted to the peculiar touch-hole of the gun. The great disadvantage of this compound is that it forms products which corrode the touchhole; fulminating mercury is preferable.

Substituted for nitre in gunpowder. † It was proposed by Berthollet to substitute this salt for nitre, in the preparation of gunpowder and the attempt was made at Essone in 1788; but, as might have been expected, no sooner was the mixture of the chlorate with the sulphur and charcoal submitted to trituration than it exploded with violence, and proved fatal to several people.

Perchlorates. Effect of heat.

1428. *Perchlorates.* The neutral proto-salts of perchloric acid consist of 1 eq. acid and base, as is expressed by the formula $MO+Cl^{2}O^{7}$. Most of these salts are deliquescent, very soluble in water, and soluble in alcohol. Heated to redness they yield oxygen gas and metallic chlorides; and they are distinguished from the chlorates by not acquiring a yellow tint on the addition of hydrochloric acid.

Solubility in alcohol useful,

1429. The solubility in alcohol of the perchlorates of baryta, soda, and oxide of silver, is a property which the analytical chemist may avail himself of in analysis, for the separation of potassa and soda from each other.

Chlorites, Recognised.

1430. *Chlorites.* The alkaline salts of chlorous acid are readily made by transmitting a current of chlorous acid gas into a solution of the pure alkalies. They are soluble in water, and are remarkable for their bleaching and oxidizing properties. By the latter properties and the evolution of chlorous acid on the addition of any of the stronger acids their presence is readily recognised.

Hypochlorites.

1431. *Hypochlorites.* The hypochlorites may be produced by the addition of chlorine gas on the salifiable bases. The most important of them is hypochlorite of lime, the well known bleaching powder (901). During absorption of the chlorine, chloride of calcium and hypochlorite of lime are produced in equivalent proportions.*

Bleaching powder,

1432. It is a dry white powder, with the odour of chlorine and a strong taste. It dissolves partially in water and the solution bleaches; it contains both chlorine and lime; the undissolved portion is hydrate of lime, retaining a small quantity of chlorine. The solution is decomposed by exposure, its chlorine being set free, and carbonate of lime generated.

Uses.

1433. It is largely employed in bleaching, for the purpose of removing offensive odours, and of arresting putrefaction.† With hydrochlorate of ammonia it affords nitrogen gas from the decomposition of the ammonia (420).

Into a small tubulated retort introduce the bleaching salt, add sufficient water to bring it to the consistence of cream; drop in lumps of the hydrochlorate of ammonia; effervescence will take place, and the nitrogen be disengaged.

Iodates, their general character,

1434. *Iodates.* The general character of the iodates is similar to that of the chlorates. In all neutral protiodates the oxygen contained in the oxide and acid is in the ratio of 1 to 5. They deflagrate with combustibles, and yield oxygen gas at a red heat, a metallic iodide remaining.

Recognised.

1435. The iodates are recognised by the facility with which their acid is decomposed by deoxidizing agents. Hydrosulphuric acid occasions the formation of hydriodic acid, by yielding hydrogen to the iodine. Hence an iodate of potassa may be converted into the iodide by transmitting a current of HS through its solution. The iodates are very sparingly soluble, or actually insoluble in water, excepting the iodates of the alkalies.

Iodate of potassa,

1436. *Iodate of Potassa* may be procured by adding iodine to a concentrated hot solution of pure potassa, until the alkali is completely neutralized.

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* Turner.

† For details respecting its manufacture, &c., see Ure's *Dict. of Arts*, &c., and for the methods of estimating the value of this substance, see page 243.

Process, The liquid, which contains an iodate and iodide is evaporated to dryness by a gentle heat, and the residue, when cold, is treated by repeated portions of boiling alcohol. The iodate, which is insoluble in that menstruum, is left, while the iodide of potassium is dissolved.

Another. A better process is founded on the property which iodide of potassium possesses, of absorbing oxygen while in the act of escaping from decomposing chlorate of potassa. For this purpose,

Henry's. Iodide of potassium is fused in a capacious Hessian crucible, and when, after removal from the fire, it is yet semi-fluid, successive portions of pulverized chlorate of potassa are projected into it, stirring well after each addition. The materials froth up considerably, and when the action is over, a white, opaque, cellular mass remains, easily separable from the crucible; tepid water dissolves out the chloride of potassium, and leaves the iodate. Convenient proportions are one part of iodide of potassium and rather more than one and a half of chlorate of potassa.*

Use. 1437. From this salt all the insoluble iodates may be procured by double decomposition. Thus iodate of baryta may be formed by mixing chloride of barium with a solution of iodate of potassa.

The *Bromates* have many characters in common with the chlorates and iodates. T.

Phosphates. 1438. *Phosphates.* As there are three isomeric modifications of the same acid, which have been described under the names of *phosphoric*, *pyrophosphoric*, and *metaphosphoric* acid (page 174), it is necessary to have three corresponding families of salts, the *phosphates*, *pyrophosphates* and *metaphosphates*.†

Three families.

Protophosphates. 1439. All the protophosphates which are neutral in composition are soluble in water, and redden litmus paper; whence they are commonly called superphosphates. The triphosphates, except those of the pure alkalies, are either sparingly soluble or insoluble in water; but they are all dissolved by dilute nitric or phosphoric acid, being converted into the soluble phosphates. All the triphosphates with fixed and strong bases bear a red heat without change; but the phosphates and diphosphates, to judge from experiments on the soda salts, are converted into metaphosphates and pyrophosphates. Most of the phosphates of the second class of metals are resolved into phosphurets by the conjoint agency of heat and combustible matter.

Triphosphates.

Effect of heat.

The phosphates of the alkalies are only partially decomposed under these circumstances, and the phosphates of baryta, strontia, and lime, undergo no change.

Soluble phosphates detected, 1440. The presence of a soluble phosphate may be distinguished by the test for phosphoric acid.‡

The insoluble phosphates are decomposed when boiled with a

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* *Jour. de Phar.*, July, 1832

Formula. † An equiv. of each of the three acids, is a compound of 31.4 parts or 2 eq. of phosphorus + 40 parts or 5 eq. of oxygen = 71.4, expressed by the formula P^2O^5. To form a salt *neutral in composition* 1 eq. of an alkaline base is requisite, and in the case of any protoxide, indicated by MO, the general formula will be $MO+P^2O^5$. If 2 eq. of a protoxide are united with one of the acid, we have a *disalt*, $2MO+P^2O^5$; and if 3 eq. of a base combine with 1 eq. of the acid, it is a *trisalt*, $3MO+P^2O^5$. It seems also that water plays the part of an alkaline base towards each of the three acids, either alone or conjointly with another base; the salts with such compound bases can scarcely be viewed in the light of double salts, since the two bases act together as one electro-positive element.

Water a base.

Test of phosphoric acid. ‡ When phosphoric acid is neutralized by ammonia and mixed with nitrate of oxide of silver, the yellow phosphate of that oxide subsides, a character by which it is distinguished from all acids, except the arsenious. T. 316.

strong solution of carbonate of potassa or soda, the acid uniting with the alkali so as to form a soluble phosphate; the earthy phosphates require continued ebullition, and should preferably be fused with an alkaline carbonate, like an insoluble sulphate. T.

Insoluble, decomposed.

Triphos. Soda, Process.

1441. *Triphosphate of Soda.* $3NO+P^2O^5$, 93.9 3 eq. base + 71.4 1 eq. acid = 165.3; in crystals with 216 or 24 eq. water = 381.3. This salt is made by adding pure soda to a solution of the succeeding compound until the liquid feels soapy to the fingers, an excess of soda not being injurious. The liquid is then evaporated until a pellicle appears, and the crystals which form on cooling are quickly redissolved in water and recrystallized.

Properties.

1442. The crystals are colourless six-sided prisms, with a strong alkaline taste and reaction, requiring five times their weight of water at 60° for solution. They fuse at 170°, and may be exposed to a red heat without losing their characters of a phosphate. The feeblest acids deprive the salt of one third of its soda.

Triphosphate of soda and basic water, Process.

1443. *Triphosphate of Soda and Basic Water.* $2NaO.HO+P^2O^5$, 62.6 2 eq. soda, 9 1 eq. water + 71.4 1 eq. acid = 143; in crystals with 216 or 24 eq. water = 359, with 135 or 15 eq. water = 278. This salt is the most common of the phosphates, being manufactured on a large scale by neutralizing with carbonate of soda the acid phosphate of lime procured by the action of sulphuric acid on burned bones (p. 169). It is generally described as the neutral phosphate of soda.

Crystals.

1444. It crystallizes best out of an alkaline solution; but however prepared is always alkaline to test paper. The crystals effloresce, and require four times their weight of cold, and twice their weight of hot water for solution.

Acid Triph. S. and B. water.

1445. *Acid Triphosphate of Soda and Basic Water.* $NaO. 2HO+P^2O^5$, 31.3 1 eq. sod. 18 2 eq. water + 71.4 1 eq. acid = 120.7; in crystals with 18 or 2 eq. water = 138.7. This salt, commonly called *biphosphate of soda*, may be formed by adding phosphoric acid to a solution of carbonate of soda, or to either of the preceding phosphates, until it ceases to give a precipitate with chloride of barium. Being very soluble in water, the solution must be concentrated in order that it may crystallize. This salt is capable of yielding two different kinds of crystals without varying its composition.*

Crystals.

1446. *Triphosphate of Soda, Oxide of Ammonium, and Basic Water,* $NaO., H^4NO. HO+P^2O^5$, 31.3 1 eq soda, 26.15 1 eq. ox. am. 9 1 eq. water + 71.4 1 eq. acid = 137.85 eq.; in crystals with 72 or 8 eq. water = 209.85. Prepared by mixing 1 eq. of hydrochlorate of ammonia and 2 eq. of the neutral phosphate of soda, each being previously dissolved in a small quantity of boiling water. It has been long known as *microcosmic salt*, and is much

Microcosmic salt.

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* For which see Liebig and Turner's *Elem.* 684.

Triphosphate of Potassa. $3KO+P^2O^5$, 141.45 3 eq. base + 71.4 1 eq. acid = 212.85. Formed by adding caustic potassa in excess to a solution of phosphoric acid.

Triphosphate of Potassa and Basic Water. $2KO.HO+P^2O^5$, 94 3 2 eq. KO, 9 1 eq. HO + 71.4 1 eq. acid = 174.7. Prepared by neutralizing the superphosphate of lime from bones with carbonate of potassa.

Acid Triphosphate of Potassa and Basic Water. $KO{\cdot}2HO+P_2O^5$, 47.15 1 eq. pot. 18 2 eq. water + 71.4 1 eq. acid = 136.55 eq. Formed by adding phosphoric acid to carbonate of potassa until the liquid ceases to give a precipitate with chloride of barium, and setting aside to crystallize.

Chap. V.

employed in experiments with the blow-pipe. When heated it parts with its water and ammonia, and a very fusible metaphosphate of soda remains.*

Phosphates of lime,

1447. *Phosphates of Lime.* The peculiar compound called the *bone phosphate,*† exists in bones after calcination, and falls as a gelatinous precipitate on pouring chloride of calcium into a solution of the rhombic phosphate of soda, or on adding ammonia to a solution of any phosphate of lime in acids.‡

Triphosphate,

1448. *Triphosphate of Lime and Basic Water*, $2CaO.\ HO + P^2O^5$, 57 2 eq. lime, 9 1 eq. water + 71.4 1 eq. acid = 137.4 eq. This salt is commonly called ***neutral phosphate;*** it falls as a granular precipitate when the rhombic phosphate of soda is added drop by drop to chloride of calcium in excess. The triphosphate of lime occurs in the mineral called apatite.

Acid triphosphate and basic water.

1449. *Acid Triphos. of Lime and Basic Water*, $CaO2HO + P^2O^5$, 28.5 1 eq. lime, 18 2 eq. water + 71.4 1 eq. acid = 117.9. This is called the ***biphosphate*** from its acid reaction, and is formed by dissolving either of the preceding salts in a slight excess of phosphoric acid. It exists in the urine.

Of magnesia.

1450. *Triphosphate of Magnesia and Basic Water*, is formed by mixing hot saturated solutions of the rhombic phosphate of soda and sulphate of magnesia, and separates on cooling in small crystals which contain 13 eq. of water to 1 of the salt.

Phosphate of ammonia and magnesia.

1451. The ***phosphate of ammonia and magnesia***, subsides as a pulverulent granular precipitate from neutral or alkaline solutions, containing phosphoric acid, ammonia, and magnesia. It is readily dissolved by acids and is sparingly soluble in pure water, especially when carbonic acid is present; but it is insoluble in a solution of most neutral salts, such as hydrochlorate of ammonia. It constitutes one variety of urinary concretions, according to Berzelius it consists of

Phosphoric acid . .	71.4	1 eq.	P^2O_5.
Magnesia . .	41.4	2 eq.	$2MgO$.
Ammonia . .	34.3	2 eq.	$2H_3N$.
Water . .	90	10 eq.	$1HO$.

Effect of heat.

1452. By a red heat it loses its water and ammonia, and the residue is diphosphate of magnesia, which contains 36.67 per cent. of pure magnesia. At a strong red heat it fuses, and appears when cold as a white enamel.

Triphosphate of silver.

1453. *Triphosphate of Oxide of Silver* subsides, of a characteristic yellow colour, (1440) when the rhombic phosphate of soda is mixed in solution with nitrate of oxide of silver, $\overset{\cdot\cdot\cdot\cdot\cdot}{N}$ being set free at the same time. This salt is very soluble in $\overset{\cdot\cdot\cdot\cdot\cdot}{N}$ and $\underline{\overset{\cdot\cdot\cdot\cdot\cdot}{P}}$, forming the

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* *Triphosphate of Oxide of Am. and Basic Water*, $2H^4NO.\ HO + P^2O^5$, 52.30 2 eq. ox. Am. 9 1 eq. water + 71.4 1 eq. acid = 132.70 eq., formed by adding ammonia to concentrated phosphoric acid until a precipitate appears. On applying heat, the precipitate is dissolved, and on abandoning the solution to itself, the neutral salt crystallizes. The crystals are oblique rhombic prisms, the smaller angle being 84° 30′.

† *Bone Phosphate of Lime*, $8CaO + 3P^2O^5$, 228 8 eq. base + 214.2 3 eq. acid = 442.2 eq.

‡ *Triphosphate of Lime*, $3CaO + P^2O^5$, 85.5 3 eq. base + 71.4 1 eq. acid = 156.9.

soluble phosphate and in ammonia. It is blackened by exposure to light.

Pyrophosphates.

1454. When phosphoric acid, with the aid of heat is made to combine with 2 eq. either of water or some fixed base, the modification of phosphoric acid, termed *pyrophosphoric* (569) is procured. Combined with bases it forms *pyrophosphates.**

1455. The oxides of most metals of the second class yield with this acid insoluble or sparingly soluble salts, which may be prepared by double decomposition with dipyrophosphate of soda.†

Arseniates.

1456. *Arseniates.* Arsenic acid resembles the phosphoric in composition and in many of its properties. It forms tribasic salts. Those with 2 eq. of basic water are soluble in water and redden litmus; with 1 eq. of basic water, in which the oxygen of the alkaline base and acid is as 2 to 5, the salt is usually called a neutral arseniate. When no basic water is present, the salt is usually described as a subarseniate.

Effect of heat.

1457. Many of the arseniates bear a red heat without decomposition, but they are all decomposed when heated to redness along with charcoal, metallic arsenic being set at liberty.

Arseniates recognised.

The soluble arseniates are easily recognised by the tests for arsenic (1053), and the insoluble arseniates, when boiled in a strong solution of the fixed alkaline carbonates, are deprived of their acid, which may then be detected in the usual manner. The free alkali, however, should first be exactly neutralized by pure nitric acid.

Arsenites.

Properties.

1458. *Arsenites.* The arsenites of potassa, soda, and ammonia, may be prepared by acting with those alkalies on arsenious acid; they are very soluble in water, have an alkaline reaction, and have not been obtained in regular crystals. Most of the other arsenites are insoluble, or sparingly soluble, in pure water; but they are dissolved by an excess of their own acid, with great facility by $\overset{\cdot\cdot\cdot\cdot\cdot}{N}$, and by most other acids with which their bases do not form insoluble compounds. The insoluble arsenites are easily formed by double decomposition.

1459. All the arsenites are decomposed when heated in close vessels, the arsenious acid being either dissipated in vapour, or converted, with disengagement of some metallic arsenic, into arseniates. Heated with charcoal or black flux, the acid is reduced (1054.)

Soluble arsenites distinguished.

Scheele's green.

1460. The soluble arsenites, if quite neutral, are characterized by forming a yellow arsenite of oxide of silver when mixed with the nitrate of that base, and a green arsenite of protoxide of copper, *Scheele's green,* with sulphate of that oxide. When acidulated with acetic or hydrochloric acid, hydrosulphuric acid gas causes the formation of orpiment. The insoluble arsenites are all decomposed when boiled in a solution of carbonate of potassa or soda. The arsenite of potassa is the active principle of *Fowler's arsenical solution.*

Chromates.

1461. *Chromates.* The salts of chromic acid are mostly either of a yellow or red colour, the latter tint predominating whenever

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* For which see Turner and Liebig's *Elem.* 667.

† For description of *Metaphosphates* see T. and L. *Elem.* 689; and Graham in *Philos. Trans.* 1833, part 2d.

Effect of heat,

And combustibles.

the acid is in excess. The chromates of oxides of the second class of metals are decomposed by a strong red heat, by which the acid is resolved into the green oxide of chromium and oxygen gas; but the chromates of the fixed alkalies sustain a very high temperature without decomposition. They are all decomposed by the united agency of heat and combustible matter. The neutral chromates of protoxides are similar in constitution to the sulphates, being formed of 1 eq. of the base and 1 of chromic acid, the formula being $MO + CrO^3$.

Distinguished.

1462. The chromates are in general sufficiently distinguished by their colour. They may be known chemically by the following characters: on boiling a chromate in hydrochloric acid mixed with alcohol, the chromic acid is at first set free, and is then decomposed, a green solution of the chloride of chromium being generated.

Chromate of potassa.

1463. *Chromates of Potassa.* The neutral chromate from which all the compounds of chromium are directly or indirectly prepared, is made by heating to redness the native oxide of chromium and iron, *chromate of iron*, with nitrate of potassa (1077), when chromic acid is generated, and unites with the alkali of the nitre.

Properties.

1464. Chromate of potassa has a cool, bitter and disagreeable taste; it is soluble to great extent in boiling water, and in twice its weight of that liquid at 60°; but it is insoluble in alcohol. According to Thomson it is neutral in composition, consisting of 52 parts or 1 eq. of chromic acid, and 47.15 parts or 1 eq. of potassa.[*]

Bichromate.

Crystals.

1465. *Bichromate of Potassa* is made in large quantity for dyeing, by acidulating the neutral chromate with sulphuric, or still better with acetic acid, and allowing the solution to crystallize by spontaneous evaporation. When slowly formed it is deposited in four-sided tabular crystals, the form of which is an oblique rhombic prism. They have a rich red colour, are anhydrous, and consist of 1 eq. of the alkali, and 2 eq. of chromic acid.[†] They are soluble in about ten times their weight of water at 60°, and the solution reddens litmus paper.

Insoluble chromates.

Chromate of lead.

1466. The insoluble salts of chromic acid such as the chromates of baryta and oxides of zinc, lead, mercury and silver, are prepared by mixing the soluble salts of those bases with a solution of chromate of potassa. The yellow chromate of lead is much used as a pigment, it consists of 1 eq. of acid and 1 eq. of oxide.[‡]

Borates.

1467. *Borates.* Boracic acid is a feeble acid and neutralizes imperfectly, hence the borates of soda, potassa and oxide of ammonium have always an alkaline reaction. For the same reason, when the borates are digested in any of the more powerful acids, the bo-

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[*] *Ann. of Philos.* xvi. [†] Thomson.

Dichromate.

Process.

[‡] The chromate of oxide of zinc may be used for the same purpose. A dichromate composed of 1 eq. chromic acid and 2 eq. protox. lead, may be formed by boiling the carbonate of that oxide with excess of chromate of potassa. It is of a beautiful red colour, and has been recommended as a pigment (*Ann. Philos.* xxv. 303.) It may also be made by boiling the neutral chromate with ammonia or lime water; or by fusing nitre at a low red heat, and adding chromate of oxide of lead by degrees until the nitre is nearly exhausted. The chromate of potassa and nitre are then removed by water, and the dichromate is left crystalline in texture, and of a beautiful tint. (*Pog. An.* xxi. 580.)[*]

[*] For *Chromates of Silver*, and of *Chlorids of Potassium*, see T. and L. *Elem.* 695.

racic acid is separated from its base. But at a red heat this acid decomposes all salts, the acid of which is volatile.

Properties, &c.

1468. The borates of the alkalies are soluble in water, but most of the salts of this acid are of sparing solubility. They are not decomposed by heat, and the alkaline and earthy borates resist the action of heat and combustible matter. They are remarkably fusible, a property owing to the great fusibility of the acid itself.

Distinguished.

1469. The borates are distinguished by the following character: by digesting any borate in a slight excess of strong sulphuric acid, evaporating to dryness, and boiling the residue in strong alcohol, a solution is formed which has the property of burning with a green flame.

Borax,

1470. *Biborate of Soda—Borax.* This salt, which has been very long known, is imported from India in the impure state, under the name of *Tincal,* which, after being purified, constitutes the *refined borax* of commerce. It is frequently called *sub-borate of soda.*

Crystals.

1471. It crystallizes in prisms of the oblique system, which effloresce; they require 20 parts of cold, and 6 of boiling water, for solution. Exposed to heat the crystals lose their water of crystallization, fuse, and then form a vitreous substance called *glass of borax.* The crystals are composed of 69.8 parts or 2 eq. of acid, 31.3 or 1 eq. soda, and 90 or 10 parts of water.

Use.

1472. The chief use of borax is as a flux, and for the preparation of boracic acid.*

Carbonates, characters of,

1473. *Carbonates.* The carbonates are distinguished by being decomposed with effervescence, owing to the escape of $\ddot{C}$, by nearly all the acids; and all of them, except the carbonates of potassa, soda and lithia, may be deprived of their acid by heat. The carbonates of baryta and strontia, especially the former, require an intense heat for decomposition; those of lime and magnesia are reduced to the caustic state by a full red heat; and the other carbonates part with their carbonic acid when heated to dull redness.

Solubility.

1474. All the carbonates, except those of potassa, soda and ammonia, are of sparing solubility in pure water; but all of them are more or less soluble in an excess of carbonic acid, owing probably to the formation of supersalts. Several of the carbonates occur native.

Carbonate of potassa.

1475. *Carbonate of Potassa,* $KO+CO^2$, 47.15 1 eq. base $+$ 22.12 1 eq. acid $=$ 69.27 eq. This is a salt of great importance in many arts and manufactures, and is known in commerce in different states of purity, under the names of *wood-ash*, *pot-ash*, and *pearl-ash.* It is the *subcarbonate of potassa* of the *U. S. Pharmacop.*

Exp.

The simplest mode of showing the absorption of carbonic acid by potassa, is the following: Fill a common phial with carbonic acid gas over water; and

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New biborate of soda.

* The *Boracite* of mineralogists is a biborate of magnesia. A new *biborate of soda*, containing half as much water of crystallization as the above, has been described. It is harder and denser than borax, is not efflorescent, and crystallizes in octohedrons. It is made by dissolving borax in boiling water until the sp. gr. of the solution is at 30° or 32° of Beaumé's hydrometer; the solution is then very slowly cooled, and when the temperature falls to about 133° the salt is deposited. It is found to be more convenient for the use of jewellers than common borax. *Ann. de Chim. et Phy.* xxxvii. 419.

Process.

when full, stop it by applying the thumb. Then invert the bottle in a solution of pure potassa contained in a cup, and rather exceeding in quantity what is sufficient to fill the bottle. The solution will rise into the bottle. and if the gas be pure, will fill it entirely. Pour out the alkaline liquor, fill the bottle with water, and again displace it by the gas. Proceed as before, and repeat the process several times. It will be found that the solution will condense many times its bulk of the gas; whereas water combines only with its own volume.

Exp.

This experiment may be made in a much more striking manner, over mercury, by passing into a jar, about three fourths filled with this gas, a comparatively small bulk of a solution of pure potassa, which will condense the whole of a large quantity of the gas. If dry hydrate of potassa be substituted in this experiment, no change will ensue; which proves that solution is essential to the action of alkalies on this gas. A solution of potassa, which has condensed all the carbonic acid it is capable of absorbing, when evaporated to dryness, affords *carbonate of potassa*. H. 1. 541.

Effect of heat,

1476. This salt is fusible without decomposition, at a red heat: it is very soluble in water, and deliquesces by exposure to air, forming a dense solution, once called *oil of tartar per deliquium.* Its taste is alkaline, and it renders vegetable blues green.

The solution of carbonate of potassa will be found to have a much milder taste than the pure alkali, and no longer to destroy the texture of woollen cloth; but it still turns to green the blue infusion of vegetables.

Sources of potassa.

1477. The great consumption of this article in various manufactures is exclusively supplied by the combustion of vegetables, and consequently its production is almost limited to those countries which require clearing of timber, or where there are vast natural forests. The English market is chiefly supplied from North America. If any vegetable growing in a soil not impregnated with sea-salt be burned, its ashes will be found alkaline from the presence of carbonate of potassa. If the ashes be submitted to heat, so as to burn away the carbonaceous matter entirely, they become a white mass generally termed *pearl-ash.**

Bicarbonate, Formed.

1478. *Bi-carbonate of Potassa*, $KO+2CO^2$, 47.15 1 eq. base + 44.24 2 eq. acid = 91.39 eq.; in crystals with 9 or 1 eq. water = 100.39. This salt is formed by passing a current of $\ddot{C}$ into a solution of the carbonate; or by evaporating a mixture of the carbonates of ammonia and potassa, the ammonia being dissipated in a pure state. By slow evaporation, the bicarbonate is deposited from the liquid in hydrated prisms with eight sides, terminated with dihedral summits.

Properties.

1479. This salt is milder than the carbonate. It does not deliquesce on exposure. It requires 4 times its weight of water at 60° for solution. At a low red heat it is converted into the carbonate.

Carbonate of soda. Sources of.

1480. *Carbonate of Soda*, $NaO+CO^2$ 31.3 1 eq. base + 22.12 1 eq. acid = 53.42 eq.; in crystals with 90 or 10 eq. water =143.42, with 63 or 7 eq. water = 116.42 eq., is chiefly obtained by the combustion of marine plants, the ashes of which afford, by lixiviation, the impure alkali called *soda*. Two kinds of rough soda occur in the market: *barilla* and *kelp*; besides which, some *native carbonate of soda* is also imported. Barilla is the semifused ash of the *salsola*

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* For ascertaining the value of different samples of pearlash, that is to determine the quantity of real carbonate of potassa in a given weight of impure carbonate, see (510.)

soda, which is largely cultivated upon the Mediterranean shore of Spain, in the vicinity of Alicant. Kelp consists of the ashes of sea-weeds, which are collected upon the sea coast and burned in kilns, or merely in excavations made in the ground and surrounded by stones. It seldom contains more than 5 per cent. of carbonated alkali, and about 24 tons of sea-weed are required to produce one ton of kelp. The best produce is from the hardest *fuci*, such as the *serratus*, *digitatus*, *nodosus*, and *vesiculosus*.* The rough alkali is contaminated by common salt, and impurities, from which it may be separated by solution in a small portion of water, filtrating the solution, and evaporating it at a low heat; the common salt may be skimmed off as its crystals form upon the surface.†

Crystals.

Solubility.

1481. It crystallizes in rhombic octohedrons, the acute angles generally truncated. The crystals effloresce, and when heated dissolve in their water of crystallization. By continued heat they are rendered anhydrous without loss of carbonic acid. They dissolve in about two parts of cold, and rather less than their weight of boiling water; the solution being alkaline. The crystals usually contain 10 eq. of water.‡

Bicarbonate.

1482. *Bicarbonate of Soda.* $NaO+2CO^2$, 31.3 1 eq. base + 44.24 2 eq. acid = 75.54; in crystals with 9 or 1 eq. water = 84.54 eq. This salt is made by the same processes as bicarbonate of potassa, and is deposited in hydrated crystalline grains by evaporation. It is milder than the carbonate and less soluble, requiring about ten times its weight of water at 60° for solution. It is converted into the carbonate by a red heat.

Sesquicarbonate.

1483. *Sesquicarbonate*, $2NaO.\,3CO^2+4HO$, occurs native in Africa, on the banks of soda lakes, and is called *Trona*.§

Carbonate of ammonia.

1484. *Carbonate of Ammonia.* H^3N+C, 17.15 1 eq. base + 22.12 1 eq. acid = 39.27 eq. The only method of obtaining the substance so called is by mixing perfectly dry $\ddot{C}$ and NH^3. In what-

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* McCulloch's *Western Islands*, i. 122.

† The crystals of soda-carb. as well as the soda-ash of G. B. are made by the decomposition of sea-salt; for a description of the process see Ure's *Dict. Arts and Man.* 1151.

‡ The purity of barilla or other carbonates of soda, may be ascertained by the alkalimeter (510). In the analysis of barilla and kelp, to ascertain the relative proportion of soda, it may be useful to know that 100 parts of dilute nitric acid, specific gravity 1.36, will saturate 60 parts of dry carbonate of soda, which are equivalent to about 29 of pure soda.

§ Phillips in *Jour. Sci.* vii.

Soda water. Soda water is a solution of soda highly charged with carbonic acid gas, whereby it acquires a sparkling appearance, and agreeable pungent taste, and certain medicinal powers. For a plan and description of the apparatus see Ure's *Dict. Arts and Man.* 1156.

Seltzer water. To make seltzer water, for each 12 lbs. Troy take 55 grs. carb. soda, 17 carb. lime, 18 carb. magnesia, 3½ subphosphate alumina, 3 chloride potassium, 155 chlor. sodium, and 3 of finely precipitated silica, this solution is charged with 353 cubic inches of carb. acid gas. *Ibid*, 1155.

Labarraque's liquid. The *disinfecting soda liquid* of Labarraque is prepared by the following process. Dissolve 2800 grains of crystallized carbonate of soda in 1.28 pints of water, having placed the solution in a Woulfe's apparatus, pass through it a current of chlorine gas evolved from a mixture of 957 grains of salt, and 750 of oxide of manganese, acted upon by 967 grains of oil of vitriol previously diluted with 750 grains of water. The operation should be conducted slowly.

For most purposes the common *bleaching powder* sprinkled about or dissolved in water is quite as effectual and more economical, but for medical uses the preparation should be more nicely attended to. See *Quart. Jour. of Sci.*, &c. N. S. i. 236—ii. 460—iii. 84; and *Amer. Jour.* &c. xiv. 251.

ever proportion the two gases be mixed, they unite only in the ratio of 1 vol. of the former to 2 of the latter, and condense into a white powder. It is decomposed by water into ammonia and the sesquicarbonate.

Bicarbonate of oxide ammonium.

1485. ***Bicarbonate of Oxide of Ammonium*** is formed by transmitting a current of $\ddot{C}$ through a solution of the common carbonate of ammonia. On evaporating the liquid by a gentle heat, the bicarbonate is deposited in small prisms of the right rhombic system, having no smell, and very little taste. It contains twice as much $\ddot{C}$ as the carbonate. It cannot exist without the presence of water, of which it contains 22.7 per cent.,* or 2 eq. It may therefore be considered as carbonate of basic water and carbonate of oxide of ammonium, or $HO.CO^2+H^4NO.CO^2$.

Sesquicarbonate of oxide of ammonium.

1486. ***Sesquicarbonate of Oxide of Ammonium.*** The common carbonate of ammonia of the shops, *Sub-carbonas Ammoniæ* of the Pharmacop., is different from both these compounds. It is prepared by heating a mixture of one part of hydrochlorate of ammonia with one part and a half of carbonate of lime, carefully dried. Double decomposition ensues during the process; chloride of calcium remains in the retort, and hydrated sesquicarbonate of ammonia is sublimed. The carbonic acid and ammonia are, indeed, in proper proportion in the mixture for forming the real carbonate: but, owing to the presence of water, generated by the combination of the oxygen of the lime with the hydrogen of the hydrochloric acid, part of the ammonia is disengaged in a free state.

1487. The salt thus formed consists of 34.3 parts or 2 eq of ammonia, 66.36 parts or 3 eq. of carbonic acid, and 18 parts or 2 eq. of water. It is, therefore, anhydrous sesquicarbonate of oxide of ammonium, or $2H^4NO+3CO^2$. When recently prepared, it is hard, compact, translucent, of a crystalline texture, and pungent ammoniacal odour; but if exposed to the air, it loses weight rapidly from the escape of pure ammonia, and becomes an opaque brittle mass, which is the bicarbonate.

Carbonate of baryta.

1488. ***Carbonate of Baryta,*** $BaO+CO^2$, 76.7 1 eq. base + 22.12 1 eq. acid = 98.82 eq., occurs abundantly in the lead mines of the north of England, where it was discovered by Withering, and has hence received the name of ***Witherite.*** It may be prepared by way of double decomposition, by mixing a soluble salt of baryta with any of the alkaline carbonates or bicarbonates. It is anhydrous, exceedingly insoluble in distilled water, requiring 4300 times its weight of water at 60°, and 2300 of boiling water for solution; but when recently precipitated, it is dissolved much more freely by a solution of carbonic acid. It is higly poisonous.

Carbonate of strontia.

1489. ***Carbonate of Strontia,*** $SrO+CO^2$, 51.8 1 eq. base + 22.12 1 eq. acid = 73.92 eq., occurs native at Strontian in Argyleshire, and is known by the name of ***Strontianite;*** it may be prepared in the same manner as carbonate of baryta. It is anhydrous, and very insoluble in pure water, but is dissolved by an excess of carbonic acid.

Carbonate of lime.

1490. ***Carbonate of Lime.*** $CaO+CO^2$, 28.5 1 eq. base + 22.12, acid = 50.62 eq. This salt is a very abundant natural production

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* Berzelius.

and occurs under a great variety of forms, such as common limestone, chalk, marble, and Iceland spar, and in regular anhydrous crystals, the density of which is 2.7. Though sparingly soluble in pure water, it is dissolved by carbonic acid in excess; and hence the spring-water of limestone districts always contains carbonate of lime, which is deposited when the water is boiled.

Carbonate.

1491. Lime has a strong attraction for *carbonic acid*, but not when perfectly dry; for if a piece of dry quicklime be passed into a jar of carbonic acid gas over mercury, no absorption whatever ensues.

Exp.

But if a bottle, filled with carb. acid gas, be inverted over a mixture of lime and water of the consistence of cream, a rapid absorption will be observed, especially if the bottle be agitated; or if a jar or bottle, filled with carbonic acid, be brought over a vessel of lime water, on agitating the vessel, a rapid diminution will ensue, and the lime water will become milky.

Action of air.

1492. When a shallow vessel of lime water is exposed to the air, a white crust forms on the surface, and this, if broken, falls to the bottom, and is succeeded by another till the whole of the lime is precipitated from the solution. This is owing to the absorption of carbonic acid gas from the air by the lime, which is thus rendered insoluble in water. Dry lime, also, when exposed to the atmosphere, first acquires moisture, and having become a hydrate, next absorbs carbonic acid. In a sufficient space of time, all the characters distinguishing it as lime disappear, and it acquires the property of effervescing with acids. The strong affinity of lime for carbonic acid enables it to take this acid from other substances. Thus carbonates of alkalies are decomposed by lime. H. I. 687.

Carbonic acid expelled by heat.

1493. The carbonic acid existing in carbonate of lime is expelled by a strong red heat. If distilled in an earthen retort, carbonic acid gas is obtained, and lime remains in the retort in a pure or caustic state. By this process carbonate of lime loses about 45 per cent.

Carbonate of magnesia.

1494. *Carbonate of Magnesia.* $MgO+CO^2$, 20.7 1 eq. base $+$ 22.12 1 eq. acid $=$ 42.82 eq.; in crystals, with 27 or 3 eq. water $=$ 69.82. It is met with occasionally in rhombohedral crystals, and in a pulverulent earthy state, but more commonly as a compact mineral of an earthy fracture called *magnesite*. It is abundant in the East Indies, of a snow-white colour, of density 2.56, and so hard that it strikes fire with steel.* It is obtained in minute transparent hexagonal prisms with three eq. of water, when a solution of bicarbonate of magnesia evaporates spontaneously in an open vessel. The crystals lose their water and become opaque by a very gentle heat, and even in a dry air at 60°. By cold water they are decomposed, yielding a soluble bicarbonate, and an insoluble white compound of hydrate and carbonate of magnesia; and hot water produces the same change with disengagement of carbonic acid, without dissolving any magnesia.†

1495. When carbonate of potassa is added in excess to a hot solution of sulphate of magnesia, a white precipitate falls, which after being well washed has been long considered as pure carbonate of magnesia; but Berzelius has shown that it consists of the following ingredients:—

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* *Ann. of Philos.* xvii. 252.

† Berzelius.

Magnesia	44.75	82.8 or 4 eq.	Probable formula is $MgO.4HO+3MgOCO^2$
Carbonic acid	35.77	66.36 or 3 eq.	
Water	19.48	36 or 4 eq.	
	100.00	185.16 or 1 eq.	

This compound is said to require 2493 parts of cold, and 9000 of hot water for solution. It is freely dissolved by a solution of carbonic acid, bicarbonate of magnesia being generated; but on allowing the solution to evaporate spontaneously, carbonic acid is given off, and crystals of the hydrated carbonate above mentioned are obtained.

Carbonate of protoxide of iron.

1496. *Carbonate of Protoxide of Iron.* $FeO+CO^2$, 36 1 eq. base + 22.12 1 eq. acid = 58.12 eq. Carbonic acid, with the protoxide of iron, constitutes a salt which is an abundant natural production, occurring sometimes massive, and at other times crystallized in rhombohedrons. This protocarbonate is contained also in most of the chalybeate mineral waters, being held in solution by free carbonic acid; and it may be formed by mixing an alkaline carbonate with the sulphate of protoxide of iron. When prepared by precipitation it attracts oxygen rapidly from the atmosphere, and the protoxide of iron, passing into the state of sesquioxide, parts with carbonic acid. For this reason, the carbonate of iron of the Pharmacop. is of a red colour, and consists chiefly of the sesquioxide.

Dicarbonate of protoxide of copper.

1497. *Dicarbonate of Protoxide of Copper.* $2CuO+CO^2$, 79.2 2 eq. base + 22.12 1 eq. acid = 101.32 eq.* It occurs as a hydrate in the beautiful green mineral called *malachite;* and the same compound, as a green powder, the *mineral green* of painters, may be obtained by precipitation from a hot solution of sulphate of protoxide of copper, by carbonate of soda or potassa. When obtained from a cold solution, it falls as a bulky hydrate of a greenish-blue colour, which contains more water than the green precipitate. By careful drying its water may be expelled. When the hydrate is boiled for a long time in water, it loses both carbonic acid and combined water, and the colour changes to brown. The rust of copper, prepared by exposing metallic copper to air and moisture, is a hydrated dicarbonate.

The blue pigment called *verditer,* prepared by decomposing nitrate of protoxide of copper with chalk, has a similar composition.†

Carbonate of protoxide of lead.

1498. *Carbonate of Protoxide of Lead.* 111.6 1 eq. base + 22.12 1 eq. acid = 133.72 eq. This salt, which is the *white lead* or *ceruse* of painters, occurs native in white prismatic crystals derived from a right rhombic prism, the sp. gr. of which is 6.72. It is obtained as a white pulverulent precipitate by mixing solutions of an alkaline carbonate with acetate of protoxide of lead; and it is prepared as an article of commerce from the subacetate by a current of

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* In Malachite with 9 or 1 eq. water eq. 110.32.

Refiner's verditer.

† There is a fine blue cupreous preparation, called *Refiner's Verditer,* principally made by silver refiners. It consists, according to Phillips, of three proportionals of oxide, four of carbonic acid, and two of water. (*Quart. Jour. of Sci.* iv. 277.)

According to Pelletier, a good verditer may be obtained as follows: add a sufficient quantity of lime to nitrate of copper to throw down the oxide; it gives a greenish precipitate that is to be washed and nearly dried upon a strainer; then incorporate it with from eight to ten per cent. of fresh lime, which will give it a blue colour, and dry it carefully. For processes see Ure's *Dict. Arts. and Man.* 1274.

carbonic acid; by exposing metallic lead in minute division to air and moisture; and by the action on thin sheets of lead of the vapour of vinegar, by which the metal is both oxidized and converted into a carbonate.

Double carbonates.

1499. *Double Carbonates.* One of the most remarkable of these is the double carbonate of lime and magnesia,* which constitutes the minerals called bitter-spar, pearl-spar, and Dolomite. The two former occur in rhombohedrons of nearly the same dimensions as carbonate of lime. Some specimens consist of the two carbonates in the ratio of their equivalents; but this ratio is very variable, since isomorphous substances crystallize together in all proportions. T. & L. 706.

SECTION II. *Order 2d. Hydro-Salts.*

Hydro-salts.

This section includes those salts, the acid or base of which contains hydrogen. The salts formerly called *muriates* or *hydrochlorates* of metallic oxides, have been already described as chlorides of metals; as also those of hydriodic and other hydracids; the neutralizing power of the acids being considered as due to the direct union of the chlorine, iodine, &c., with the metal itself. Some of these compounds may be more properly placed in the fourth section, as in them the hydracid acts rather as a base or electro-positive ingredient, than as an acid or electro-negative substance.†

Ammoniacal salts.

1500. The compounds of ammonia with the hydracids may be described as chlorides of the hypothetical radical ammonium.

1501. *Ammoniacal Salts* are recognized by the addition of pure potassa or lime, when the odour of ammonia may be perceived. Those which contain a volatile acid may in general be sublimed without decomposition; but the ammonia is expelled by heat from those acids which are much more fixed than itself.

Hydrochlorate of ammonia.

1502. *Hydrochlorate of Ammonia,* H^3N+HCl, 17.15 1 eq. base + 36.42 1 eq. acid = 53.57. This salt, *sal ammoniac* of commerce, was formerly imported from Egypt, where it is procured by sublimation from the soot of camel's dung; but it is now manufactured by several processes. The most usual is to decompose sulphate of ammonia by the chloride either of sodium or magnesium, when double decomposition ensues, giving rise in both cases to hydrochlorate of ammonia, and to sulphate of soda when chloride of sodium is used, and to sulphate of magnesia when chloride of magnesium is employed. The sal ammoniac is afterwards obtained in a pure state by sublimation. The method now generally used for obtaining sulphate of oxide of ammonium is to decompose with sulphuric acid the hydrosulphate and hydrocyanate of ammonia which is collected in the manufacture of coal-gas; but it may also be procured either by lixiviating the soot of coal, which contains sulphate of oxide of ammonium in considerable quantity, or by digesting with gypsum impure sesquicarbonate of oxide of ammonium, carbonate of ammonia, procured from the destructive distillation

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* $MgOCO^2+CaOCO^2$. 50.62 1 eq. carb. lime + 42.82 1 eq. carb. mag. = 93.44 eq.

† See Kane's observations in Dublin *Jour. of Sci.* i. 265.

of bones and other animal substances, so as to form an insoluble carbonate of lime and a soluble sulphate of oxide of ammonium.

Properties. 1503. Hydrochlorate of ammonia has a pungent saline taste, a density of 1.45, and is tough and difficult to be pulverized. It is soluble in alcohol and water, requiring for solution three times its weight of water at 60°, and an equal weight at 212°. It usually crystallizes from its solution in feathery crystals, but sometimes in cubes or octohedrons. At a temperature below that of ignition it sublimes without fusion or decomposition, and condenses on cool surfaces as anhydrous salt, which absorbs humidity in a damp atmosphere, but is not deliquescent. In commerce it usually occurs as procured by sublimation, in white cakes, hard and somewhat elastic.

Native. 1504. *Native Hydrochlorate of Ammonia*, occurs massive and crystallized, in the vicinity of volcanoes, and in the cracks and pores of lava, near their craters. An efflorescence of native sal ammoniac is sometimes seen upon pit-coal. Its colour varies from the admixture of foreign matter, and it is frequently yellow from the presence of sulphur. It is said that considerable quantities of native sal-ammoniac are also found in the country of Bucharia, where it occurs with sulphur in rocks of indurated clay. **Origin of the name.** The ancients, according to Pliny, called this salt *ammoniac*, because it was found near the temple of Jupiter Ammon, in Africa.

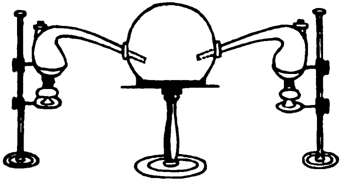

Fig. 186.

Formation illustrated. 1505. This salt may be produced directly by means of the apparatus (Fig. 186.) Into one of the retorts a small quantity of hydrochloric acid or the materials from which the acid gas is usually obtained (628,) is introduced; and into the other liquid ammonia (or the mixture of lime and hydrochlorate of ammonia (729.) The evolved gases passing into the globe unite producing dense clouds of hydrochlorate of ammonia which concrete upon the inner surface.

We may also form it by mixing over mercury, equal measures of ammoniacal gas, and hydrochloric acid gas, which are entirely condensed into a white solid.

Uses, 1506. Sal-ammoniac is used in the arts for a variety of purposes, especially in certain metallurgic operations. It is used in tinning, to prevent the oxidation of the surface of copper; and small quantities are used by dyers. Dissolved in nitric acid, it forms the ***aqua regia*** of commerce, used for dissolving gold, instead of a mixture of nitric and hydrochloric acids (637.)*

Hydrofluate of ammonia. 1507. *Hydrofluate of Ammonia*, H^3N+HF, 36.83 eq. It is prepared by mixing 1 part of sal ammoniac with 2¼ of fluoride of sodium, both dry and in fine powder, gently heating the mixture in a platinum vessel, and receiving the sublimed salt in a second platinum vessel, the temperature of which is not allowed to exceed 212°.

Hydrosulphate of ammonia. 1508. *Hydrosulphate of Ammonia*, H^3N+HS, 17.15 1 eq. base + 17.1 1 eq. acid = 34.25. This salt, also called hydrosulphuret of ammonia, and formerly the *fuming liquor of Boyle*, is prepared by heating a mixture of one part of sulphur, two of sal ammoniac,

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[*] *Hydriodate*, H^3N+HI, 17.15 base + 127.3 1 eq. acid = 144.45 eq., and *Hydrobromate of ammonia*, may be formed by similar processes.

and two of unslaked lime. The volatile products are ammonia and hydrosulphate of ammonia; and the fixed residue consists of sulphate of lime with chloride and sulphuret of calcium. The hydrosulphuric acid is formed from the hydrogen of hydrochloric acid uniting with sulphur, and the oxygen of the sulphuric acid is derived from decomposed lime, the calcium of which is divided between the chlorine of the hydrochloric acid and the sulphur. Hydrosulphate of ammonia may also be formed by the direct union of its constituent gases, and if they are mixed in a glass globe kept cool by ice, the salt is deposited in crystals. It is much used as a reagent, and for this purpose is usually prepared by saturating a solution of ammonia with hydrosulphuric acid gas.* Use.

1509. *Salts of Phosphuretted Hydrogen.* Phosphuretted hydrogen is a feeble alkaline base, which combines with some of the hydracids.

The salt best known is the hydriodate of phosphuretted hydrogen, first noticed by Gay-Lussac, which is formed of 127.3 parts or 1 eq. of acid and 34.4 parts or 1 eq. of base, and crystallizes in cubes.

SECTION III. *Order 3d. Sulphur-Salts.*

Sulphur-salts. The compounds described in this section are double sulphurets, just as the oxy-salts in general are double oxides. Their resemblance in composition to salts is perfect. The principal *sulphur-bases* are the protosulphurets of potassium, sodium, lithium, barium, strontium, calcium, and magnesium, and hydrosulphate of ammonia; and the principal *sulphur-acids* are the sulphurets of arsenic, antimony, tungsten, molybdenum, tellurium, tin, and gold, together with hydrosulphuric acid, bisulphuret of carbon, and sulphuret of selenium. The sulphur-salts with two metals are so constituted, that if the sulphur in each were replaced by an equivalent quantity of oxygen, an oxy-salt would result. The analogy between oxy-salts and sulphur-salts is rendered still closer by the circumstance that hydrosulphuric and hydrosulphocyanic acids have the characteristic properties of acidity, and unite both with ammonia and with sulphur-bases.

Division of sulphur-salts. The sulphur-salts may be divided into families, characterized by

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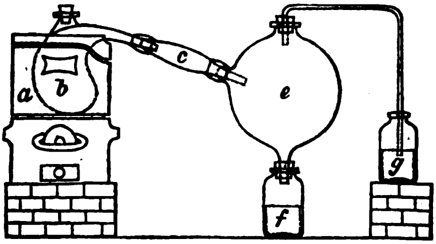
Fig. 187.



* Fig. 187, represents the disposition of the apparatus for this process: *a*, a small furnace; *b*, a tubulated earthern retort containing the above materials; *c*, an adapting tube; *e*, a glass balloon for condensing the vapour; *f*, a receiver; *g*, a bottle of water, into which the glass tube, issuing from the upper part of the receiver, *e*, is made to dip about half an inch. The product in the bottle *f*, may be mixed with the water in *g*, and the whole used for washing out the receiver *e*. It is retained in the pharmacopæia, and may be extemporaneously made by passing hydrosulphuric acid gas from an oil flask with a bent tube into aqua ammoniæ kept cold.

containing the same sulphur-acid. For the purpose of indicating that such salts are double sulphurets, as well as to distinguish them readily from other kinds of salts, the generic name of each family may be constructed from the sulphur-acid terminated with sulphuret. Thus the salts which contain persulphuret of arsenic or hydrosulphuric acid as the sulphur-acid are termed *arsenio-sulphurets* and *hydro-sulphurets;* and a salt composed of each of these sulphur-acids with sulphuret of potassium is termed *arsenio-sulphuret* and *hydro-sulphuret* of sulphuret of potassium. For the sake of brevity the metal of the base may alone be expressed, it being understood that the positive metal in a sulphur-salt enters as a protosulphuret into the compound.

Hydro-sulphurets. 1510. *Hydro-Sulphurets.* The sulphur-salts contained in this group have hydro-sulphuric acid for their electro-negative ingredient. Most of them which have been studied are soluble in water, and may be obtained in crystals by evaporation. They are decomposed by exposure to the air, yielding at first bisulphurets of the metal, and then a hyposulphite. By acids the hydrosulphuric acid is expelled with effervescence.

Hydro-sulphuret of potassium. 1511. *Hydro-sulphuret of Potassium,* $KS+HS$, 55.25 1 eq. sulphur-base + 17.1 1 eq. sulphur acid = 72.35 eq. This salt is obtained in the anhydrous state by introducing anhydrous carbonate of potassa into a tubulated retort, transmitting through it a current of hydrosulphuric acid gas, and heating the salt to low redness.

Process. The same salt is prepared in the moist way by introducing a solution of pure potassa, free from carbonic acid, into a tubulated retort, expelling atmospheric air by a current of hydrogen gas, and then saturating the solution with hydrosulphuric acid. At first the potassa, as in the former process, interchanges elements with the gas, yielding water and protosulphuret of potassium; after which the protosulphuret unites with hydrosulphuric acid. The solution should be evaporated in the retort to the consistence of syrup, a current of hydrogen gas being transmitted through the apparatus the whole time; and on cooling the salt crystallizes in large four or six sided prisms, which are colourless if air was perfectly excluded.

Hydro-sulphuret of barium. 1512. *Hydrosulphuret of Barium,* $BaS+HS$, 84.8 1 eq. sulphur base, + 17.1 acid = 101.9 eq. It is prepared by the action of hydrosulphuric acid on a solution of baryta with the precautions already mentioned for excluding atmospheric air, and crystallizes by evaporation in four-sided prisms, which are very soluble in water.*

Carbo-sulphurets. 1513. *Carbo-sulphurets.* The acid of these sulphur-salts is bisulphuret of carbon.

Carbo-sulphuret of potassium. 1514. *Carbo-sulphuret of Potassium,* $KS+CS^2$, 55.25 sulphur + 38.32 sulphur acid = 93.57 eq. On agitating bisulphuret of carbon with a strong alcoholic solution of protosulphuret of potassium, the liquid when set at rest separates into three layers, the lowest of which is carbo-sulphuret of potassium, and is of the consistence of syrup. Another process is to digest bisulphuret of carbon at 86° in a corked bottle full of a strong aqueous solution of protosulphuret of potassium, until the latter is saturated. A concentrated solution of this salt is of a deep orange, almost red colour;

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* For other hydrosulphurets and carbo-sulphurets see Turner and Liebig's *Elem.* 718.

and when evaporated at 86° to the consistence of syrup, a deliquescent yellow crystalline salt is deposited, which is sparingly soluble in alcohol.

Carbo-sulphuret of hydrosulphate of ammonia.

1515. *Carbo-sulphuret of Hydrosulphate of Ammonia,* $(H^3N + HS) + CS^2$, 34.25 1 eq. sulphur + 38.32 1 eq. sulphur acid = 72.57 eq. This salt is prepared by filling a bottle with 10 measures of nearly absolute alcohol saturated with ammoniacal gas and 1 measure of bisulphuret of carbon, and inserting a tight cork. As soon as the liquid has acquired a yellowish brown colour, the bottle is plunged into ice-cold water, when the carbo-sulphuret is deposited either in yellow penniform crystals or as a crystalline powder. The whole is thrown upon a linen filter, and the salt after being washed first with absolute alcohol and then with ether, is dried by pressure within folds of bibulous paper.

Process.

Volatile.

1516. This salt is very volatile and can only be preserved in well corked bottles. Exposed to the air it absorbs humidity and acquires a red colour.

Arsenio-sulphurets.

1517. *Arsenio-sulphurets.* Berzelius finds that each of the three sulphurets of arsenic (page 276) is capable of acting as a sulphur-acid, giving rise to three distinct families of sulphur-salts, distinguishable by the terms *arsenio-persulphurets, arsenio-sesquisulphurets,* and *arsenio-protosulphurets.*

1518. *Persulphuret of Arsenic,* is a very powerful sulphur-acid, violently displacing hydrosulphuric acid from its combinations with sulphur-bases, even at common temperatures; and when digested with earthy or alkaline carbonates, it expels carbonic acid. The salts of this sulphur-acid may be prepared by several methods.*

Characters.

1519. Most of the arsenio-persulphurets of the second class of metals are insoluble; but those of the metals of the alkalies and alkaline earths are very soluble in water, have a lemon-yellow colour in the anhydrous state, and are colourless when combined with water of crystallization or in solution. When exposed to heat in close vessels they give off sulphur, and an arsenio-sesquisulphuret is generated. In the solid state they are very permanent in the air, and even in solution oxidation takes place with great slowness. When decomposed by an acid, persulphuret of arsenic subsides, hydrosulphuric acid gas escapes, and a salt of the alkali is generated.

The salts in which sesquisulphuret of arsenic acts as an acid, resemble those of the persulphuret both in their general characters and mode of formation.

Molybdo-sulphurets.

1520. *Molybdo-Sulphurets.* The electro-negative ingredient of these salts is the tersulphuret of molybdenum, and the most remarkable of them is the molybdo-sulphuret of potassium, which is readily formed by decomposing with hydrosulphuric acid gas a rather strong solution of molybdate of potassa. If no iron is present, the liquid acquires a beautiful red colour, like the solution of bichromate of potassa, and on evaporation prismatic crystals with four and eight sides are deposited. Berzelius describes this compound as one of the most beautiful which chemistry can produce; the crystals, by transmitted light, are ruby-red, and their surfaces, while moist with

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* For which see Turner and Liebig's *Elem.* 716.

the solution which yielded them, shine like the wings of certain insects with a metallic lustre of a rich green tint. The crystals are anhydrous, dissolve readily in water, but are insoluble in alcohol. On the addition of sulphuric or any of the stronger acids, a salt of potassa is generated with escape of hydrosulphuric acid, and precipitation of tersulphuret of molybdenum.

Antimonio-sulphurets. 1521. *Antimonio-Sulphurets.* When two parts of carbonate of potassa are intimately mixed with four of sesquisulphuret of antimony and one part of sulphur, and the mixture is fused, an antimonio-persulphuret of potassium is generated. On digesting in water, a subantimonio-persulphuret is dissolved, and is deposited by gentle evaporation in large colourless tetrahedrons, which become yellow on exposure to the air.

Tungsto-sulphurets. 1522. *Tungsto-Sulphurets.* The best known of these salts is that of potassium, in which tersulphuret of tungsten is combined with protosulphuret of potassium. It is formed when a solution of tungstate of potassa is decomposed by hydrosulphuric acid, and crystallizes by evaporation in flat quadrilateral prisms, which are anhydrous, and are of a pale red colour.

Section IV. *Order 4th. Haloid Salts.*

Haloid salts. 1523. Under this order are included substances composed like the preceding salts of two bi-elementary compounds, one or both of which are analogous in composition to sea-salt. The principal groups consist of double chlorides, double iodides, and double fluorides. In these the haloid bases belong usually to the electro-positive metals, and the haloid acids to the metals which are electro-negative. The same principles of nomenclature are applied to them as to the sulphur salts.

Hydrargo-chlorides. 1524. *Hydrargo-chlorides.* The haloid acid of this family is bichloride of mercury, which reddens litmus paper, and loses the property when a haloid base is present, thus bearing a close analogy to ordinary acids. They are obtained by mixing the ingredients in the ratio for combining, and setting aside the solution to crystallize. The ammoniacal salt has long been known under the name of *salt of alembroth.*

Auro-chlorides. 1525. *Auro-chlorides.* The electro-negative ingredient of these salts is the terchloride of gold. They are prepared by mixing the chlorides in atomic proportions and setting aside the solution to crystallize. Most of them have an orange or yellow colour, and consist of single equivalents of their constituent chlorides.

Platino-chlorides. 1526. *Platino-chlorides.* Both the protochloride and bichloride of platinum act as haloid acids. The platino-protochloride of potassium is made by mixing chloride of potassium with a solution of protochloride of platinum in hydrochloric acid. It crystallizes in red, anhydrous prisms and consists of single equivalents of its constituent chlorides.

1527. The *Platino-bichloride of Hydrochlorate of Ammonia* falls as a lemon-yellow powder, when sal ammoniac is mixed with a strong solution of bichloride of platinum.

Palladio-chlorides. 1528. *Palladio-chlorides* are those in which the chlorides of palladium act as haloid acids, combining with many of the metallic chlorides, when their respective solutions are mixed and evaporated.

Rhodio-chlorides.

1529. *Rhodio-chlorides* are formed when sesquichloride of rhodium combines with the chlorides of potassium and sodium.

The chlorides of iridium and osmium act as haloid acids and produce *iridio-chlorides* and *osmio-chlorides.*

Oxy-chlorides.

1530. *Oxy-chlorides.* Chemists are acquainted with a considerable number of compounds in which a metallic oxide is united with a chloride either of the same metal, which is the most frequent, or of some other metal. These compounds are commonly termed *submuriates*, on the supposition that they consist of hydrochloric acid combined with two or more eq. of an oxide.

Oxy-chlorides of iron.

1531. *Oxy-chlorides of Iron.* When the crystallized protochloride of iron is heated without exposure to the air, the last portions of its water exchange elements with part of the chloride of iron, yielding hydrochloric acid, which is evolved, and protoxide of iron. On raising the heat so as to expel the pure chloride of iron, a deep green oxy-chloride in scaly crystals remains.*

1532. The ochreous matter which falls when a solution of the protochloride of iron is exposed to the air, is hydrated sesquioxide of iron combined with some sesquichloride. A similar hydrate is obtained by mixing with a solution of the sesquichloride of iron a quantity of alkali insufficient for complete decomposition. When a solution of the sesquichloride is evaporated to dryness without exposure to the air, the last portions of water exchange elements with the sesquichloride, hydrochloric acid is disengaged, and after subliming the pure anhydrous sesquichloride, a compound in large, brown, shining laminæ is left, which consists of sesquioxide and sesquichloride of iron.†

Oxy-chlorides of copper.

1533. *Oxy-chloride of Copper* falls as a green hydrate when potassa is added to a solution of chloride of copper insufficient for its complete decomposition. When its water is expelled it becomes of a liver-brown colour. According to Berzelius it consists of 1 eq. chloride and 3 eq. oxide of copper.

Brunswick green.

1534. It is used as a pigment under the name of *Brunswick green*, being prepared for that purpose by exposing metallic copper to hydrochloric acid or a solution of sal-ammoniac. The same compound is generated during the corrosion of copper in sea-water.

Oxy-chloride of lead.
Patent yellow.

1535. *Oxy-chloride of Lead* is prepared by adding pure ammonia to a hot solution of chloride of lead. Another is known under the name of *mineral* or *patent* yellow, and is prepared by the action of moist sea-salt on litharge, by which means portions of the protoxide and sea-salt exchange elements, yielding soda and chloride of lead. After washing away the alkali, the mixed oxide and chloride are dried and fused.

Chlorides with ammonia.

1536. *Chlorides with Ammonia.* The perchlorides of tin and a few other metals absorb ammonia at common temperatures, and most of the other chlorides absorb it when gently warmed. Calomel absorbs half an equiv. and forms a black compound, but on exposure to the air the ammonia flies off, and pure white calomel remains.

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* Berzelius.

† Ibid.

Corrosive sublimate, by the aid of heat, rapidly absorbs half an eq. and forms a white compound which is insoluble in water, and bears a considerable temperature without decomposition; the *white precipitate* of pharmacy is probably analogous in nature, though the ratio of its ingredients is different.

1537. Most of these compounds lose their ammonia by mere exposure to the air, and it is expelled from nearly all of them by a very moderate heat.

Chlorides with phosphuretted hydrogen.

1538. *Chlorides with phosphuretted hydrogen.* Rose has traced a remarkable analogy between ammonia and phosphuretted hydrogen, especially in the compounds which they form with metallic chlorides. The phosphuretted hydrogen is readily displaced by water, or a solution of ammonia, from the compounds of phosphuretted hydrogen and the perchlorides of tin, titanium, antimony, iron, and alumina, all of which correspond to ammoniacal chlorides of similar composition.

Double iodides.

1539. *Double Iodides.* These compounds have not yet been closely studied; but there is no doubt that the iodides are capable of forming with each other an extensive series of compounds. A variety of double iodides have been described by Boullay, and among them a compound of biniodide of mercury and hydriodic acid.* In general the double hydrargo-biniodides contain single equivalents of the respective iodides. Liebig obtained a compound of the bichloride and biniodide of mercury, consisting of two eq. of the former to one eq. of the latter, as indicated by the formula, $HgI^2+2HgCl^2$.

Several compounds of biniodide of platinum with other iodides have been studied by Kane and Lassaigne.†

Platino-biniodide of potassium.

1540. *Platino-biniodide of Potassium,* is prepared by digesting an excess of biniodide of platinum in a rather concentrated solution of iodide of potassium. By spontaneous evaporation it crystallizes in small rectangular plates surmounted sometimes with a four-sided pyramid, which are anhydrous, unchanged in the air, and insoluble in alcohol. The colour of the crystals is black with a metallic lustre, and they yield a deep claret-coloured solution with water. The biniodide of platinum appears to combine also with the iodide of platinum; but the compound has only been obtained in solution.

Platino-biniodide of hydrogen.

1541. *Platino-biniodide of Hydrogen.* This compound consists of hydriodic acid and biniodide of platinum, in which the former is regarded as the electro-positive element. It is prepared by acting on biniodide of platinum with a cold dilute solution of hydriodic acid, which gradually acquires a deep claret colour, and by evaporation under a bell-jar with quicklime, deposits black acicular crystals. The crystals become moist by exposure to the air.

Oxy-iodides.

1542. *Oxy-iodides.* The principal oxy-iodides at present known to chemists are those formed by the oxide and iodide of lead. When iodide of potassium is mixed with acetate of oxide of lead in excess, the yellow iodide at first formed combines with oxide of lead and acquires a white colour; and the same compound is obtained directly by employing a subacetate. Denot finds that there are three oxy-

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* *Ann. de Chem. et de Phys.* xxxiv.

† *Dublin Jour. of Sci.* i. 304, and *Ann. de Chim. et de Phys.* li. 125.

iodides, in which 1 eq. of iodide of lead is united with one, two, and five equivalents of oxide of lead.

Double fluorides.

1543. *Double Fluorides.* The researches of Berzelius have led to the formation of several extensive families of double fluorides, in which the fluorides of boron, silicon, titanium, and of other electro-negative metals are the acids, and the fluorides of electro-positive metals are bases. In some instances hydrofluoric acid is a haloid acid; but more commonly it acts the part of a base.

Hydro-fluorides.

1544. *Hydro-fluorides.* In this family hydrofluoric acid is combined with the fluorides of electro-positive metals. If an equivalent of any electro-positive metal be indicated by M, then the general formula for this family is $MF+HF$.

Boro-fluorides.

1545. *Boro-fluorides.* When the terfluoride of boron (fluoboric acid gas) is acted upon by water, one out of every four eq. of the gas interchanges elements with water, giving rise to hydrofluoric and boracic acids, the former of which combines as a haloid-base with undecomposed terfluoride of boron, constituting the boro-hydrofluoric acid, but which may be viewed as the *boro-fluoride of hydrogen.* This change is such that

4 eq. terfluoride of boron	$4(B+3F)$	yield	3 eq. terfluoride of boron	$3(B+3F)$
			3 eq. hydrofluoric acid	$3(H+F)$
and 3 eq. of water	$3(H+O)$		and 1 eq. boracic acid	$B+3O$

By careful concentration and cooling, the boracic acid separates as a crystalline powder, and the boro-fluoride of hydrogen remains in solution. It is strongly acid to test paper, and its composition is indicated by the formula $HF+BF^3$ being an equiv. of each fluoride.

Boro-fluoride of potassium.

1546. *Boro-fluoride of Potassium.* It is prepared by dropping boro-fluoride of hydrogen drop by drop into a solution of a salt of potassa, and falls as a gelatinous transparent hydrate, which is a white very fine powder when dried. It has a slightly bitter taste, and is quite neutral to test paper, is very sparingly soluble in alcohol and cold water, but is dissolved freely by hot water, and subsides on cooling in small, brilliant, anhydrous crystals. At a strong red heat it gives off the terfluoride of boron and fluoride of potassium remains.

Silico-fluorides.

1547. *Silico-fluorides.* The acid solution, called *silico-hydrofluoric acid* may be viewed as the *subsesqui-silico fluoride of hydrogen*, a compound of 157.16 parts or 2 eq. of fluoride of silicon and 59.04 or 3 eq. of fluoride of hydrogen (hydrofluoric acid), as indicated by the formula $3HF+2SiF^3$. When the solution is neutralized with potassa, the alkali interchanges elements with the fluoride of hydrogen, water and fluoride of potassium are generated, and the latter combines with the fluoride of silicon. This double fluoride consists, therefore, of 157.16 parts or two eq. of fluoride of silicon, and 173.49 or 3 eq. of fluoride of potassium, the formula of which is $3KF+2SiF^3$. A similar change ensues with the protoxides of most other metals, and hence the general formula of the silico-fluorides is $3MF+2SiF^3$. On exposing these compounds to a red heat, fluoride of silicon is disengaged.

Titano-florides.

1548. *Titano-fluorides.* Hydrofluoric acid dissolves titanic-acid, and forms with it an acid solution which may be viewed as the titano-fluoride of hydrogen. When mixed with potassa, water and fluoride of potassium are generated, and the titano-fluoride of potassium results, the formula of which is $KF+TiF^2$. By substituting most other protoxides for potassa, similar salts may be prepared, the general formula being $MF+TiF^2$.

CHAPTER VI.

ORGANIC CHEMISTRY.

Section I. *Vegetable Bodies.*

Vegetable principles. 1549. The chemical principles of which animals and vegetables are composed are exceedingly numerous.* We can seldom obtain these principles in a state of such purity as to enable us to examine their properties with accuracy, unless when they are capable of crystallizing, or of entering into definite compounds with acids or alkalies.

Compounds. 1550. These principles are all compounds, and consist sometimes of two, sometimes of three, and sometimes of four, simple bodies united together; but seldom of more. **Simple bodies.** These simple bodies are hydrogen, carbon, oxygen and nitrogen, which may be considered as constituting in a great measure, the basis of the animal and vegetable kingdoms.

Compounds of two ingredients, 1551. Organized principles composed of two ingredients are of four kinds. 1, composed of hydrogen and carbon, as oil of turpentine; 2, of hydrogen and oxygen, as water; 3, of carbon and oxygen, as oxalic acid; 4, of carbon and nitrogen, as cyanogen.

Of three, 1552. Those composed of three constituents are much more numerous.

The most common constituents are carbon, hydrogen and oxygen. The greater number of the acids, alcohol, ethers, sugars, gums, &c., are thus constituted.

Some few organized bodies are composed of carbon, hydrogen, and nitrogen. Some are supposed to be composed of carbon, nitrogen and oxygen.

Of four, 1553. The organic principles composed of four constituents, consist of carbon, hydrogen, nitrogen and oxygen, united in various proportions. The number of atoms of nitrogen contained in these compounds is generally small compared with that of the other three constituents, and there is almost always a great preponderance in the atoms of carbon and hydrogen over those of nitrogen and oxygen.

Supposed difference in affinities of atoms of organized and unorganized bodies, 1554. It has been supposed by some chemists that there is an essential difference between the affinities which unite the atoms

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* The number of discoveries which have of late been made in this department of chemistry, is such that the limits of this work will not allow of a full account of them. For minute details the student must be referred to the recent elaborate work of Thomson: *Chemistry of Organic Bodies, Vegetables.* London, 1838, p. 1076, and the third part of Liebig and Turner's *Elements;* as the former is complete, and comprises an account of all the recent researches of the European chemists in this department, it will be employed as the basis of this chapter. Of Liebig's continuation of Turner's *Elements*, but 100 pages have appeared. The letter T will refer to the first and L to the second.

constituting organic principles, and those which unite the atoms of unorganized bodies; that there is some unknown power besides chemical affinity, which interferes with, and regulates the combinations and decompositions of organized bodies, which is wanting in those that are unorganized. The great difference between the two classes of bodies consists in this, that the organized are much more complicated in their structure, containing a much greater number of atoms than the unorganized. Hence they are much more unstable, much more easily decomposed, and much more liable to decomposition than unorganized bodies.

Differ in number of atoms.

1555. The prevailing opinion is that *binary* compounds alone exist: that is to say, that one electro-negative atom is only capable of combining with one electro-positive atom. Two of these binary compounds may combine together, making a new binary compound of four atoms. Two of these binary compounds may combine with each other, making a new binary compound of eight atoms. And in this way binary compounds may be formed as complicated as any that exist.* T. a.

Prevailing opinion.

1556. Many of the principles or definite compounds which exist in the vegetable kingdom, or which may be formed from vegetable bodies, are capable of crystallizing, and in this way may be procured in a state of purity. Others are volatile, and are formed or driven off at particular temperatures. Frequently several of these volatile bodies occur together, and in such cases we have scarcely the means of obtaining them in a state of purity unless when they enter into definite and crystallizable compounds with some other substance.

Crystallizable,

Volatile principles,

1557. It is not unlikely that all the vegetable principles may be found hereafter to be capable of entering into definite compounds with other bodies, and that they will ultimately be possessed of the character of acids or bases. But there are many which, so far as our present knowledge extends, do not seem capable of forming any such definite compounds, thus caoutchouc neither combines with acids nor bases. We must consider such bodies as neutral.

All may form definite compounds.

1558. There are also several groups of bodies which have been distinguished by a common name, some of which neutralize acids, and therefore ought to constitute bases, while others of the same group neutralize bases, and therefore ought to constitute acids; while a considerable number has been so imperfectly examined that we do not know whether they be acids or alkalies. This is the case with the group of bodies distinguished by the name of volatile oils.

Groups distinguished.

1559. In consequence of the imperfect state of our knowledge of these and various other groups similarly circumstanced, a temporary class may be formed under the name of *intermediate bodies*, which will disappear, when the investigation of vegetable principles has made greater progress.

Temporary class of intermediate bodies.

1560. All the vegetable principles may be arranged under the

Four classes.

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* Thomson dissents from this, and remarks that at present we have no means of knowing how the numerous atoms that constitute organic principles are grouped together.

four following classes:—1. Acids. 2. Alkalies. 3. Intermediate principles. 4. Neutral principles.

1561. Before describing the characters of the various principles, and to render the new terms intelligible, it will be proper to notice the results of the late investigations of Wöhler, Liebig, Pelouse and Dumas.

Theory of amides.

1562. *Theory of Amides, or Amidets.* If we represent the composition of oxalic acid by the formula C^2O^3, and that of ammonia by NH^3, we may represent oxalate of ammonia by $C_2O_3+NH_2$. It was observed by Dumas, that when crystallized oxalate of ammonia is distilled there is obtained, among other products, a white tasteless powder, which he distinguished by the name of *oxamide.** On analyzing this he found it composed of $C_2O_2+NH_2$. It is therefore oxalate of ammonia deprived of an atom of water. When heated with potassa, ammonia is disengaged, and oxalate of potassa formed. By this treatment, therefore, it is converted into oxalate of ammonia, and of course must have resumed the atom of water which it had lost.

Amide, how applied.

1563. The term *amide*, has been generalized and is applied to all those anhydrous compounds of an acid and ammonia which by heat may be deprived of an atom of water; or to all those compounds, which, by the addition of an atom of water, can be converted into a salt of ammonia.

Benzoic acid consists of	$C_{14}H_5O_3$
Ammonia	H_3N
Benzoate of Ammonia of . . .	$C_{14}H_5O_3+H_3N$

Now Wöhler and Liebig obtained a substance to which they gave the name of *Benzamide*, composed of $C_{14}H_5O_2+H_2N$, so that it differed from benzoate of ammonia by containing HO or an atom of water less. Now as oxalate of ammonia and benzoate of ammonia are in all probability binary compounds, it has been inferred that oxamide and benzamide are also binary compounds, thus

Oxamide	$C_2O_2+H_2N$
Benzamide	$C_{14}H_5O_2+H_2N$

If this be admitted, it will follow that C_2O_2 and $C_{14}H_5O_2$ are compounds capable of existing and of combining with other bodies; and likewise that there is such a compound as H_2N.

Liebig's application of amide.

1564. Liebig applies the name *amide* to the hypothetical compound of two atoms of hydrogen and one atom nitrogen. If potassium is heated to the point of fusion and a current of dry ammonia passed over it, hydrogen gas is evolved, and the potassium at first increases in bulk, loses the metallic lustre, and is converted into a clear liquid, which on cooling concretes into a gray silky mass; it is instantly converted into potassa and ammonia on the addition of water. It is called *potassamide*, or a compound of

1 atom potassium	K
1 " of	H_2N
Potassamide	$K+H_2N$

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* A contraction of oxalate of ammonia.

Add 1 atom water	HO
and we have	$KO+H_3N$

or an atom of potassa and an atom of ammonia.*

Amidets of Dumas.

1565. Dumas has given to these compounds the name of *amidet*. Thus oxamide he calls *amidet of oxide of carbon* $H_2N+C_2O_2$; C_2O_2 being a compound similar in constitution to oxide of carbon, which is CO.†

Theory of benzoyl.

1566. *Theory of Benzoyl.* A remarkable train of discoveries has been made by Wöhler and Liebig while investigating the volatile oil of bitter almonds. They have led to the inference that the basis of benzoic acid is a substance, to which they have given the name of *benzoyl* composed of $C_{14}H_5O_2$.

The oil of bitter almonds is a hydret; or	$C_{14}H_5O_2+H$
Benzoic acid is an oxide, or	$C_{14}H_5O_2+O$

They obtained also chloride, bromide, sulphuret and cyanide of benzoyl.

These discoveries render it almost certain that benzoyl exists as a separate compound, and that it is capable of combining with the supporters of combustion and cyanogen, also with hydrogen, sulphur, and doubtless other simple substances or compounds. Similar compounds have been discovered by Löwig in the volatile oil of spiræa ulmaria, which is a hydret of spiroil.‡ Analogy leads to the inference that other (probably all the) vegetable acids have, like the benzoic, a base, and that the acid is a compound of that base with oxygen.

Theory of ethers.

1567. *Theory of Ethers.* According to Dumas the base of ether is C_4H_4.§ Sulphuric ether is C_4H_4+HO; oxalic ether is $(C_4H_4+HO)+C_2O_3$ and so on of the others.

Liebig's.

According to Liebig, the radical of ether is C_4H_5. Sulphuric ether is an oxide of C_4H_5, and is represented by C_4H_5+O, or (for shortness sake) by C_4H_5O. Alcohol is a hydrate of sulphuric ether, or C_4H_5O+HO.

The radical of ether is capable of combining with chlorine, bromine, and iodine, and forms chloric, bromic, and iodic ethers, composed as follows:

Chloric ether	C_4H_5+2Cl
Bromic	C_4H_5+2Br
Iodic	C_4H_5+2I

All the oxygen-acid ethers are combinations of an atom of sulphuric ether, which possesses the characters of a base with an atom of the acid.

Alcohol acids.

1568. What have been considered as alcohol acids are merely combinations of one atom of ether acting as a base with two atoms of the acid. They ought rather to be considered as salts, consisting of two atoms acid united to one atom base, than as acids *sui generis*.‖

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* According to Kane *white precipitate*, of the Pharmacop., is a mercuramide, or a compound of $Hg+H_2N$.

† For other examples see Thomson, 7, and Dumas' *Chim. appliqué*, v. 83.

‡ A supposed base.

§ Called by Thomson in *Chem. of Inorg. Bodies*, Tetarto-carbohydrogen.

‖ Thomson is disposed to prefer the theory of Liebig as the simplest, and as agreeing best with the phenomena. Liebig has extended his theory much farther, and made it to apply to sugars, &c. T. 9.

Chap. VI.

Theory of pyracids.

1569. *Theory of Pyracids.* There are several vegetable acids which, when distilled, undergo decomposition, and new acids are generated by the process, which have been distinguished by the name of *pyracids*. Thus tartaric acid when so treated, yields *pyrotartaric* acid, gallic, *pyrogallic*, &c. It has been observed by Pelouze, that the nature of the decomposition is regulated by the degree of heat applied. When the heat is not too high, the acid is resolved into a pyracid, carbonic acid and water, or sometimes into a pyracid, and one or other of the two last products. Thus when tannin is distilled at a heat of 482° it is resolved into carbonic acid, water, and metagallic acid. Tannin being $C_{18}H_8O_{12}$ three atoms of tannin are $C_{54}H_{24}O_{36}$. Now these three atoms are resolved by the heat into

Decomposition affected by heat.

6 atoms carb. acid . . .	$=C_6 \quad O_{12}$
8 " water . . .	$= \quad H_8 \; O_8$
8 " metagallic acid . .	$=C_{48} H_{16} O_{16}$
	$C_{54} H_{24} O_{36}$

When gallic acid is distilled at 419°, it is converted into pyrogallic acid and carbonic acid,

Gallic acid is	$C_7 H_3 O_5$
Pyrogallic acid is	$C_6 H_3 O_3$
Carb. " is	$C \quad O_2$
	$C_7 H_3 O_5$

At the 482° no pyrogallic acid is formed, but only metagallic acid, water, and carbonic acid,

1 atom gallic acid is . . .	$C_7 H_3 O_5$
1 " metagallic " . . .	$=C_6 H_2 O_2$
1 " carb. acid " . . .	$=C \quad O_2$
1 " water	$= \quad H \; O$
	$C_7 H_3 O_5$

Sometimes the saturating power of a vegetable acid is not altered by converting it into a pyroacid; sometimes, according to Pelouze, it is reduced one half.*

From these observations it has been inferred that gallic acid is a compound of pyrogallic acid and water, and so of others.†

Theory of substitutions.

1570. *Theory of Substitutions.* Oxygen, chlorine, bromine, and iodine may be made to unite with various compound bodies, while at the same time these bodies give out hydrogen. Thus when dry chlorine gas is passed into pure oil of bitter almonds, which is composed of $C_{14}H_5O_2+H$, it loses its atom of hydrogen which constituted it a hydret, for which an atom of chlorine is substituted, making a compound consisting of $C_{14}H_5O_2+Cl$, which is a chloride of benzoyl. This and analogous facts have been generalized by Dumas, who has drawn from them the following general conclusions.

Dumas's conclusions.

1571. 1. When a body containing hydrogen is subjected to the

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* *Ann. de Chim. et Phys.* lvi. 303.

† Thomson does not agree in this opinion and thinks it more probable, that by the temperature applied, a certain portion of the carbon, or hydrogen, or of both, undergoes combustion, and that the remaining atoms arrange themselves so as to constitute the pyroacids.

dehydrogenizing action of oxygen, chlorine, bromine, or iodine, for every atom of hydrogen that it loses it gains an atom of oxygen, chlorine, bromine, or iodine. 2. When the hydrogenous body contains water, this last body loses its hydrogen without anything being replaced. If, after this, any hydrogen be abstracted, it is replaced by a corresponding number of atoms of oxygen, chlorine, &c.* T.

Laurent's view.

1572. Laurent† considers the base or radical of every organic body to be a compound of carbon and hydrogen united together, so that the atoms of the carbon bear a simple relation to those of the hydrogen. When these radicals are subjected to a dehydrogenizing process, as by passing a current of chlorine through them, they gradually lose their hydrogen or a part of it, but gain as many atoms of the dehydrogenizing body as they lose of hydrogen. So that if we add the number of atoms of the new body to those of hydrogen remaining, the sum will make up the number of atoms of hydrogen originally present in the radical.

1573. The dehydrogenizing body, or a part of it, being converted into water, nitric acid, hydrochloric acid, &c., may either be disengaged or remain combined with the new compound formed.

Neutral. Acid. Effect of heat.

1574. The fundamental radical and its derivatives will be neutral or alkaline, whatever be the portion of oxygen, hydrogen, &c. entering into it. But when the oxygen, &c. enters into combination with the radical, it renders it *acid*, how small soever the uniting portion may be. Those bodies which enter into combination without being a part of the radical, may be removed by heat, alkalies, &c., without being replaced by anything else. But when a body constitutes a part of the radical, this cannot be done. T. 13.

Compound radicals of Liebig.

1575. Liebig has termed certain compound bodies, which have the property of uniting with simple bodies, compound radicals. Those which unite with hydrogen give rise to *hydracids*. He has arranged these combinations in groups, according to the radical of each; the individual members of each group arising from the combinations of the radical with the elements, and from the union of the compounds thus formed with other compound bodies.

New compounds. Oxygen removed.

1576. Whenever one or more of the constituent parts is removed from any of these, a new compound of another radical is produced. When the oxygen has been removed, and its place supplied by its equivalent of sulphur, a sulphur-compound of the same radical is formed, and its properties are similar to those of the oxygen-compound.

Hydrogen.

When the hydrogen is displaced, and its position occupied by its equivalent of chlorine or oxygen, there will be formed either a similar compound of a similarly constituted radical, or several new compounds of a more simple radical.

Combinations of compound radicals not containing nitrogen,

1577. All combinations of compound radicals not containing nitrogen, are reduced when exposed to the action of oxygen to oxides of more simple radicals, the higher or lower degree of oxidation being dependent upon the quantity of oxygen present.

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* For examples see T. *Org. Chem.* 11.

† *Ann. de Chim. et Phys.* lxi. 128.

Decomposed.

1578. Organic compounds not containing nitrogen, may be decomposed in three different ways, when brought into contact with concentrated or anhydrous sulphuric acid; firstly, the acid may withdraw water from the compound, or at least oxygen and hydrogen in the proportions in which they form water; in this case the other component parts unite into one or more new compounds; thus oxalic and sulphuric acids give rise to the formation of water, of carbonic oxide and of carbonic acid; or, secondly, the acid may at the same time give oxygen to a part of the carbon of the compound, when the above products, together with sulphurous acid, will be produced; or, thirdly, the acid may give oxygen to the hydrogen of the compound, and in this case be converted into hyposulphurous acid, which usually enters into very intimate combination with the organic substance thus modified.

Action of strong acids.

1579. By the action of strong acids upon substances containing nitrogen, there is frequently produced through the medium of the constituents of water, on the one hand ammonia, which combines with the acid, and on the other an oxide of a new radical, in which all the carbon of the original compound is present. Hydrocyanic acid and hydrochloric acid; oxamid, urea, and sulphuric acid, &c. &c.

Action of potassa, on compounds not containing nitrogen.

1580. All organic compounds not containing nitrogen, are decomposed by being fused with hydrate of potassa, and if the latter be present in sufficient quantity, the decomposition is not attended with the separation of carbon; the products which are formed are the same as those resulting from the action of powerfully oxidizing agents; water is generally decomposed, its oxygen unites with the carbon and hydrogen of the substance, while its hydrogen is liberated, and either escapes in the form of gas, or enters into some new combination. The resulting products of this decomposition may be either ulmic, acetic, and oxalic acids, oxalic acid alone, or solely carbonic acid, according to the degree of temperature to which the mixture is exposed.

Products.

Action on those containing nitrogen.

1581. All organic compounds containing nitrogen are decomposed by being boiled in a solution of caustic potassa, or by being fused with the hydrate; the products are generally the same as those generated by the action of a strong acid upon the same substances, only that with potassa the ammonia is liberated, while the oxide of the new carbonized radical enters into combination with the potassa. Many substances which are very rich in nitrogen are converted, with the separation of a part of the nitrogen as ammonia, and the absorption of oxygen, into cyanic acid, and this, by uniting with the potassa escapes further decomposition; in this case the fused residue is completely decomposed into ammonia and carbonic acid by being dissolved in a little water and boiled.

Products.

Destructive distillation; products.

1582. When organic bodies are exposed to the destructive distillation, their constituents give rise to the production of new volatile compounds of more simple radicals, either with or without the deposition of carbon. The products vary with the temperature, which gives rise to the division of the distillation into several periods. In the first are produced organic acid of more simple radicals, carbonic acid, water, and combustible fluids, which admit of being mixed with water. In the second period, the products of the decomposition of the new substances formed during the first, are generated; the acids disappear, their oxygen unites with a part of their hydrogen and carbon, forming more simple compounds, as carbonic oxide, carbonic acid, and water, a portion of the carbon is generally deposited, while the rest unites with hydrogen, giving rise to volatile or fixed oleaginous substances. In the last period, only charcoal and gases are obtained; the latter generally consisting of a mixture of carbonic oxide, olefiant and light carburetted hydrogen gases.

Substances containing nitrogen form, under the same circumstances, ammonia, and sometimes cyanic acid; in the last period, cyanogen and hydrocyanic acid.

Effect of strong base, &c.

1583. When an organic compound is exposed to a similar decomposition in contact with a strong base, which is not reduced by a red heat, it is generally decomposed into carbonic acid, which remains in combination with the base, and into one or more new substances. Should these latter contain oxygen, they may be entirely deprived of it by a new distillation with the base, the oxygen giving rise to another portion of carbonic acid, while the other constituents of the substance are obtained in the form of solid, fluid, or gaseous compounds of carbon and hydrogen. L. 738.

Oxygen removed.

Section II. *Vegetable Acids.*

Thompson's division of acids.

1584. These acids may be divided into seven sets—1. *Volatile Acids*, or those which may be volatilized without decomposition; 2. *Fixed Acids*, such as cannot be volatilized or distilled over without decomposition; and these may be subdivided into such as are decomposed when exposed to heat, but furnish at the same time *pyracids;* and, 3, into those whose pyracids are unknown. 4. *Oily Acids*, or those into which oils or wax are converted, when boiled with potassa or soda. The combination with the alkali constituting soap. 5. Acids *containing nitrogen*. 6. Acids *imperfectly examined*. 7. *Compound Acids*, consisting of a vegetable principle united to a strong mineral or vegetable acid.

Oxalic acid.

1585. *Oxalic Acid*, $_2CO+O$, 2 eq. carb. oxide + 1 oxy. = 36.24. (L.) C_2O_3 = 36. (T.) This acid was discovered by Scheele in 1776. It occurs in several plants, particularly of the genera oxalis, rumex, &c; combined with potassa in roots and with lime in several kinds of lichens.* Oxalate of lime is also an ingredient of several urinary calculi; the acid is a product of the decomposition of uric acid, of all organic compounds not containing nitrogen when oxidized by nitric acid, or acted upon by hydrate of potassa, or by permanganic acid; it is also formed by the decomposition of cyanogen with water and ammonia. L.

Process 1.

1586. It is obtained by digesting by aid of gentle heat one part of sugar, or better still, of potato starch, in 5 parts of nitric acid of sp. gr. 1.42, diluted with 10 parts of water, as long as gaseous products are evolved; by evaporation the acid is obtained in crystals, which may be purified by a second crystallization after being well dried on paper or porous earthen ware.

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* Said to occur in *Humboltine* with oxide of iron by Rivero—not confirmed by Thomson's analysis. See his *Mineralogy*, ii. 469.

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When prepared on the large scale the process is conducted in cylindrical vessels of earthern ware, which are heated by being surrounded with warm water; on a small scale it may be made in a porcelain dish. From 12 parts of potato starch 5 of the acid are obtained. The mother liquor should be treated with an additional quantity of acid, and again warmed, when a second crop of crystals will be formed; this is repeated until the solution is quite exhausted. On account of the cheapness of nitric acid, this is the usual process now adopted in the manufactories. Any $\overset{\cdot\cdot\cdot\cdot\cdot}{N}$ adhering to the crystals, may be removed by gently heating them in a porcelain dish, or by repeated crystallization.* L.

Process 2. It may also be obtained by precipitating a solution of the superoxalates of potassa by acetate of lead or sulphuret of barium, carefully washing the precipitate, and decomposing it while yet moist by dilute $\dddot{S}$. Filter and evaporate. To decompose the oxalate of lead or baryta five parts of strong $\dddot{S}$ must be employed diluted with ten of water for every seven parts of the binoxalate of potassa. Nine tenths of the dilute $\dddot{S}$ is to be added in successive portions to the moist lead or barytic precipitate; sulphate of lead or baryta is instantly formed, and the oxalic acid is dissolved by the water. After the mixture has stood some hours, the clear liquid should be poured from the precipitate, which should be repeatedly washed. The solution yields upon evaporation, crystals of pure oxalic acid; any trace of lead may be removed by hydrosulphuric acid gas. The residue of sulphate of lead or baryta, which still contains some undecomposed oxalate, must be treated with the remaining tenth of the dilute $\dddot{S}$, and heated with a little more water; in this manner an additional quantity of impure oxalic acid is obtained, but the $\dddot{S}$ may be separated from the crystals by washing.

Theory. 1587. The production of oxalic acid from organic matter is a consequence of the oxidation of the elements of the latter by the oxygen of the $\overset{\cdot\cdot\cdot\cdot\cdot}{N}$; hence those substances give it in greatest quantity which contain oxygen and hydrogen in the same proportion as water. In the second process sulphuret of potassium and oxalate of baryta, or acetate of potassa and oxalate of lead are formed. The oxalate of baryta or lead is decomposed by $\dddot{S}$, giving rise to free oxalic acid and sulphates of lead or baryta. L.

Crystals, 1588. The crystallized acid is, according to Liebig, a compound of the hydrate with water of crystallization. The crystals are transparent oblique rhombic prisms, with one or two terminal planes, one pair of the lateral edges of the latter is sometimes truncated.

How distinguished from Epsom salts. 1589. This acid has no odour; tastes and reacts strongly acid, and is poisonous, and from the resemblance which the crystals bear to those of Epsom salt, many fatal mistakes have arisen. The acid taste is in itself a sufficient mark of distinction; or without tasting it, if a few drops of water be placed on a slip of the dark blue paper which is commonly wrapped round sugar loaves, and a small quantity of the suspected crystals be added, if it be oxalic acid it will change the colour of the paper to a reddish brown. The solution also of a small quantity of this acid in a tea-spoonful of water, will effervesce with a little scraped chalk or whiting. H. When the acid has been swallowed, copious draughts of lime water, or magnesia and water, should be administered, and vomiting excited as speedily as possible.

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* If shavings of wood be mixed with caustic potassa, and exposed to a heat considerably higher than that of boiling water, the wood suffers decomposition, and is partly converted into oxalic acid, which combines with the potassa; a process followed by some manufacturers of this acid. T.

Effect of heat. 1590. The crystals when heated fall into powder, and lose 28 per cent. = 2 eq. of water of crystallization; the hydrate of oxalic acid is left When rapidly heated to the temperature of 350°, they fuse and lose their water of crystallization, a part of them decomposing, while another portion sublimes as hydrate in dense white fumes of a strong odour, which cover the surface of the fused acid in the form of a woolly crystalline mass. If heated in a retort to 310° it is decomposed into $\dot{C}$, $\ddot{C}$ and formic acid.

Decomposed by $\dddot{S}$. 1591. Heated in strong $\dddot{S}$, it is decomposed into $\ddot{C}$, $\dot{C}$ and water. The anhydrous oxalic acid may be considered as a compound of 1 eq. $\dot{C}+1$ eq. $\ddot{C}$, which acoounts for the production of equal vols. of the two gases whenever the pure acid or any of its salts is heated in strong $\dddot{S}$ (512).

Solubility. 1592. The crystals dissolve in eight parts of water at 60°, in their own weight of boiling water, and in four parts of alcohol at 60°. **Test of purity.** When pure it should give a precipitate with salts of baryta that is perfectly soluble in $\overset{.:.}{N}$, if it contain lead it is blackened by hydrosulphuric acid gas: it should sublime without leaving a residue.

1593. This acid and its soluble salts are important reagents for detecting and separating lime.*

Oxamide. 1594. By distilling oxalate of ammonia, or oxalates, with ammoniacal salts, a substance has been obtained by Dumas which he has called *oxamide*,† which will be noticed hereafter.

Oxalate of ammonia. 1595. *Oxalate of Ammonia.* $NH_4OC_2O_3+$aq. crystals. This is a very useful salt for the purpose of separating lime from magnesia, and generally for precipitating lime from its solutions.

Obtained. It is obtained by neutralizing a solution of pure oxalic acid by caustic or carbonate of ammonia, or by decomposing the oxalate of lead by sulphuret of ammonium, and evaporating the solution to crystallization.

It may also be prepared by neutralizing the bin- or quadroxalate of potassa with carb. of ammonia; the first crop of crystals consists of oxalate of ammonia, which may be completely freed from potassa by repeated crystallization, the mother liquor contains the neutral oxalate of potassa.

Crystals. 1596. The crystals are long, colourless, transparent prisms, of the right prismatic system; with a strong saline taste, less soluble than the oxalic acid and efflorescent, losing 12.6 per cent. of water of crystallization. By heat it is decomposed, giving rise to oxamide.

Binoxalate of potassa. 1597. *Binoxalate of Potassa.* $HO.C_2O_3,KO.C_2O_3+2$ aq. eq. = 155.63. This salt is used and sold as the *essential salt of lemons*,

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* In the neutral salts of oxalic acid, the oxygen of the base is to that of the anhydrous acid in the proportion of 1 : 3. If the oxygen of the metallic oxide be considered as a part of the acid, the compound contains $\ddot{C}$ and a metal. Many salts of oxalic acid, whose bases are oxides easily reduced to the metallic state, are decomposed by heat into $\ddot{C}$ and metal (oxalate of silver with a slight explosion). The oxalates of the alkalies under the same circumstances evolve $\dot{C}$, and are converted into carbonates. Many metallic oxides when heated with an oxalate are reduced by the $\dot{C}$ evolved. There exist both neutral and acid salts of this acid, the latter contain double, and sometimes four times as much acid as the former. (Liebig.)

† Abbreviated from oxalic acid and ammonia.

for removing iron-moulds and other metallic stains (ink, &c). It exists ready formed in the juice of the *oxalis acetosella* or wood sorrel, from which it was formerly procured.

Prepared.

1598. It may be made by neutralizing one part of crystallized oxalic acid by carbonate of potassa, and afterwards adding to the neutral salt another part of oxalic acid and crystallizing. The crystals are transparent oblique rhombic prisms, with an acid taste and reaction.

Properties.

It is poisonous. Soluble in 40 parts of cold and 6 of boiling water.

1599. When pure it should fuse and decompose without emitting a burnt odour, and the residue should be of a gray, not of a black colour.*

Quadroxalate.

1600. *Quadroxalate of Potassa* is sold in commerce as binoxalate. It is procured by dissolving the binoxalate in hydrochloric acid and crystallizing; it is made on the large scale by neutralizing one part of crystallized oxalic acid and adding to the solution three parts of the pure acid.

Crystals.

1601. Its crystals are transparent prisms of the doubly oblique prismatic system; at 262° it loses two atoms or fourteen per cent. of water, at higher temperatures oxalic acid passes off and it is decomposed. If pure its reaction when heated is similar to that of the binoxalate; if three parts are converted into carbonate by a red heat, and added to a solution of one part, the neutral oxalate should be obtained.

Oxalate of lime.

1602. *Oxalate of Lime*, $CaO.C_2O_3+2$ aq. $= 82.74$, occurs in several species of lichen, of which it forms the firm, hard skeleton, so that many of them may be used for preparing oxalic acid, but not very advantageously.†

Distinguished.

1603. The insolubility of this salt in water, ammonia, and acetic acid, and its solubility in the nitric and hydrochloric acids, distinguishes it from most other precipitates. Advantage is taken of this to detect lime in solutions from which all other precipitable metallic oxides have been separated by other means, the alkaline oxalates being the best reagents for this purpose; thus these oxalates are used to separate lime from magnesia, with the latter of which they form soluble double salts. On the other hand, lime may be used to detect oxalic acid.‡

Colour, &c.

1604. Recently precipitated oxalate of lime is a snow-white flocculent powder, insoluble in acetic acid, readily dissolved by free nitric or hydrochloric acid, and by a red heat is converted, without being perceptibly blackened, into carbonate of lime; from the weight of which, either the oxalic acid or the lime may be calculated. L. 750.

Impurities detected.

* The presence of cream of tartar is recognised by the carbonaceous residue, and the peculiar odour which it emits on burning; that of sulphate of potassa by the common tests of $\ddot{S}$. If of two equal parts by weight, of the salt, the one be exposed to a red heat, and the other be dissolved in water, the solution of the latter should be deprived of its acid reaction by the addition of the residue of the former; if this does not happen, it is not the binoxalate but the *quadroxalate*, which is met with in commerce under that name. (Liebig.)

† See Braconnot's process *Ann. de Chim. et Phys.* xxviii. 318, and *Quart. Jour.* xix.

‡ It should be remembered that oxalic acid is imperfectly precipitated by salts of lime from a solution which contains the oxides of chromium, iron, or manganese. (Liebig.)

Rhodizonic acid.

1605. *Rhodizonic Acid.* $C_7H_3O_{10}$. When a stream of dry carbonic oxide gas is transmitted over a portion of fused potassium, the gas is absorbed in large quantity; the potassium coats the surface of the glass tube, becomes green, and at last a black porous mass is obtained, which, if exposed to the air when warm, inflames, and if covered with water dissolves with the rapid evolution of a combustible gas; if moistened with water it burns, and forms a red solution which contains rhodizonate of potassa.

How obtained.

1606. This compound of potassium and carbonic oxide was obtained by Gmelin in considerable quantity as a secondary product during the preparation of potassium by Brunner's process (839), when it separates from the gases evolved in the form of a gray powder, which may be readily collected. Exposed to moist air it absorbs water, and is converted, without combustion, into rhodizonate of potassa of a scarlet colour; by being treated with alcohol, in which it is soluble, the free potassa may be separated. All its compounds are of a red colour, or, in the dry state, of a brilliant metallic green.

Remarkable changes.

1607. The changes which are produced on rhodizonate of potassa when its aqueous solution is heated, are very remarkable; without the evolution of gases it is decomposed into free potassa, oxalate of potassa, and into the potassa salt of a new acid, which has been called by Gmelin the croconic acid. L. 752.

Croconic acid.

1608. *Croconic Acid.* $C_5O_4 = 62$. The croconic acid is prepared by adding hydrofluosilicic acid to a solution of its potassa salt, and evaporating to dryness; the pure acid is removed from the yellow residue by water; it is yellow,* readily crystallized, tastes and reacts strongly acid, is soluble in water and alcohol; all its salts are yellow, and, with the exception of the ammoniacal salts, are all of them insoluble in alcohol.

Croconate of potassa.

1609. *Croconate of Potassa* crystallizes in long six-sided prisms, of an orange-yellow colour, tastes similar to nitre, and is neutral with respect to vegetable colours. When heated it loses 15 per cent. = 2 eq. water and becomes of a lemon-yellow colour. It burns like tinder into a mixture of carbonate of potassa and carbon, with evolution of $\dot{C}$ and $\ddot{C}$; it is decomposed by chlorine and $\overset{\cdot\cdot\cdot\cdot\cdot}{N}$ with effervescence into peculiar salts.

Formic acid. History.

1610. *Formic Acid.* $C_2H\ O_3 = 37$. This acid was first noticed by Ray, in 1671,† in an account of the acid spontaneously given out by ants, and which they yielded when distilled. In 1812 Gehlen examined it and pointed out some of its characters. It has been since analyzed by Berzelius, and an artificial method of preparing it discovered by Dobereiner.

1611. It may be obtained from ants by the following process:

Process for.

Any quantity of ants may be infused in about thrice their weight of water, put the mixture into a silver, or tinned copper still, and draw off the water by distillation as long as it continues to come over without any burnt smell; the distillation must be stopped as soon as that is perceived Saturate the water in the receiver with carbonate of potassa, and evaporate to dryness. Mix the white mass thus obtained with as much sulphuric acid, previously diluted with its weight of water, as is sufficient to saturate the potassa. Introduce the mixture into a retort, and

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* Hence its name from *crocus*, *saffron*.

† *Phil. Trans.*

distil slowly to dryness. The liqnid which comes over into the receiver is to be again rectified by a very moderate heat, to get rid of any portion of sulphuric acid that may be present.

Obtained from sugar, &c. 1612. It may be prepared from sugar and many other vegetable substances, when treated with binoxide of manganese and sulphuric acid. The following process has been pointed out by Dobereiner.

Process. Dissolve 1 part of sugar, starch, &c., in 2 parts of water, mix the solution (in a large vessel) with 2½ or three parts of binoxide of manganese in fine powder. Heat the mixture to 140°, add, by little and little at a time, 3 parts of concentrated sulphuric acid, previously diluted with its own weight of water, carefully agitating the mixture after every addition, with a wooden rod. After the addition of the first third of the acid so violent an effervescence takes place, that unless the vessel be at least 15 times the bulk of the mixture, a portion will run over.*

1613. A pound of sugar yields a quantity of the acid, capable of saturating five or six ounces of carbonate of lime. **Concentrated.** To obtain the formic acid in a concentrated state, evaporate the formate of lime to dryness, and mix seven parts of this dry salt, in powder, with ten parts of concentrated sulphuric acid and four parts of water, and distil in a retort. If we substitute six parts of alcohol for the four parts of water and distil, we obtain formic ether.

Emmet's process. 1614. The following process has been given by Emmet,† who affirms that the oxide of manganese is of no use in the process.

Mix together in a retort equal measures of water, oil of vitriol, and clean, but unground rye, or cracked maize; let them be heated to the boiling point, and as soon as the mass has become thoroughly blackened, add another measure of water and distil off one measure of formic acid. The addition of more water, and fresh distillation will afford an additional quantity of a weaker acid.

Detected. 1615. The presence of formic acid may be easily ascertained. When the acid or formate of soda is put into a solution of any salt of gold, platinum, or silver, an effervescence takes place, $\ddot{C}$ is given off, and the metal is deposited.‡ When formate of soda is mixed with a solution of corrosive sublimate, calomel is deposited. When the acid is added to a solution of nitrate of lead, crystals of formate of lead in needles are deposited.

Liebig's acid. 1616. Liebig has found that formic acid may be obtained, containing only one atom water, by decomposing dry formate of lead by hydrosulphuric acid. When of this strength it is much more corrosive **Properties.** than concentrated $\dddot{S}$. The smallest drop applied to the skin occasions a sensation like that produced by red-hot iron. A sore is produced, which is long in healing. This hydrate crystallizes at 32° and boils at 212° like water. The common acid, which is a bihydrate, crystallizes at 5° and boils at 226½°.§ Formic acid has a

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* The effervescence is owing to carbonic acid. Pungent vapours of formic acid are exhaled. To preserve these, the mixture should be made in a copper alembic the top of which should be put on and connected with the worm in the refrigeratory. When the violence of the effervescence is over, the rest of the sulphuric acid is to be added, the mixture is to be agitated, and the whole distilled over almost to dryness. A limpid acid liquid is obtained, having a strong smell, and consisting of water, formic acid, and an etherial liquor. Saturate the formic acid with carbonate of lime, and distil the liquor a second time to preserve the etherial liquid which comes over with the water, and from which it may be afterwards separated by distilling it off fused chloride of calcium. T.

† See his interesting paper in *Amer. Jour.* xxxii. 140.

‡ *Ann. de Chim. et de Phys.* lii. 107.

§ *Jour. de Pharm.* xxi. 381.

considerable resemblance to acetic. Very dilute formic acid is said to undergo spontaneous decomposition like vinegar.*

Mellitic acid.

1617. *Mellitic Acid.* $C_4O_4+H = 57.48$. (L.) Combined with alumina this acid constitutes a rare mineral, *mellite* or *honey-stone.* It may be obtained by the following process of Wöhler.

Process.

Reduce mellite to fine powder, digest in a solution of carbonate of ammonia; after the liquid has taken up all the mellitic acid, the excess of ammonia is expelled by boiling; filter, evaporate until crystals appear. The crystals are then dissolved in water, and acetate of lead added. The mellitate of lead is decomposed by hydrosulphuric acid. The solution separated by filtration from the sulphuret of lead yields, on evaporation, a white slightly crystalline powder; it is soluble in alcohol, from which it may be obtained by very slow evaporation in radiated groups of acicular crystals.

Effect of heat, &c.

1618. The dry acid is not changed by boiling in $\overset{\cdot\cdot\cdot\cdot\cdot}{N}$ or $\dddot{S}$. The aqueous solution tastes and reacts strongly acid. Boiled in alcohol, it seems to form an acid mellitate of ether. It forms salts by uniting with the base; its alkaline salts are soluble, and may be obtained in crystals, but with the other metallic oxides it forms either insoluble or very sparingly soluble compounds. These salts are decomposed by heat, but the silver salt suffers in the first instance a peculiar change; at 356° 1 eq. of water is separated.†

Succinic acid.

1619. *Succinic Acid.* $C_4H_2O_3, = 50$. (T.) This acid is obtained from amber (*succinum*), and hence its name.

Process.

Fill a retort half way with powdered amber, and cover the powder with a quantity of dry sand; lute on a receiver, and distil in a sand-bath without employing too much heat. The succinic acid attaches itself to the neck of the retort. It is purified by dissolving in hot water and putting in the filter a little cotton, previously moistened with oil of amber, which retains most of the oil, and allows the solution to pass clear. It is subsequently crystallized by gentle evaporation, and this process is to be repeated till the acid is sufficiently pure.

May be obtained in three states.

1620. Succinic acid may be obtained in three states: 1. combined with an atom of water; 2. with half an atom; and, 3. anhydrous.

The first is the crystallized acid of the shops, when pure. It is soluble in water, but less so in alcohol, and scarcely at all in ether. It melts at 356° and boils at 455°. When the crystallized acid is kept for a long time in a retort at a temperature between 266° and 284°, it undergoes a remarkable change. A great number of white needles are deposited and a little water is disengaged. These needles consist of succinic acid deprived of half its water, while the portion in the retort remains unaltered.

Anhydrous acid.

1621. The anhydrous acid may be obtained by distilling a mixture of dry phosphoric acid with crystallized succinic acid. The best method is to fuse the succinic acid in a retort, and then add the phosphoric acid, and distil slowly.

Solubility.

Succinic acid dissolves in 96 parts of water at 50°, in 24 parts at

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* Thomson states that he has preserved for several years, formic acid prepared by Dobereiner's process, dilute, but stronger than vinegar.

† Since the silver salt, dried at 212°, can retain no water, it is probable that the water is first formed at the above heat by the hydrogen of the acid, and the oxygen of the oxide of silver, when the salt passes into a combination of silver and carbonic oxide C_4O_4, the latter acting the part of chlorine or any other haloid substance. (Liebig.)

52°, and in 2 parts at 212°. The anhydrous acid is less soluble in water than the hydrous, but more soluble in alcohol and ether.

Succinates.

1622. The compounds which this acid forms with bases are termed *succinates.* The alkaline succinates are soluble in water. This is not the case with succinate of baryta, hence baryta is precipitated from a neutral solution by succinate of ammonia. This salt likewise precipitates mercury and lead. It throws down iron from all solutions provided the iron be in the state of peroxide and there be no excess of acid present.

Acetic acid.

1623. *Acetic Acid.* $C_4H_3O_3 = 51$. (T.) This acid is employed in three different states. When first prepared it is called *vinegar;* when purified by distillation it assumes the name of *distilled vinegar*, usually called *acetous acid* by chemists; when concentrated as much as possible it is called *radical vinegar* and *acetic acid.*

Vinegar.

1624. Vinegar is usually prepared by subjecting liquids that have undergone the vinous fermentation, to the action of air; much oxygen is then absorbed. Many solutions of vegetable matter produce vinegar.*

Distilled or acetous acid.

When distilled at a temperature not exceeding that of boiling water, till about two thirds or five sixths of it have passed over, most of the impurities are left behind and the product is pure acid, diluted with water. *Distilled vinegar* or *acetous acid* is transparent and colourless, of a strong acid taste and an agreeable odour.

Acetic acid.

Obtained.

1625. To obtain *acetic* acid, or, as it has been sometimes called, *radical vinegar*, distilled vinegar may be saturated with some metallic oxide, and the acetate thus obtained, subsequently decomposed. It is thus procured by distilling *acetate of copper*, or *crystallized verdigris*, in a glass retort heated gradually to redness: it requires re-distillation to free it from a little oxide of copper which passes over in the first instance. Acetic acid may also be obtained by distilling *acetate of soda* or *acetate of lead* with half its weight of sulphuric acid: or from a mixture of equal parts of sulphate of copper and acetate of lead; in these cases, the acid passes over at a moderate temperature.

Pyroligneous acid.

1626. A considerable quantity of acetic acid is also now procured by the distillation of wood in the process of preparing charcoal for the manufacture of gunpowder. The liquor at first procured is usually termed *pyroligneous acid;* it is empyreumatic and impure, and several processes have been contrived to free it from tar and other matters which it contains. It may be saturated with chalk and evaporated, by which an impure acetate of lime will be obtained, and which, mixed with sulphate of soda, furnishes, by double decomposition, sulphate of lime and acetate of soda; the latter distilled with sulphuric acid affords a sufficiently pure acetic acid, which by dilution with water may be reduced to any required strength. The purification of this acid has been brought to great perfection.†

Properties of acetic acid.

1627. Acetic acid obtained by the processes described is transparent and colourless, its odour highly pungent and it blisters and excoriates when applied to the skin. Its specific gravity is 1.060.

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* For other details see *Fermentation.*

† For a full account of the processes see Ure's *Dict. Arts and Man.* 8.

Sect. II.

It is extremely volatile, and its vapour readily burns. It combines in all proportions with water, and when considerably diluted resembles distilled vinegar. When highly concentrated, it crystallizes at the temperature of 40° F., but liquefies when its heat is a little above that point. In this state it is called *glacial acetic acid.*

Properties.

1628. Liquid acetic acid, consisting of one atom acetic acid, and one of water. which has a specific gravity of 1.06296, does not redden litmus paper. It may be kept in contact with dry carbonate of lime, or even boiled over it without disengaging a single bubble of $\ddot{C}$ gas, or combining with the lime, yet it dissolves quicklime instantly. It decomposes carbonate of potassa, soda, lead, zinc, strontia, baryta and magnesia, disengaging $\ddot{C}$. When mixed with several times its volume of alcohol, it loses its action upon these carbonates.*

Combining power.

1629. Acetic acid possesses but little energy in combining with bases, being displaced by most of the other acids. It forms with bases a class of salts called *acetates*, several of which are important. They are all soluble in water.†

1630. When the vapour of alcohol is brought into contact in the atmosphere with the black powder obtained by mixing hydrochlorate of platinum, potassa and alcohol, vinegar is rapidly formed. It is thus prepared in Germany.‡

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* Pelouze, *Ann. de Chim. et de Phys.* i. 314.

† Thomson's *Org. Chem.*

Platina-Mohr. Process for.

‡ The powder is called Platina-Mohr and is thus made: melt platinum ore with double its weight of zinc, reduce the alloy to powder, and treat it at first with dilute $\dddot{S}$, and next with dilute $\overset{.\,.\,.\,.\,.}{N}$, to oxidize and dissolve out all the zinc, which is somewhat difficult, even at a boiling heat. The insoluble black-gray powder contains some osmiuret of iridium united with the crude platinum. This compound acts like simple platina-black after it has been purified by digestion in potash ley, and washing with water. Its oxidizing power is so great as to transform not only formic acid into the carbonic, and alcohol into vinegar, but even some osmic acid, from the metallic osmium. This powder explodes by heat.

Action upon alcohol produces acetic acid.

When the platina-*mohr*, prepared by means of zinc, is moistened with alcohol, it becomes incandescent, and emits osmic acid; but if it be mixed with alcohol into a paste, and spread upon a watch-glass, nothing but acetic will be disengaged; affording an elegant means of diffusing the odour of vinegar in an apartment.

With this powder vinegar may be made in the following manner: Under a large case, which, for experimental purposes may be made of glass, several saucer-shaped dishes of pottery or wood are to be placed in rows, upon shelves over each other, a few inches apart. A portion of the black platina powder moistened being suspended over each dish, let as much vinous spirits be put into them as the oxygen of the included air shall be adequate to acidify. This quantity may be inferred from the fact, that 1000 cubic inches of air can oxygenate 110 grs. of absolute alcohol, converting them into 122 grs. of absolute acetic acid and 64½ grs. of water.

The above apparatus is to be set in a light place (in sunshine, if convenient), at a temperature of from 68° to 86° F., and the evaporation of the alcohol is to be promoted by hanging several leaves of porous paper in the case, with their bottom edges dipped in the spirit. In the course of a few minutes the mutual action of the platina and the alcohol will be displayed by an increase of temperature, and a generation of acid vapours, which, condensing on the sides of the glass case, trickle in streams to the bottom. This continues till all the oxygen of the air is consumed. If we wish to renew the process, the case must be opened, and replenished with air. With a box of 12 cubic feet in capacity, and with 7 or 8 ounces of the platina powder we can in the course of a day, convert one pound of alcohol into pure acetic acid, fit for every purpose, culinary or chemical. With from 20 to 30 lbs. of the powder (which does not waste), we may transform, daily, nearly 300 lbs. of bad spirits into the finest vinegar.

589.64 parts by weight of alcohol . . = $H_{12}\,C_4\,O_2$
consist of 74.88 of hydrogen . . = H_{12}
305.76 of carbon . . = C_4
200.00 of oxygen . . = O_2

The following are among the most important of the acetates:

Acetate of ammonia.

1631. *Acetate of Ammonia* is a very deliquescent, soluble salt, and extremely difficultly crystallizable. In solution, obtained by saturating distilled vinegar with carbonate of ammonia, it constitutes the *ammoniæ acetas liquidus* of the *U. S. P.* which has long been used in medicine as a diaphoretic, under the name of *spirit of Mindererus*.

Of potassa,

1632. *Acetate of Potassa* is usually formed by saturating distilled vinegar with carbonate of potassa, and evaporating to dryness. If this salt be carefully fused, it concretes into a lamellar deliquescent mass on cooling. It is the *terra foliata tartari*, and *febrifuge salt of Sylvius* of old pharmacy. It dissolves in its own weight of water at 60°, and the solution has an acrid saline taste.

Of lime,

1633. *Acetate of Lime*, is a difficultly crystallizable salt, readily soluble in water, and of a bitter saline taste consisting of 1 at. lime, 1 at. acid, and 6 at. water.* It is sometimes obtained by saturating the vinegar formed during the distillation of wood, and employed in the preparation of *acetate of alumina*, which is used by the calico-printers as a mordant.

Of iron,

1634. *Acetate of Iron*. The *protacetate* is formed by digesting sulphuret of iron in acetic acid;† it yields green prismatic crystals, of a styptic taste, and readily soluble in water; the solution becomes brown by exposure to air, and passes into *peracetate*, which is uncrystallizable, and obtained by digesting iron in acetic acid. This compound is used by calico-printers, who prepare it either by digesting iron in pyroligneous acid, or by mixing solution of acetate of lead with sulphate of iron, and exposing the filtered solution to air.

Of zinc,

1635. *Acetate of Zinc*, 1 at. acid, 5 ox. zinc, 7 water, (T.) is formed either by dissolving oxide of zinc in acetic acid, or by mixing a solution of sulphate of zinc with one of acetate of lead. It crystallizes in thin shining plates of a bitter and metallic taste, very soluble, but not deliquescent. This salt is sometimes used in pharmacy, chiefly as an external application.‡

Of tin,

1636. *Acetate of Tin*. This mineral is slowly acted on by acetic acid, but a *protacetate* and *peracetate of tin* may be made by mixing acetate of lead with saturated solutions of the protochloride and perchloride of tin. These solutions have been recommended as mordants for the use of dyers. The protacetate is crystallizable. Vinegar kept in tin vessels dissolves a very minute portion of the metal; and in pewter vessels it likewise dissolves a small portion of the lead, where in contact both with the vinegar and air; hence distilled

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If we combine with this mixturc 400 parts of oxygen $= O_4$
we have of water 337.44 . . . $= H_6 O_3$
acetic acid 643.20 . . . $= H_6 C_4 O_3$

Hence 100 parts by weight of alcohol take 68.89 parts of oxygen, and there are produced 68.11 parts of water, and 110.78 of acetic acid. Ure's *Dict. of Arts and Manuf.* 2 and 1001.

* Thomson.

† According to Thomson it consists of 1 atom acetic acid, 1 protoxide of iron, 3 atoms water.

‡ According to Messrs Aikin, the specific gravity of a saturated solution of acetate of zinc, made by digesting the salt in distilled vinegar, is 1056. Of this solution 900 grains contain 53 of dry, or 82.6 of crystallized acetate. One ounce by measure of the solution weighs 506 grains, and contain 29.8 grains of dry, or 46.5 grains of crystallized salt.

vinegar, which has been condensed in a pewter worm, affords generally traces of both metals.*

Acetate of copper,

1637. *Acetate of Copper.* By exposing copper to the fumes of vinegar, it becomes gradually incrusted with a green powder called *verdigris*,† which is separable by the action of water into an insoluble *subacetate of copper*, and a soluble *acetate*.

Acetate of copper may be obtained by digesting verdigris, or oxide of copper, in acetic acid; by evaporating this solution, it is obtained in prismatic crystals of a fine green tint. It dissolves sparingly in water and alcohol, and communicates a beautiful blue-green colour to the flame of the latter; by distillation it affords a very pure acetic acid.

Of lead,

1638. *Acetate of Lead.* 1 at. acid, 1 protox. lead, 3 water (T). This is the *Sugar of Lead*, and *Salt of Saturn* of the old chemists: it may be regarded as the most important of the acetates; it is used in pharmacy, and by dyers and calico-printers for the preparation of acetate of alumina and of iron, which are formed by mixing its solution with that of the sulphates of those metals, an insoluble sulphate of lead being at the same time produced. Acetate of lead is formed by digesting the carbonate in distilled vinegar, or in the acetic acid obtained by the destructive distillation of wood; it usually occurs in masses composed of acicular crystals; the crystalline form is an oblique angled prism.‡ Its taste is sweet and astringent, and it is soluble in about four parts of water at 60°.

When exposed to the air it undergoes no change. When dissolved in water, a small quantity of white powder falls, which is a carbonate of lead, formed by the carbonic acid which usually exists in water, or a sulphate when sulphuric acid is present. If carbonate of lead is formed a slight addition of acetic acid renders the solution clear.

Sub-acetate of lead.

1639. The *sub-acetate* of lead,§ commonly called *extractum saturni*, is prepared by boiling acetate of lead with litharge. This salt is less sweet and less soluble in water than the acetate, has an alkaline reaction and crystallizes in white plates by evaporation. It is decomposed by a current of carbonic acid, with production of pure carbonate of lead; and forms a turbid solution. It appears from the analysis of Berzelius to consist of 1 atom of acid and 3 atoms of the oxide of lead.

Acetates of mercury.

1640. *Protacetate of Mercury* is formed by mixing a solution of nitrate of mercury with acetate of potassa.

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* Vauquelin, *Ann. de Chim.* xxxii.

† *Diacetate* of Thomson, 1 atom acid, 2 oxide of copper, 6 water. According to Ure, verdigris is a mixture of crystallized acetate and subacetate in varying proportions. See description of the manufacture in Ure's *Dict.* 1273.

The composition of the acetate, as stated by Thomson, is 1 at. acid, 1 oxide copper, 1 water. Phillips has given the following comparative statement of the composition of the different kinds of verdigris:

	Blue Crystals.	French Verdigris.	English.
Acetic acid . . .	28.30	29.3	29.62
Peroxide copper . .	43.25	43.5	42.25
Water . . .	28.45	25.2	27.51
Impurity . . .	0	2.0	0.62
	100	100	100

‡ Brooke, in *Ann. Philos.* (2d series) vi. 374.

§ *Trisacetate* of Thomson who has described several acetates of lead, for an account of which see *Inorg. Chem.* ii. 642.

For this purpose dissolve three ounces of mercury in about four ounces and a half of cold nitric acid, and mix this solution with three ounces of acetate of potassa previously dissolved in eight pints of boiling water, and set the whole aside to crystallize, which takes place as the liquor cools, and the acetate of mercury then separates in the form of micaceous crystalline plates, which are to be washed in cold water, and dried on blotting-paper.[*]

This salt has an acrid taste, and is very difficultly soluble in water, requiring, according to Braconnot,[†] 600 parts of water. It is insoluble in alcohol. It was once used in medicine.[‡] The peracetate is formed by dissolving red oxide of mercury in acetic acid, and boiling the solution on fresh oxide till the acid is saturated.

Acetate of alumina. 1641. *Acetate of Alumina.* This salt is extensively employed by calico-printers as a mordant or basis for fixing colours; they produce it by mixing solutions of alum and acetate of lead: about three pounds of alum are dissolved in eight gallons of water, and a pound and a half of sugar of lead stirred into it; a copious formation of sulphate of lead ensues which is allowed to subside, and the clear liquor holding acetate of alumina and a portion of undecomposed alum in solution, is then drawn off, a portion of pearlash and chalk being added to it previous to use, in order to saturate any excess of acid.

1642. Acetate of alumina, formed by digesting recently precipitated alumina in acetic acid, may be procured in deliquescent acicular crystals of an astringent taste, and containing, according to Richter, 73.81 acid + 26.19 alumina: hence it is probably a *binacetate.*

This salt is also produced by the mutual decomposition of acetate of lime and alum. A gallon of a solution of the acetate, of a sp. gr. of about 1.050, equivalent to nearly half a pound avoirdupois of dry acetic acid, is employed for every 2¾ lbs of alum.[§]

Lactic acid. 1643. *Lactic Acid.* $C_6H_4O_4 = 72$. When milk is kept for some time it turns sour, and to the acid evolved Scheele gave the name *lactic;* it has since been obtained from several vegetable bodies left to spontaneous fermentation. Gay-Lussac and Pelouze have obtained it from the beet root juice.[||] It is colourless, of a syrupy consistence, and at 69° has a sp. gr. of 1.215. It has no smell, but is extremely sour. Water and alcohol dissolve it. Boiled with concentrated $\overset{\cdot\cdot\cdot\cdot\cdot}{N}$ it is converted into oxalic acid. It dissolves the phosphate of lime of bones rapidly; boiled with acetate of potassa, it disengages the acetic acid.

Effect of heat. 1644. The concentrated acid, heated gradually, becomes more fluid, darker, and gives a white solid, which when pure dissolves in boiling alcohol, from which crystals are deposited on cooling. The crystals fuse at 125°, and boil at 482°: they give out white irritating vapours, which condense upon cold surfaces and recrystallize; they are inflammable. The salts formed with this acid are termed *lactates.*[¶]

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[*] *Edin. Pharmacop.* In preparing this salt, the quantity of water for dissolving the acetate need not be so large as above directed, one pint being sufficient, but it is necessary to pour the mercurial solution into the acetate.

[†] *Ann. de Chim.* lxxxvi. 92.

[‡] Proust, *Jour. de Phys.* lvi.

[§] Ure's *Dict.*—art. *Alumina.*

[||] For details of the process see Thomson's *Chem. of Org. Bodies,* 1.22.

[¶] Liebig has shown that the acid in *sauer kraut* is the lactic. *Ann. de Pharm.*, xxiii. 113.

Sect. II.

Benzoic acid.

1645. *Benzoic Acid.* This acid exists in gum benzoin, in dragon blood, &c.; it is formed according to Liebig by the oxidation of the hyduret of benzule[*] in the air, and by the decomposition of many compounds of benzule and of hippuric acid and amygdaline by oxidizing agents; by the action of potassa on the essential oils, cinnamon oil, &c.

Process.

Gum benzoin, in coarse powder, alone or mixed with an equal weight of sand, is spread upon the bottom of a round vessel of iron, the sides of which should not be more than three inches high. A sheet of dry bibulous paper is stretched tightly over the opening, and fastened to the sides of the vessel by a little paste. A hat made of thick paper, and of the common form of a man's hat, is made to cover the whole, and tightly tied to the sides of the vessel by a strong string. The vessel is now placed upon sand spread upon an iron plate, below which a fire is kept for 3—4 hours. The vapours of the sublimed benzoic acid pass readily through the pores of the bibulous paper, and are deposited in crystals upon the hat; the crystals are prevented from falling back into the iron vessel by the paper which closes its opening.[†] This is continued as long as a deposite of crystals is observed.

The moist way.

Or in the moist way; equal parts of finely powdered benzoin and hydrate of lime are most intimately mixed, and then boiled for several hours in 40 parts of water; the filtered liquid must then be evaporated to one fifth its vol. and treated with hydrochloric acid, when the benzoic acid will crystallize as the solution cools.[‡]

Another.

Or hippuric acid[§] is boiled for one quarter of an hour in nitric acid of sp. gr. 1.42, after which water is added and the solution allowed to crystallize. The acid obtained from gum benzoin is purified either by a second sublimation, or being boiled in nitric acid, or by passing chlorine gas through its boiling aqueous solution.

Ready formed in benzoin.

1646. The benzoic acid exists ready formed, and principally in a free state, in the gum benzoin, from which it is separated by sublimation. On boiling hydrate of lime with gum benzoin, the benzoic acid is dissolved, and the resinous parts left; by a strong acid the benzoate of lime is decomposed, and the benzoic acid separated.[||]

Properties.

1647. This acid crystallizes in soft white scales, which are flexible, transparent, and of a pearly lustre; or in hexagonal needles. When pure it is inodorous, but if gently warmed it smells like gum benzoin; it has a slightly biting but sweetish taste, produces a burning sensation in the throat, reddens litmus feebly, fuses at 250°, sub-

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Suberic Acid, $C_8H_6O_3$, is obtained by digesting cork in nitric acid.

Naphthalic Acid, see Naphthaline.

[*] Benzule denotes the hypothetical radical of a series of compounds which are produced from the volatile oil of the bitter almond, or are connected with it by certain relations. The oil of bitter almonds itself is always a product of the decomposition of amygdalin, which exists in the kernels of most stone fruits, and in the leaf of the laurocerassus, from which it may be obtained in a variety of ways. Its formula is $C_{14}H_5O_2$; symb. = Bz; eq. = 106.68. Liebig and Turner's *Elem.* 823.

Benzule has not been obtained in a free state, but may be separated from one substance and transferred to another in numerous combinations.

[†] Mohr.

[‡] If less lime be taken, or if a perfect admixture be neglected, the whole will bake into a solid mass in the boiling water; in this case the hard fragments, after the whole has cooled, must be again mixed with hydrate of lime.

[§] An acid obtained from the urine of the horse, convertible into benzoic acid, see process in Thomson's *Org. Chem.* 47.

[||] For an economical method of purifying the acid see *Ann. de Chim. et Phys.*, lvi. 443, and Thomson's *Org. Chem.* 42.

limes at 300°, (an appearance of light is frequently observed in the dark,) boils at 462°, yielding a vapour of sp. gr. 4.27.

The sublimation may be beautifully seen by suspending a small branch of a shrub within a tall glass without a bottom, placing a small quantity of the acid upon a plate of metal on a stand, covering it with the jar and applying the heat of a lamp to vaporize the acid; the branch will be covered with delicate white crystals of the acid.

Fig. 188.

Action of chlorine, &c.

1648. It is not changed by chlorine, or by being boiled with dilute $\overset{\cdot\cdot\cdot\cdot\cdot}{N}$, but by the fuming acid it is converted into a yellow resinous substance of a strongly bitter taste. It is dissolved by concentrated $\overset{\cdots}{S}$, but falls upon the addition of water. It is soluble in 200 parts of cold and 25 parts of boiling water. Its formula is $C_{14}H_5O_3+aq.$, or $BzO+aq.$; eq. =123.68.

Benzoate of ammonia.

1649. *Benzoate of Ammonia*, NH_4O, BzO, is prepared by dissolving benzoic acid in pure concentrated ammonia, by the aid of heat, till the latter is saturated, when it is allowed to cool. It forms feathery acicular crystals, which deliquesce in a moist air, and are soluble in absolute alcohol. The acid salt is formed by boiling and exposing to spontaneous evaporation the neutral salt, with the loss of ammonia, it is deposited in large regular crystals.

Soluble and insoluble benzoate.

1650. The soluble benzoates of metallic oxides have a strong biting saline taste, and are decomposed by most other acids with the separation of benzoic acid; the same change occurs with the insoluble salts, when the acid which is added forms a soluble salt with the metallic oxide. The benzoates of the alkalies are decomposed by destructive distillation into carbonates, and a variety of new products. Exposed to a red heat with an excess of hydrate of lime, the acid is decomposed into benzole,* and carbonic acid which unites with the lime.† L.

Fixed Acids.

Malic acid.

1651. *Malic Acid.* $C_4H_2O_4$, eq. 60.0. The existence of a peculiar acid in the juice of apples, was shown by Scheele, in 1785. He obtained it by adding solution of acetate of lead to the expressed juice of unripe apples, by which a *malate of lead* was formed, and afterwards decomposed by sulphuric acid. Vauquelin obtained it by a similar process from the juice of the *house-leek*. The same acid exists in the berries of the *mountain-ash*, from which it was first obtained by Donovan in 1815, and called by him *sorbic-acid;* he has given the following process for its preparation.‡

Process.

Express the juice of the ripe berries, and add solution of acetate of lead, filter, and wash the precipitate with cold water, then pour boiling water upon the filter, and allow it to pass through the precipitate into glass jars; after some hours crystals are deposited, which are to be boiled with 2.3 times their weight of sulphuric acid, specific gravity 1.090. The clear liquor is to be poured off, and, while still

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* 73.44 carb.+6 hyd. = 79.44; $C_{12}H_6$. (Liebig.)

† For description of *benzoates* see Turner and Liebig's *Elem.* 827.

Cinnamomic Acid was obtained by Dumas and Peligot from oil of cinnamon, which they consider a compound of hydrogen and the base of this acid or *cinnamoyl*. The oil they term *hydret of cinnamoyl*. This acid occurs in old oil of cinnamon in large yellow crystals, soluble in boiling water.

Esculic Acid is obtained from the horse-chestnut (*Esculus* hippocastatum).

‡ *Phil. Trans.* 1815.

hot, a stream of sulphuretted hydrogen is to be passed through it, to precipitate the remaining lead; the liquid is then filtered, and when boiled so as to expel the sulphuretted hydrogen, is a solution of the pure vegetable acid.

Malic acid may also be obtained by steeping sheet-lead in the juice of apples; in a few days, crystals of malate of lead form, which may be collected and decomposed by dilute sulphuric acid.[*]

Properties.

1652. Malic acid, when carefully prepared, is colourless and very sour. It forms crystallizable salts with many of the metallic oxides, and its salts are termed *malates*.[†]

Citric acid.

1653. *Citric Acid*, $C_4H_2O_4$, eq. 60.0, is obtained by the following process from lemon or lime juice:

How prepared.

Boil the expressed juice for a few minutes, and when cold, strain it through fine linen; then add powdered chalk as long as it produces effervescence, heat the mixture, and strain it as before: a quantity of citrate of lime remains upon the strainer, which, having been washed with cold water, is to be put into a mixture of sulphuric acid with twenty parts of water: the proportion of acid may be about equal to that of the chalk employed. In the course of twentyfour hours the citrate of lime will have suffered decomposition, and sulphate of lime is formed, which is separated by filtration. The filtered liquor, by careful evaporation, as directed for tartaric acid, furnishes crystallized citric acid.[‡]

In different states of purity it is employed by the calico-printers, and used for domestic consumption. The proportion of citric acid afforded by a gallon of good lemon-juice, is about eight ounces.[§]

Process with currants.

1654. Citric acid may be obtained from currants by the following process:

Pound the currants and cause them to ferment; when this is over, distil to separate the alcohol. Saturate the hot liquid with chalk; wash the citrate of lime with water, and press. Mix the citrate of lime with water, and reduce to the consistence of syrup; decompose by sulphuric acid diluted with twice its weight of water. Saturate the citric acid, thus obtained, with carbonate of lime; press and treat as before with sulphuric acid. Remove the colour by animal charcoal and evaporate.[‖]

Characters.

1655. Citric acid forms prismatic crystals of a very sour taste, very soluble in water, and containing, according to Berzelius, 1 atom real acid + 2 atoms water, a portion of which it loses by exposure to heat.

1656. Exposed to heat, the crystals undergo the watery fusion, and the acid is itself decomposed.[¶]

Tartaric acid.

1657. *Tartaric Acid.* $C_4H_2O_5$, eq. 66.24. { Derivative Acids. *Pyrotartaric. Pyruvic.*

This acid exists in several vegetable substances; it is one of the sour principles of many fruits, and is said to be abundant in the potato-apple. Tartaric acid is generally obtained from the *bi-tartrate of potassa*, (*purified cream of tartar.*)

Mode of obtaining.

Mix 100 parts of this salt in fine powder with 30 of powdered chalk, and gradually throw the mixture into 10 times its weight of boiling water; when the liquor has cooled, pour the whole upon a linen strainer, and wash the white

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[*] For other processes, &c., see Thomson's *Inorg. Bodies*, ii. 76.

[†] For an account of which, and of the acids derived from the decomposition of malic acid, see T. *Org. Bodies*, 53.

[‡] For a mode of obtaining it from gooseberries see *Ann. Philos.* N. S. iv. 152. Many circumstances which have not here been alluded to, are requisite to ensure complete success in the operation; these have been fully described by Parkes, in his *Chem. Essays*.

[§] Twenty gals. of good lemon-juice afford 10 lbs. of crystals. (Ure.)

[‖] Tillog in *Ann. de Chim. et de Phys.* xxxix. 222.

[¶] For derivative acids see T. or B. 62, and for *Citrates*, B. ii. 515.

powder which remains with cold water; this is a *tartrate of lime;* diffuse it through a sufficient quantity of water, add sulphuric acid equal in weight to the chalk employed, and occasionally stir the mixture during 24 hours; then filter, and carefully evaporate the liquor to about one fourth its original bulk; filter again, and evaporate with much care nearly to dryness; re-dissolve the dry mass in about 6 times its weight of water, render it clear by filtration, evaporate slowly to the consistency of sirup, and set aside to crystallize.

By two or three successive solutions and crystallizations, tartaric acid will be obtained in colourless crystals, soluble in 6 parts of water at 60°. Their primary form is an oblique rhombic prism.*

Properties. 1658. The crystals melt at a heat a little exceeding 212° into a fluid which boils at 250° and leaves a semi-transparent mass on cooling, slightly deliquescent.

The aqueous solution of tartaric, in common with the other vegetable acids, soon becomes mouldy, and suffers decomposition.

Forms double salts. 1659. Tartaric acid has a great tendency to combine at once with two bases and form double salts. In consequence of this property it prevents antimony from being precipitated as usual by water, and even hinders alkaline bodies from precipitating solutions of the metal in acids as they usually do. T.

Tartrate of potassa. 1660. *Tartrate of Potassa,* (formerly *soluble tartar*) is formed by saturating the excess of acid in *tartar* by potassa, and boiling. According to Phillips,† 100 parts of tartar require 43.5 of sub-carbonate of potassa. The resulting salt is soluble in less than twice its weight of water; it forms large prismatic crystals. These contain 1 atom acid, 1 potassa, and 2½ water.

This salt is used in pharmacy as an aperient; it is the *potassæ tartras* of the *Pharmacop.* Its taste is saline, and somewhat bitter.

Bitartrate, or crude tartar. 1661. *Bi-tartrate,* or *Supertartrate of Potassa. Tartar.* This substance exists in considerable abundance in the juice of the grape, and is deposited in wine casks, in the form of a crystallized incrustation: called *argol* or *crude tartar.* It is purified by solution and crystallization, which renders it perfectly white;‡ when in fine powder it is termed *cream of tartar.*

It may also be formed by adding excess of tartaric acid to a solution of potassa. The mixture presently deposits crystalline grains, and furnishes a striking example of the diminution of solubility by increase of acid in the salt. **Tartaric acid test for potassa.** Upon this circumstance the use of tartaric acid as a test for potassa depends, for soda forms an easily soluble supertartrate and consequently affords no precipitate. B. Its constituents are 2 at. acid, 1 potassa, 2 water. T.

Impurities. 1662. The tartar of commerce is never quite pure. According to Thomson it contains five per cent. of tartrate of lime.§ It is sometimes adulterated by the addition of pounded quartz, and by calcareous spar; the former may be detected as an insoluble residue by boiling the powdered tartar with half its weight of potassa or of borax in eight parts of water; the latter produces effervescence with dilute hydrochloric acid.

Acts as a simple acid. 1663. Bi-tartrate of potassa, it is observed by Gay-Lussac, acts, in

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* Brooke in *Ann. Philos.* vi. N. S.

† *Remarks on Pharmacop.*

‡ See process B. ii. 500, and *Jour. de Phys.* i. 67.

§ *Inorg. Chem.* ii. 433. When present it separates in tufts of acicular crystals from the hot solution. B. 502.

many cases, like a simple acid, and even dissolves oxides that are insoluble in the mineral acids and in the tartaric acid. He proposed its use, therefore, in mineral analysis.

Effect of heat, &c.

1664. When exposed to heat, tartar fuses, blackens, and is decomposed: and carbonate of potassa is the remaining result. Provided the tartar be free from lime, which however is seldom the case, this furnishes a good process for obtaining pure carbonate of potassa. The aqueous solution of tartar becomes mouldy when exposed to air, and the tartaric acid being entirely decomposed leaves a weak solution of carbonate of potassa.

Use.

The component parts of tartar render it an excellent flux in the reduction of metallic ores upon a small scale, its alkali promoting their fusion, and the carbonaceous matter tending to reduce the oxides.

Tartrate of potassa and soda,

1665. *Tartrate of Potassa and Soda* is prepared by saturating the excess of acid in tartar, with carbonate of soda; it is the *tartras potassæ et sodæ* of the *Pharmacop.*; it forms prismatic crystals.[*] It has long been used in pharmacy under the name of *Rochelle Salt* and *Sel de Seignette*. It consists of 1 atom of the tartrate of potassa, 1 atom of the tartrate of soda, and 10 atoms of water. T. II.793.

It is frequently made extemporaneously by dissolving equal weights of tartaric acid and the sesquicarbonate of soda in separate portions of water, and then mixing the solutions.[†]

Of iron and potassa.

1666. *Tartrate of Iron and Potassa.* This is the *Ferrum tartarisatum* of the London *Pharmacop.*, but it is most conveniently employed as a medicine in solution, which may be formed by digesting 1 part of soft iron filings with 4 of tartar.

This mixture should be made into a thin paste with water, and digested for some weeks, till the acid is neutralized, fresh portions of water being occasionally added to prevent exsiccation. The solution of this compound which contains the iron in the state of peroxide, is possessed of some curious properties, first pointed out by Phillips.[‡]

Brunswick green.

1667. *Tartrate of Potassa and Copper* is formed by boiling oxide of copper and tartar in water: the solution yields blue crystals on evaporation; or if boiled to dryness, furnishes one of the pigments called *Brunswick green*.

Tartrate of antimony and potassa.

1668. *Tartrate of Antimony and Potassa—Emetic Tartar.* This compound may be obtained by boiling protoxide of antimony, with pure supertartrate of potassa. It is the *antimonium tartarizatum* of the *London and U. S. Pharmacop.*

Preparation of emetic tartar.

Emetic tartar may be prepared by boiling a solution of 100 parts of tartar with 100 parts of finely levigated glass of antimony, or of the sesquioxide; the ebullition should be continued for half an hour, and the filtered liquor evaporated to about half its bulk, and set aside to crystallize; octohedral and tertrahedral crystals of the emetic salt are thus obtained; and there is generally formed along with them a portion of tartrate of lime and potassa, which is deposited in small

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[*] The forms of its crystals arising from the modification of a right rhombic prism, are represented by Brooke in *Ann. Philos.* N. S. v. 451.

Soda powders.

[†] *Soda or Sodaic* powders of the shops are packed in two distinct papers, the one blue and the other white, the blue containing half a drachm of carbonate of soda, the white gr. xxv. of tartaric acid: when dissolved and mixed, effervescence takes place, but the liquid is by no means similar to "soda water."

[‡] Experimental Examination of the *London Pharmacop.* 98.

tufts of a radiated texture, and which may easily be separated when the mass is dried.*

Properties.

1669. Emetic tartar is a white salt, slightly efflorescent, soluble in about 14 parts of cold and 2 parts of boiling water. It is decomposed by the alkalies, and when heated with ammonia, a portion of protoxide of antimony is thrown down, and a very soluble compound remains in the liquor. Hydrosulphuric acid gas produces an orange-coloured precipitate in its solution. It is decomposed by bitter and astringent vegetable infusions, but they do not render it inactive as a medicine.† Phillips has shown that emetic tartar consists of 1 atom bi-tartrate of potassa, 3 sesquioxide of antimony, 3 water.

Analysis.

According to Thomson emetic tartar consists of 2 atoms tartaric acid, 3 atoms sesquioxide of antimony, 1 atom of potassa and 2 atoms of water.‡

Meconic acid.

1670. *Meconic Acid.* $C_7H_2O_7$ eq. 100.00.

Derivative Acids.
Pyromeconic $C_{10}H_3O_4$.
Metameconic $C_{12}H_4O_{10}$.

This acid exists in opium and was discovered by Sertürner and called meconic acid from the Greek Μηκων, *poppy*. It is procured by several processes of which the following is recommended by Thomson§ as the easiest.

Process for.

Make an infusion of opium in water acidulated with sulphuric acid. The infusion is mixed wilh chloride of calcium in sufficient quantity to throw down the sulphuric and meconic acids in combination with lime. This precipitate is washed, first with cold water, and afterwards with boiling alcohol. It is next mixed with ten times its weight of water, and heated to about 194°. Add by little and little, agitating violently, a quantity of hydrochloric acid, sufficient to dissolve the meconate of lime, which constitutes the greater part of the precipitate. Pour the liquid upon a filter, previously washed with hydrochloric acid. On cooling, light and brilliant crystals of bimeconate of lime are deposited, which are to be dried between the folds of a cloth; dissolve them in hot water, and add a sufficient quantity of hydrochloric acid to decompose the salt. Keep the liquid for some time hot, but under 212°; on cooling, crystals of meconic acid are deposited.‖

To deprive it of colour, saturate by a dilute solution of caustic potassa. Dissolve the meconate of potassa formed, in a small quantity of hot water; let it cool, and expose the resulting magma to pressure. Dissolve and crystallize anew, and finally decompose the salt by hydrochloric acid.

Hare's.

Hare has given the following process:¶ To an aqueous infusion of opium add acetate of lead, collect the meconate of lead by a filter, and expose it to hydrosulphuric acid gas; the meconic acid will be set free. The solution is of a reddish amber colour, and furnishes, by evaporation, crystals of the same hue. Instead of hydrosulphuric acid, sulphuric acid may be used to liberate the meconic acid.

Properties.

1671. Meconic acid crystallizes in white transparent scales. It is not altered by cold $\dddot{S}$ or hydrochloric acid; dilute $\overset{\cdot\cdot\cdot\cdot\cdot}{N}$ converts it

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* Phillips, in his *Experimental Examinations of the London Pharmacop.*, has stated several facts respecting the formation of this salt, which will be found useful to the manufacturer. See Bigelow's *Sequel*, 75.

† According to Orfila, the compound of tannin and oxide of antimony is inert, and he recommends a decoction of cinchona bark as an antidote.

‡ *Inorg. Chem.* 11.799. For an account of *racemic acid* and remarks on its compounds see T. *Org. Chem.* 67.

§ *Org. Bodies*, 80.

‖ If the crystals are mixed with bimeconate of lime, repeat the treatment with hydrochloric acid, or separate the crystals of bimeconate, which are much lighter, by levigation. T. *Chem. Org. Bodies*, 80.

¶ *Amer. Jour.* xii. 293. For other processes, see B. 11, 535.

into oxalic acid. It is soluble in 4 times its weight of hot water; when long boiled the solution becomes yellowish, then red, and at last deep brown, at the same time $\ddot{C}$ is disengaged, and the acid is changed into metameconic acid, which is no longer altered by the water. This change may be produced by the action of a water-bath continued for several days. The new acid precipitates during the cooling. It consists, according to Liebig, of carbon 41.54, hydrogen 2.07, oxygen 56.39.

Forms salts. 1672. Meconic acid combines with bases in three proportions and it forms with them neutral salts; the bisalts strike a very deep red with the persalts of iron, which disappears when the iron is reduced to protoxide, but re-appears when the iron is again peroxidized. The meconates are, in general, insoluble in alcohol.

Action of nitrate of silver. 1673. When nitrate of silver is poured into a solution of meconic acid, and a little more $\overset{\cdot\cdot\cdot\cdot\cdot}{N}$ added than is sufficient to dissolve the meconate of silver, if we heat the liquid the salt is converted into cyanide of silver. The liquid, at first limpid, becomes gradually filled with flocks of cyanide. It contains also oxalate of silver in solution. If too much $\overset{\cdot\cdot\cdot\cdot\cdot}{N}$ be added, much oxalate of silver is formed, but no cyanide.*

Gallic acid. 1674. *Gallic Acid.* $C_7H_3O_5$, eq. 85.00. $\left\{\begin{array}{l}\textit{Derivative Acids.}\\ \text{Pyrogallic } C_6H_3O_3\\ \text{Metagallic } C_{12}H_3O_3\end{array}\right\}$ This acid derives its name from the *gallnut*, whence it was first procured by Scheele. It may be obtained by several processes,† among which the following deserve notice:

How obtained. Moisten bruised gallnuts, and expose them for four or five weeks, to a temperature of about 80°. A mouldy paste is formed, which is to be squeezed dry, and digested in boiling water; it then affords a solution of gallic acid, which may be whitened by animal charcoal, and which, on evaporation, yields gallic acid, crystallized in white needles.‡

Boil an ounce of powdered galls in 16 ounces of water down to 8, and strain; dissolve 2 ounces of alum in water, precipitate the alumina by carbonate of potassa, and, after edulcorating it, stir it into the decoction; the next day filter the mixture; wash the precipitate with warm water, till this will no longer blacken sulphate of iron; mix the washing with the filtered liquor, evaporate, and the gallic acid will be obtained in acicular crystals.§

Properties. 1675. Gallic acid when pure is in snow-white needles, requiring 100 times their weight of cold water to dissolve them. When dropped into a solution of persulphate of iron, a deep blue precipitate falls, which dissolves slowly in the liquid, and after an interval of some days, the liquid becomes almost colourless. Sulphuric acid removes nearly all the iron and protosulphate of iron crystallizes. The same changes are quickly produced by boiling, with the disengagement of $\ddot{C}$.

Precipitates. 1676. Gallic acid forms white precipitates with baryta, strontia, and lime water which redissolves in an excess of acid. Acetate or nitrate of lead produces a white precipitate, not altered in colour by exposure to the air.‖

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* Liebig. † For others see T. *Inorg. Bodies*, ii. 99, and B. 519.

‡ Braconnot, *Ann. de Chim. et Phys.* ix. 181.

§ Fiedler in Nicholson's *Dict.* 1.236.

‖ Pelouze in *Ann. de Chim. et Phys.* liv. 348.

Characteristic property.

1677. The characteristic property of gallic acid is to strike a deep blue with the salts of iron, particularly the sulphate. The tannin, which is another constituent of nutgalls, possesses the same property.

1678. Gallic acid and tannin are of great importance in the formation of ink, and the precipitate formed is retained in suspension by mucilage.*

Kinic acid.

1679. *Kinic Acid.* $C_{15}H_9O_9$, eq. 171.00. { *Deriv. Acid.* Pyrokinic. } Kinic acid derives its name from having been discovered in Peruvian bark. A watery infusion of the bark evaporated to a syrup and treated with alcohol, leaves a viscid mass containing kinate of lime and gum. By solution and crystallization, kinate of lime may be procured in crystals, from which the lime may be separated, by dissolving the kinate in water, and adding sulphuric or oxalic acid. It forms soluble salts with alkalies, and metallic oxides.†

Obtained.

Tannic acid.

1680. *Tannic Acid—Tannin.* $C_{18}H_8O_{12}$, eq. 212. This substance exists in an impure state in the excrescences of several species of oak, called gallnuts; in the bark of most trees; in some inspissated juices, such as kino and catechu; in the leaves of the tea-plant, sumach and ~~whortleberry~~ bear-berry (uva ursa), and in astringent plants generally, being the chief cause of the astringency of vegetable matter. It is frequently associated with gallic acid, as in gallnuts, in most kinds of bark, and in tea; but in kino, catechu, and cinchona bark, little or no gallic acid is present.

Source.

It may be prepared pure from nutgalls by the following process:

Obtained.

Into the mouth of a flask, fit, by grinding, a narrow glass vessel, fitted with a cork, or stopper, at the upper end. Fill the bottom of the long narrow glass vessel, where it enters the flask, with a little cotton, and place above the cotton a quantity of nut-galls, in fine powder, filling about half the vessel. Pour over this a sufficient quantity of the common sulphuric ether of commerce to fill the rest of the vessel. Put in the stopper and set the whole aside. The following day, there will be found in the flask two distinct layers of liquid: one very light and fluid in the upper part; the other heavier, of a light amber colour, occupying the bottom. Pour the whole into a funnel, stopping the bottom with the finger; let it remain at rest for a few minutes, till the two liquids

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Ink.

* To make twelve gallons of good ink, we may take nutgalls 12 lbs., green sulphate of iron 5 lbs., gum senegal 5 lbs., water 12 gals. The nutgalls are to be put into a cylindrical copper, of a depth equal to its diameter, and boiled, during three hours with three fourths of the above quantity of water, adding fresh water to replace what is lost by evaporation. Empty the decoction into a tub, draw off the clear liquor and drain the lees. Dissolve the gum in a small quantity of hot water, filter, and add to the clear decoction. The sulphate of iron must be separately dissolved and mixed. The colour darkens by exposure. But ink is more durable when used pale. Ure's *Dict. Arts and Man.* 677.

The following gives a good ink. Bruised galls 8 oz., sulphate of iron 4 oz., gum arabic 3 oz., sugar candy 1 oz. Boil the galls in twelve pints of water down to six, strain, and add the other ingredients, stirring till dissolved. After twentyfour hours decant and bottle. See other methods in R. 11.523.

The tendency of the ink to become mouldy is much diminished by keeping a few cloves in the ink bottle, or by dissolving in each pint of the ink about three grains of corrosive sublimate.

The colour of common writing ink is apt to fade, in consequence of the decomposition of its vegetable matter; and when thus illegible, it may often be restored by washing the writing with vinegar, and subsequently with infusion of galls. Acids also destroy its colouring matter, and those inks which resist their action contain some other colouring principle, usually finely powdered charcoal. Common writing ink is, for this reason, much improved by dissolving in the quantity above-mentioned about an ounce of *Indian Ink*, which is lamp-black made into a cake with isinglass. See Macculloch on Indelible Ink, &c. Brewster's *Jour.* i. 318, and *Bost. Jour.* ii. 344.

† For details, and other fixed acids, see T. *Org. Bodies*, 89.

separate; allow the heavier to fall into a capsule, and set the lighter portion aside in order to recover the ether, of which it principally consists, by distillation. Wash the dense liquid two or three times with sulphuric ether; then dry it in a stove, or, *in vacuo*, over sulphuric acid. Much vapour of ether and water is disengaged; the bulk increases, and a spongy residue is left, brilliant, and sometimes colourless, though usually yellowish. This substance is *tannin* in a pure state. T. 109.

Properties.

1681. Pure tannic acid is colourless and inodorous, has a purely astringent taste without bitterness, and may be preserved without change in the solid state, very soluble in water, reddens litmus, and decomposes alkaline carbonates with effervescence. Alcohol and ether dissolve tannic acid, but more sparingly than water. Solutions of tannic acid do not affect pure protosalts of iron, but strike a deep blue precipitate with the persalts: a strong solution of it yields a copious white precipitate with the sulphuric, nitric, hydrochloric, phosphoric, and arsenic acids, but none with the oxalic, tartaric, lactic, acetic, citric, succinic, and selenious acids. It is precipitated also by the carbonates of potassa and ammonia, by the alkaline earths, alumina, and many solutions of the second class of metals. With cinchonia, quinia, brucia, strychnia, codeia, narcotina, and morphia, it yields white tannates, which are sparingly soluble in pure water, but are dissolved readily by acetic acid. By digestion with nitric acid it yields oxalic acid.

Absorbs oxygen.

1682. A solution of tannic acid may be preserved without change, provided it be excluded from oxygen gas; but in open vessels, it gradually absorbs oxygen, an equal volume of carbonic acid is evolved, it becomes turbid, and deposits a crystalline matter of a gray colour, nearly all of which is gallic acid. After digestion with a little animal charcoal, the gallic acid is perfectly white and pure. There is no doubt, therefore, of the conversion of tannic into gallic acid.

Distinguished.

1683. Tannic acid is distinguished from all substances, except gallic acid, by forming a deep blue precipitate with persalts of iron, and from gallic acid, by yielding with a solution of gelatin a white flaky precipitate, which is soluble in a solution of gelatin, but insoluble in water and gallic acid. This substance, to which the name of *tanno-gelatin* has been applied, is the basis of leather, being always formed when skins are macerated in an infusion of bark. When dried it becomes hard and tough, and resists putrefaction. Its composition is apt to vary, according to the relative quantities of the materials used in its formation.

Leather.

Exp.

To a strong solution of gelatin (common glue answers) add a strong infusion of gallnuts, the white precipitate may be collected upon a glass rod and pressed together, forming a tough extensible mass resembling new leather.

1684. From the experiments of Davy, it appears that the inner cortical layers of bark are the richest in tannic acid. Its quantity is greatest in early spring, and smallest during winter. Of all the varieties of bark which he examined, that of the oak contains the largest quantity of tannic acid.

1685. The various kinds of tannic acid obtained from cinchona bark, kino, and other sources, correspond in most respects with that above described; but at the same time some difference is observable, some kinds striking a green instead of a deep blue colour with the persalts of iron.[*] The tannic acid from catechu is less highly oxidized than that from gallnuts.

Artificial tannic acid.

1686. *Artificial Tannic Acid.* This substance was discovered by Hatchett, and is prepared by the action of nitric acid on charcoal.[†]

For this purpose 100 grains of charcoal in fine powder are digested in an ounce of nitric acid, of density 1.4, diluted with two ounces of water, with a gentle heat, until the charcoal is dissolved. The reddish-brown solution is then evaporated to dryness, in order to expel the nitric acid, the temperature being carefully regulated towards the close of the process, so that the product may not be decomposed.

Properties.

Artificial tannic acid is a brown fusible substance of a resinous fracture, astringent taste, and acid reaction; soluble in cold water and in alcohol. With a salt of iron and solution of gelatin it acts precisely in the same manner as natural tannic acid. It differs, however, from that substance in not being decomposed by the action of strong nitric acid.

1687. Artificial tannic acid is generated by the action of nitric acid, both on animal or vegetable charcoal, and on pit-coal, asphaltum, jet, indigo, common resin, and several other resinous substances. It is also procured by treating common resin, elemi, assafœtida, camphor, balsams, &c., first with sulphuric acid, and then with alcohol.

Oily Acids.

Oily acids.

1688. These acids are so called, because they are formed from oils or fat, and enter into the composition of soaps, or because they possess many of the characters of oils.[‡]

Margaric acid.

1689. In 1813 Chevreul made known an acid substance which enters into the composition of soaps, to which he gave the name of *margarine* and afterwards distinguished it as *margaric acid.* He found that this acid extracted from different bodies existed in two different states, and as the one contained more oxygen than the other, he distinguished them at first by the name of *margarous* and *margaric acids.* But he afterwards thought better to give to margarous acid the name of *stearic* acid,[§] and to retain the term *margaric* acid for the latter.

Stearic acid, Process for,

1690. The method of procuring stearic acid is as follows:

Make a soap by boiling mutton suet and caustic potassa together, with a sufficient quantity of water, till the whole is converted into soap. Dissolve one part of this soap in 6 parts of warm water, and mix the solution with about 40 parts of cold water, and leave it for some time in a temperature about 60°, or between 60° and 70°. A substance precipitates of a pearly lustre, which is a mixture of *bistearate of potassa* and *margarate* of potassa. Collect this on a filter and wash it. The liquid that has passed through the filter being mixed with a little acid to saturate the potassa, will yield an additional quantity of this two-fold soapy salt. By repeating this process several times, all the bistearate and margarate of potassa is obtained, and the water retains only the oleate of potassa. The bistearate and margarate of potassa is to be dried and dissolved in about 20 times its weight of hot alcohol of 0.82. When the alcohol cools, a quantity of bistear-

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[*] These have been distinguished by names formed from that of the substances which afford them. See Thomson, *Org. Bodies*, 112.

[†] *Phil. Trans.* 1805—6.

[‡] Thomson includes twentythree acids in this group. They were first distinguished by Chevreul, who devoted ten years to the assiduous study of fixed oils and fats. A few only of the most important will be described in the following pages, referring to Thomson's work for the study of the greater number.

[§] From στεαρ, tallow.

ate of potassa, mixed with margarate, precipitates, and oleate and margarate of potassa remains in solution in the alcohol. By repeated solution in boiling alcohol and cooling, the two substances are separated. If the acid does not now melt in water till the temperature rises to 158° it is pure stearic acid. The pure stearate of potassa is then decomposed by boiling with hydrochloric acid and water; when cool the stearic acid is separated.

Properties. 1691. *Stearic Acid*, $C_{70}H_{6}O_{5}$, eq. 527, is white, tasteless, and destitute of smell, insoluble in water; soluble in alcohol at 167° from which it crystallizes at 122°, becoming solid at 113°. It reddens vegetable blues and combines with bases forming salts called *stearates*. It burns like wax.

Margaric acid. 1692. *Margaric Acid*,* $C_{70}H_{70}O_{9}$, eq. 562, is distinguished from the last by melting at 140°, while that requires a temperature of 158°. When it is distilled with lime, a soft matter is obtained, which when pressed between folds of blotting paper, gives out oil, and a white substance remains which has been named *margarone*.

Obtained. 1693. To obtain pure margarone it is to be repeatedly dissolved in alcohol, and allowed to separate by crystallization. It is white, brilliant, and has a pearly lustre. It is a non-conductor of electricity and becomes electric by friction and pressure. It dissolves in fifty times its weight of boiling alcohol, of sp. gr. 0.836 but is mostly deposited on cooling; is incapable of forming a soap. It differs from margaric acid by wanting an atom of carbonic acid.

Oleic acid. 1694. *Oleic Acid*, $C_{70}H_{62}O_{7}$, eq. 538, is obtained from soap made with linseed or hemp oil with potassa. It is somewhat coloured and has an etherial smell, is insoluble in water, but soluble in alcohol. It decomposes the alkaline carbonates, reddens litmus, and forms salts, or rather soaps, to which the name of *oleates* is given. It burns like the fixed oils.

Action of sulphuric acid. 1695. When olive oil is treated with half its weight of concentrated sulphuric acid three acids are obtained, one of which has been called *sulpho-oleic*,† and this decomposed affords *hydro-oleic acid*. From the last named acid two liquids have been obtained having the same composition as olefiant gas, one of these boils at 131°, the other at 230°. The first has been recently called *Olein*, the second *Elain*.

Olein. 1696. *Olein* is white, very liquid, and lighter than water, with a strong odour, very combustible, and burning with a greenish flame. Its vapour appears to be poisonous.

Elain. *Elain* is less soluble in alcohol, and burns with a fine white flame. According to Thomson, olein is composed of 6 carbon and 6 hydrogen, and elain of 9 carbon and 9 hydrogen.‡

Acids containing Nitrogen.§

Azulmic acid. 1697. *Azulmic Acid*. $C_{8}H_{4}N_{4}O_{4}$. eq. 140. Boullay has given this name to an acid obtained from cyanogen gas that has undergone spontaneous decomposition. It is insoluble in water, but is dissolved by nitric acid and assumes a beautiful aurora-red colour. By heat it is

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* From *μαϱγαϱιτης a pearl.*

† Fremy, *Ann. de Pharm.* xx. 50.

‡ *Chlorophenisic* and *chlorophenesic* acids have been obtained from coal-tar by Laurent, by the action of chlorine, and were named from a supposed base, *phene* (from *φαινω I shine*), from their supposed existence in oil gas. *Ann. de Chim. et de Phys.* lxiii. 27. For details see T. *Org. Bodies*, 129.

§ Of these Thomson describes eight.

converted into hydrocyanate of ammonia, and a gas is evolved which burns with a blue flame and the odour of cyanogen.

Indigotic acid.

1698. *Indigotic Acid.* $C_{28}H7\frac{1}{2}N1\frac{1}{2}O_{15}$. This acid is obtained by boiling indigo in rather dilute nitric acid, formed by mixing nitric acid of sp. gr. 1.2 with an equal weight of water. To the solution, kept boiling, indigo, in coarse powder is gradually added, as long as effervescence continues; and hot water is occasionally added to supply loss by evaporation. The impure indigotic acid, deposited in cooling, is boiled with oxide of lead and filtered, in order to separate resin; and the clear yellow solution is decomposed by sulphuric acid, and again filtered at a boiling temperature. On cooling, the acid crystallizes in yellowish-white needles. In order to purify them completely, they were digested in water with carbonate of baryta; and the indigotate of baryta, deposited from the hot filtered solution in cooling, was dissolved in hot water, and decomposed by an acid. Indigotic acid was thus obtained in acicular crystals, of snowy whiteness, which contracted greatly in drying, and lost their crystalline aspect; but the dry mass was dazzling white, and had a silky lustre.

Properties.

1699. Indigotic acid decomposes carbonates, but is a feeble acid, and reddens litmus faintly. It requires 1000 times its weight of cold water for solution, but is soluble to any extent in hot water and alcohol. Heated in a tube it fuses, and sublimes without decomposition; and the fused mass, in cooling, crystallizes in six-sided plates. When heated in open vessels, it is inflamed, and burns with much smoke.*

Carbazotic acid,

1700. *Carbazotic Acid.* $C_{15}N_3O_{15}$, eq. 252. This name has been applied by Liebig to a peculiar acid formed by the action of nitric acid on indigo.

It is made by dissolving small fragments of the best indigo in 8 or 10 times their weight of moderately strong nitric acid, and boiling as long as nitrous acid fumes are evolved. During the action, carbonic, hydrocyanic, and nitrous acids are evolved; and in the liquid, besides carbazotic acid, is found a resinous matter, artificial tannin, and indigotic acid. On cooling, carbazotic acid is freely deposited in transparent yellow crystals; and on evaporating the residual liquid, and adding cold water, an additional quantity of the acid is procured. To render it quite pure, it should be dissolved in hot water, and neutralized by carbonate of potassa. As the liquid cools, carbazotate of potassa crystallizes, and may be purified by repeated crystallization. The acid may be precipitated from this salt by sulphuric acid.

Properties,

1701. Carbazotic acid is sparingly soluble in cold water; but it is dissolved much more freely by the aid of heat, and on cooling yields brilliant crystalline plates of a yellow colour. Ether and alcohol dissolve it readily. It is fused and volatilized by heat without decomposition; but when suddenly exposed to a strong heat, it inflames without explosion, and burns with a yellow flame, with a residue of charcoal. Its solution has a bright yellow colour, reddens litmus paper, is extremely bitter, and acts like a strong acid on metallic oxides. It is said to be poisonous.†

Salts of.

1702. The salts of carbazotic acid are for the most part crystal-

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* From the analysis by Dumas, Thomson considers it as merely indigo, containing five times as much oxygen as that pigment does. T. 142.

† *Jour. of Sci.* ii. 210.

lizable, of a yellow colour, and brilliant lustre. They have the property, when rapidly heated, either of detonating like fulminating silver, or of burning rapidly with scintillations. The sparing solubility of carbazotate of potassa is the cause of carbazotic acid being used as a test of that alkali.

1703. Carbazotic acid is generated by the action of nitric acid on many substances, both animal and vegetable, especially on those which contain nitrogen. The bitter principle, formed with nitric acid and silk by Welter, is carbazotic acid.

Acids Imperfectly Examined.

Pectic acid.

1704. *Pectic Acid.* $C_{11}H_7O_{10}$, = 153 eq. Braconnot has given this name* to a principle found in several plants which has the property of being coagulated by alcohol, metallic solutions, the acids, &c. It appears to be the same substance previously discovered by Torrey in the Tuckahoe, *Sclerotium giganteum*,† a fungus common in the sandy barrens of the southern states, and to which he gave the name *Sclerotin*. It is readily soluble in a solution of caustic potassa, and this solution is gelatinized by almost every known body.

How obtained.

1705. Braconnot's process for obtaining this substance is as follows:

If roots containing starch be operated upon, such as those of celery and carrot, they are to be reduced to pulp by rasping, the juice expressed, the residue boiled in water, slightly acidified with hydrochloric acid, then washed, and afterwards heated with a very dilute solution of potassa or soda. A thick mucilaginous liquid results, slightly alkaline, from which hydrochloric acid separates the acid in the form of an abundant jelly, which should then be well washed.

Union with potassa.

1706. It forms a very soluble salt with potassa, which may be obtained in the state of a transparent jelly, by adding weak alcohol, which removes the excess of alkali and colouring matter, if there be any present. This jelly washed on a cloth with alcoholized water, pressed and dried, swells and dissolves in water, and leaves upon evaporation a transparent mass, resembling gum arabic. Its taste is insipid.

Use.

1707. In consequence of the property which this acid has of gelatinizing large quantities of water, it has been proposed as a means of preparing jellies.

Boil a little pectic acid in the quantity of water which is to be converted into jelly; dissolve in the water a sufficient quantity of sugar previously seasoned by being rubbed over the skin of an orange, or by any other wished for seasoning, or add to the water a little alcohol previously seasoned. In either case the whole assumes the form of a jelly, the flavour of which will of course depend upon the nature of the seasoning employed.

Pectin,

1708. There is a substance in many acid fruits, as currants and gooseberries, which gelatinizes. It has very intimate connexion with pectic acid, being instantly converted into that acid by the smallest quantity of a fixed alkali. This substance has been distinguished by Braconnot, by the name of *pectin*.

Process.

1709. It may be obtained from all fruits by means of alcohol.

Mix together the clear expressed juice of currants, with the equally clear juice

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* From πεκτις *coagulum*. *Ann. de Chim.* xxviii. 173, and *Bost. Jour.* iii. 132.

† Torrey's analysis of the Tuckahoe was published in the N. Y. *Med. Rep.* 1820.

of sour cherries. Pectin falls down. Decant off the liquid, and wash the pectin with water, as long as the liquid abstracts any colour.[*]

The analysis of pectic acid by Regnault gave, carbon 42.71, hydrogen 4.73, oxygen 52.56.[†]

Crenic acid.

1710. *Crenic Acid*, 108.[‡] (T.), was discovered by Berzelius in 1832, in the water of Porla well, in Sweden, to which it imparted a yellow colour and disagreeable taste. On exposure to the air, an ochrey sediment was deposited which consisted chiefly of crenated peroxide of iron.[§]

Properties.

1711. Crenic acid is yellow and transparent. It has no odour, but a sharp followed by an astringent taste. When in solution the latter only can be perceived. When the solution is exposed to the air, it becomes brown, and apocrenic acid is formed.

1712. It is very soluble in water and alcohol. Its salts resemble extracts, and are insoluble in absolute alcohol, but become more and more soluble as water is added. They become rapidly brown in the air, and apocrenates are formed.

1713. Crenic acid dissolves in nitric acid without change. Its salts are termed crenates. They resemble extracts in appearance, and are incapable of crystallizing.

Apocrenic acid.

1714. *Apocrenic Acid.* 132. (T.). This acid was obtained by digesting the ochre from Porla well with potassa, to extract the crenic acid, and then precipitating the acid by means of acetate of copper. The apocrenate of copper falls, from which the acid is separated by the action of hydrosulphuric acid gas, absolute alcohol and potassa.

1715. Apocrenic acid is brown, and resembles a vegetable extract. It is but slightly soluble in water, from which it is precipitated by sal ammoniac.

In waters.

1716. These acids are supposed by Berzelius to occur frequently in water, and he is of opinion that the substances so often described as existing in mineral waters, and which have been distinguished by the name of extractive, in reality consist of these acids. He thinks too that they exist abundantly in bog iron-ore.

Compound Acids.

Compound acids, Two sets.

1117. The compound acids consist of a vegetable principle, united to a strong mineral or vegetable acid. They have been divided by Thomson into two sets. The first set consists of two atoms of an acid, combined with one atom of a base, which may be driven off by a stronger base. They are, strictly speaking, not acids, but acidulous or super-salts. The second set contains hyposulphuric acid, combined with an organic substance, not acting the part of a base, and not capable of being expelled by a stronger base.

Althionic acid.

1718. *Althionic Acid.*[‖] $2(SO_3)+C_4H_5O+HO$, 126 eq. This name is given by Magnus to what was formerly called *sulphovinic acid.* It is formed by the action of strong sulphuric acid and alcohol, and

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[*] *Jour. de Phar.* xx. 467. For other acids of this group see Thomson, *Chem. Inorg. Bodies*, ii. and *Org. Bodies*, 146.

[†] *Jour. de Phar.* xxiv. 201.

[‡] From *κρηνη a fountain.*

[§] For details of the analysis see T. 148.

[‖] From *θειον*, *sulphur* and alcohol.

plays an important part in the formation of ether. When the ingredients for forming ether are mixed, and before heat is applied, much of the acid exists in the state of this acid, and may be separated by neutralizing the mixture with carbonate of baryta, when an althionate of baryta is formed which may be obtained in crystals.

Experiments of Magnus.

1719. From the experiments of Magnus it seems that when equal weights of concentrated sulphuric acid and absolute alcohol are mixed, one half of the acid deprives the other half of all its water, while every two atoms of the anhydrous acid thus formed unites with $C_4 H_5O+HO$ (or alcohol). It is considered by Thomson as a bisalt, or a bisulphate of ether.* It forms with bases, althionates.†

Ethionic acid.

1720. *Ethionic Acid.* $S_2O_6+C_4H_4O+HO$.‡ This is one of the compound acids, containing an acid combined with an organic substance, not acting the part of a base and not capable of being expelled by a stronger base. It was obtained by Sertuerner by the action of sulphuric acid and alcohol.§

Sulpho-naphthalic acid,

1721. *Sulpho-naphthalic Acid.* $S_2O_6+C_{20}H_7$, = 199.024 eq. Discovered by Faraday in 1826.

Process.

It is made by melting naphthaline with half its weight of strong sulphuric acid, when a red-coloured liquid is formed, which becomes a crystalline solid in cooling. The mass is soluble in water, and the solution contains a mixture of sulphuric and sulphonaphthalic acids. On neutralizing with carbonate of baryta, the insoluble sulphate subsides, while the soluble sulphonaphthalate remains in solution; and on decomposing this salt by a quantity of sulphuric acid precisely sufficient for precipitating the baryta, pure sulphonaphthalic acid is obtained.

Properties.

1722. The aqueous solution of the acid, as thus formed, reddens litmus paper powerfully, and has a bitter acid taste. On concentrating by heat, the liquid at last acquires a brown tint, and if then taken from the fire becomes solid as it cools. If the concentration is effected by means of sulphuric acid in an exhausted receiver, the acid becomes a soft white solid, apparently dry, and at length hard and brittle.

Forms salts.

Sulphonapthalic acid is readily soluble in water and alcohol, and is also dissolved by oil of turpentine and olive oil, in proportions dependent on the quantity of water which it contains. By the aid of heat it unites with naphthaline. It combines with alkaline bases, and forms neutral salts, which are called ***sulphonaphthalates.*** All these salts are soluble in water, and most of them in alcohol, and when exposed to heat in the open air, take fire.||

Other acids from indigo.

1723. *Sulpho-indigotic and Hypo-sulpho-indigotic Acids* are obtained from indigo dissolved in sulphuric acid.

Sulpho-indigotate of Potassa has received various names, as ***precipitated indigo, soluble indigo,*** and ***carmine of indigo.*** Crum showed that it was a compound of indigo and sulphate of potassa. He gave the name of ***cerulin,*** from its blue colour, to the soluble indigo contained in it, and that of ***ceruleo-sulphates*** to the salts consisting of this substance united with sulphates.

Cerulin.

Formo-benzoilic acid.

1724. *Formo-benzoilic acid* may be obtained by mixing the water distilled off bitter almonds with hydrochloric acid, and evaporating.

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* *Organic Bodies*, 169.

† *Phosphovinic Acid* is obtained by distilling a mixture of phosphoric acid and alcohol. ‡ Liebig. § *Ann. de Chim. et Phys.* xiii. 62.

Phosphovinic acid.

|| The sulpho-naphthalate of baryta has been found by Berzelius to be a mixture of two salts difficult to separate; one containing sulpho-naphthalic and the other hyposulpho-naphthalic acid $2(SO^3)+C_{11}H_6$.

It remains in crystalline masses mixed with sal ammoniac, from which it is freed by ether, which dissolves the new acid. It is white, very soluble in water, has a strong acid taste, neutralizes bases and forms salts with oxides of silver and copper. It is decomposed by heat, leaving charcoal, and giving out the odour of peach blossoms.

Composition. Thomson considers it a compound of

1 atom	formic acid - - -	$C_2 H O_3$
1 "	hydret of benzoil - -	$C_{14} H_6 O_2$
		$C_{16} H_7 O_5$

The hydrocyanic acid and water of the bitter almonds is decomposed into formic acid and ammonia, for

1 atom	of hydrocyanic acid - -	$C_2 H N$
3 "	water - - -	$H_3 O_3$
		$C_2 H_4 NO_3$
1 "	formic acid - - -	$C_2 H O_3$
1 "	ammonia - - -	$H_3 N$
		$C_2 H_4 N O_3$

This constitutes an acid formed by the combination of two organic bodies possessing the characters of acids, and capable of being formed at pleasure.*

SECTION III. *Cyanogen and its Compounds.*

Cyanogen, a compound radical. 1725. Cyanogen is considered by Liebig as a compound radical, and as such uniting with oxygen, hydrogen, and most other non-metallic elements, and also with the metals; many of the latter being similar to haloid salts, while others possess a very different character.

In describing the compounds of cyanogen,† it will be necessary to employ new terms, and refer to several substances which have not been described in the foregoing pages, a brief account of them is therefore introduced in this place.

Mellon, 1726. *Mellon*, C_6N_4, eq. =93.32,‡ is a yellow powder, insoluble in water, alcohol, and dilute hydrochloric and sulphuric acids, but soluble with decomposition in nitric acid and the caustic fixed alkalies, decomposable by a strong heat, into three vols. cyanogen, and one vol. nitrogen gas. It unites with potassium forming mellonuret of potassium, with hydrogen forming hydromellonic acid.§ Discovered by Liebig, and considered by him a compound radical.

Obtained. It is obtained when dry sulpho-cyanogen is heated in a retort to redness, the products of the decomposition being sulphuret of carbon, sulphur and mellon.

Melamin, 1727. *Melamin*, $C_6N_6H_6$, eq. =121.62, is a saline base discovered by Liebig, being a product of the decomposition of melam (1729) by alkalies and dilute acids. It crystallizes in colourless or slightly yellow rhombic octohedrons, transparent, anhydrous, sparingly soluble in

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* T. *Organic Bodies*, 206.

† These compounds constitute the Second Series of Liebig. For details, see Thomson, *Org. Bodies*, 768, and Liebig, *Org. Chem.* 755.

‡ The formulas are those of Liebig.

§ By dissolving mellonuret of potassium in boiling water and adding hydrochloric, sulphuric, or nitric acid, hydromellonic acid is obtained. It is decomposed by metallic oxides. See L. 796.

cold but pretty freely in boiling water, insoluble in alcohol and ether. It fuses when heated, and sublimes, partially decomposed into mellon and ammonia. Decomposed by concentrated nitric acid and sulphuric acid with the aid of heat into ammonia and ammelid or ammelin; fused with hydrate of potassa, the elements of 3 eq. of water add themselves to its constituents and form 6 eq. of ammonia, which are evolved, and 3 eq. cyanate of potassa are left.

Combination of.

1728. *Melamin* combines with dilute acids to crystallizable salts, all of which have an acid reaction, excepting the double salts. The acetate and formate of melamin are very soluble; it precipitates magnesia from hot solutions of its salts, owing to the formation of a double salt. Melamin combines directly with the anhydrous hydracids, all its salts with the oxacids correspond to the ammoniacal salt in containing an equiv. of water, without which they cannot exist; it forms double basic salts in which this equiv. of water is replaced by a metallic oxide.

Melam.

1729. *Melam.* $C_{12}N_{11}H_9$, eq. = 238.09. This product of the decomposition of sulphocyanuret of ammonium, was also discovered by Liebig. When the sulphocyanuret of ammonium, or a mixture of two parts of sal ammoniac and one of sulphocyanuret of potassium are heated to the point of fusion of the latter, the sulphocyanuret of ammonium is decomposed into three gaseous and one solid product. The former are ammonia, hydrosulphuric acid, and the sulphuret of carbon; the latter is melam, which is left in the retort mixed with chloride of potassium, and is separated by washing with water.

Properties.

1730. It is a white powder, insoluble in water, alcohol and ether; but dissolved by hot potassa, a part being decomposed, but another portion is deposited again unchanged as the solution cools. It is also soluble in hot concentrated sulphuric and nitric acids, from which alcohol and water throw down ammelid. If the solution in these acids be boiled, it is completely converted into cyanuric acid and ammonia; 1 eq. melam and 12 eq. water, contain the elements of 2 eq. of cyanuric acid and 5 eq. ammonia. It is dissolved in hydrochloric and dilute nitric acids and potassa with the formation of ammelin and melamin; fused with hydrate of potassa, ammonia is evolved, and cyanate of potassa produced; and with potassium the mellonuret of potassium is formed. When heated, it decomposes into mellon and ammonia.

Solutions converted into cyanuric acid.

Explanation.

1731. On heating 8 eq. sulphocyanuret of ammonium, they are decomposed into 1 eq. melam, 10 eq. ammonia, 4 eq. sulphuret of carbon, and 8 eq. of hydrosulphuric acid; 1 eq. of melam, on being fused with 6 eq. of hydrate of potassa, give rise, by the addition of the elements of 6 eq. water, to 6 eq. cyanate potassa and 5 eq. ammonia. By long application of heat to melam in caustic potassa, it is decomposed, together with 2 eq. of water, into 1 eq. melamin and 1 eq. ammelin. Melam is converted into ammelid by the addition of the elements of 6 eq. water, which form 1 eq. ammelid and 2 eq. ammonia.

Ammelin,

1732. *Ammelin.* $C_6N_5H_5O_2$, eq. = 128.47. A saline base, discovered by Liebig. A product of the decomposition of melam and melamin by acids and alkalies. It is precipitated from the alkaline solution from which melamin is deposited, by neutralization with acetic acid.

It is white, insoluble in alcohol and ether, soluble in caustic alkalies, yields by distillation a crystalline sublimate and ammonia, with a residue of pure mellon. By long boiling in dilute acids, or on being dissolved in concentrated sulphuric acid, it is decomposed by the addition of 1 eq. of water, into ammonia and ammelid. By fusion with caustic potassa 1 eq. of water is decomposed, and it is converted into ammonia and cyanate of potassa.

Forms salts. 1733. Ammelin is a weak salifiable base, and forms only with the strong, and not with the organic acids, crystallizable salts, which have an acid reaction, and are partially decomposed by water with the deposition of ammelin. The salts of ammelin with the oxacids contain, like the ammonia salts, 1 eq. of water, without which they cannot exist; the double salts are anhydrous.

Nitrate. 1734. Nitrate of ammelin crystallizes in large broad plates, or in long quadrangular prisms. When heated it fuses and ammelid is left, nitric acid and the products of the decomposition of nitrate of ammonia are evolved.

Ammelid. 1735. *Ammelid.* $C_{12}N_9H_9O_6$, eq. $=257.79$. A product of the decomposition of melam, melamin, and ammelin by concentrated acids. It is a white powder, insoluble in water, alcohol, and ether, but soluble in alkalies and strong acids; by continued boiling in dilute nitric or sulphuric acid it is decomposed into cyanuric acid and ammonia. L.

Theory of the composition of melamin, &c. 1736. Liebig has given the following explanation of the basic qualities of melamin, ammelin, and ammelid, and of their connexion with ammelid and cyanuric acid. It is assumed that these substances contain the same radical as cyanuric acid, together with a compound of nitrogen and hydrogen, which is composed of equal vols. of these elements, and which are supposed to be denoted by the symbol $2M = HN$; the compounds may then be represented in the following form:

Cyanuric acid - - -	$Cy_3 O_6 + H_3$
Melamin - - -	$Cy_3 M_6 + H_3$
Ammelin - - - -	$Cy_4 M_4 O_2 + H_3$
Ammelid - - - -	$Cy_3 M_3 O_3 + H_3$
Cyanuric acid - - -	$Cy_3 O_3 O_3 + H_3$

Explanation. 1737. The cyanuric acid is, as may be seen, both the commencement and termination of the series; in melamin, the 6 eq. of oxygen are replaced by $6M(N_3H_3)$, and in ammelin 4 eq. by 4M; both of them are saline bases. The ammelid has no basic properties, and in it one half of the oxygen of the cyanuric acid is replaced by 3M, and by the further removal of all M cyanuric acid is again produced. The basic properties of these bodies decrease as the quantity of oxygen which combines with the radical is increased.

Cyanuric acid, &c. compared. 1738. The cyanuric acid may be compared with the phosphoric acid, and melamin with phosphuretted hydrogen or ammonia; ammelin and melamin enter into direct combination with the hydracids and without the intervention of water, but with the oxacids only by the intervention of 1 eq. of water, which must be in the same state of combination as in the ammoniacal salts. L. 803.

Cyanogen and Oxygen.

Cyanic acid. 1739. *Cyanic Acid.* CyO, 26.39 1 eq. cy. + 8 1 eq. oxy. = 34.39 equiv. This acid was discovered by Wöhler, and is formed when cyanogen is transmitted over carbonate of potassa at a red heat, or into an alkaline solution; by exposing compounds of cyanogen at a red heat to the action of the air, of nitre, or of peroxide of manganese; by fusing ammelin, melamin, or ammelid with hydrate of potassa; it is a frequent product of the decomposition of compounds of nitrogen. It is not known in the anhydrous state.

Obtained,

Obtained as hydrate, by distilling dry cyanuric acid or cyamelide* in a retort, when the latter is converted into hydrate of cyanic acid, which must be collected in a receiver well cooled by ice.

Properties,

1740. A clear transparent fluid of a strong penetrating odour, similar to that of acetic or formic acid, exceedingly volatile, and causes blisters on the skin, which are accompanied by great pain. Mixes readily with water. Decomposes with the production of great heat shortly after its formation into a white solid of the same composition per cent. (cyamelide);† its aqueous solution reddens vegetable colours strongly; it decomposes in the course of a few minutes, together with 2 eq. of water, into bicarbonate of ammonia;

$$\begin{array}{lcr} \text{Hydrated cyanic acid} = & C^2NO+HO \\ \text{Two eq. water} \quad . \quad = & 2HO \end{array}\Bigg\} = \Bigg\{ \begin{array}{lr} \text{2 eq. carb. acid} \quad . & = 2CO_2 \\ \text{1 eq. ammonia} \quad . & = NH_3 \end{array}$$

$$\overline{C_2N \quad H_3O_4} \qquad\qquad \overline{C_2NH_3O^4}$$

Forms salts.

1741. This acid forms only one series of salts with the bases; they are readily recognised by the peculiar decomposition produced by dilute mineral acids. A few moments after mixing the salt with the acid, a rapid effervescence, accompanied by the strong penetrating odour of cyanic acid, is observed, and the solution by being mixed with hydrate of lime evolves ammonia abundantly, which previous to the decomposition cannot be detected. Its salts with the alkaline bases and with ammonia are soluble, the others are insoluble; the former, with the exception of the ammoniacal salt, are decomposed, when their solutions are boiled, into ammonia and carbonates.

Cyanates of ammonia.

1742. *Cyanates of Ammonia.* Cyanic acid forms with ammonia two compounds, one of which is particularly remarkable from its identity with urea.

Basic cyanate of ammonia,

1. *Basic Cyanate of Ammonia.* When dry ammoniacal gas and the vapour of hydrated cyanic acid are simultaneously conducted into a dry vessel, they unite, forming a white woolly crystalline compound, which contains more ammonia than corresponds to the constitution of a neutral cyanate. It is similar in all its properties to any other salt of cyanic acid; treated with an acid it is decomposed with effervescence, and alkalies effect the evolution of ammonia; but if on the contrary it be gently warmed, whether dry or in solution, or if it be left for some time exposed to the air, ammonia is given off, it loses all the above-mentioned properties, and is converted into urea.

Urea,

2. *Anomalous Cyanate of Ammonia; Urea.* Discovered by Fourcroy and Vauquelin in urine, by Wöhler as the first organic compound

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* *Insoluble Cyanuric Acid* (1767).

† This decomposition with water is the cause of the impossibility of obtaining the free acid from the aqueous solutions of its salts by the action of a stronger acid, although a small quantity, as may readily be recognised by the peculiar odour which accompanies the carbonic acid evolved, does escape.

Chap. VI.

artificially produced. It is a constituent of uric acid, and is contained in the urine in combination with lactic acid.* It is obtained,

Process,

1743. By mixing fresh urine evaporated to the consistence of a syrup at a gentle heat, which should never reach that of ebullition, when quite cold, with its own volume of colourless nitric acid of sp. gr. = 1.42. If the evaporation has been carried sufficiently far, the whole will form a thick crystalline mass; to ensure this, a small portion of the urine should be tried from time to time. The crystalline mass consists of a compound of nitric acid and urea, which is sparingly soluble in nitric acid.†

The impure crystals of nitrate of urea are to be carefully washed with dilute nitric acid, strongly pressed between folds of bibulous paper, dried upon a porous tile, and redissolved in warm water; the solution, after being freed of its colour by recently prepared charcoal, is evaporated to crystallize.

A solution of the colourless crystals of the nitrate of urea is treated with carbonate of baryta until it is rendered perfectly neutral; on evaporating, crystals of nitrate of baryta, and then of urea, will be obtained. The crystals of the latter, by being redissolved in a little cold water, are freed from the last portions of the nitrate of baryta; the solution in alcohol gives crystals of pure urea.‡

Another,

1744. Instead of using nitric acid, the concentrated urine may be added to a boiling saturated solution of oxalic acid, when the sparingly soluble oxalate of urea falls, which, after being deprived of its colour by charcoal, may be decomposed into the insoluble oxalate of lime and pure urea, by being digested with pounded chalk.§ It can also be prepared by the decomposition of the cyanate of oxide of silver by sal-ammoniac, or of the cyanate of oxide of lead by pure or carbonate of ammonia.

Properties.

1745. Crystallizes in colourless, transparent, four-sided, somewhat flattened prisms of the sp. gr. 1.35, is soluble in its own weight of cold, and in every proportion in hot water, in 4.5 parts of cold, and in 2 parts of boiling alcohol: the aqueous solution has a cooling bitter taste like nitre; when pure it is perfectly permanent in the air, is not deliquescent, fuses at 250° into a colourless liquid, is decomposed by a higher temperature into ammonia, cyanate of ammonia, and dry solid cyanuric acid. Alkalies do not cause the separation of ammonia in the cold.

Compounds,

Decomposed,

1746. Unites with several acids without decomposition to crystallizable saline compounds: by evaporating its solution with nitrate of silver or acetate of lead it is decomposed; the products being, with the first, nitrate of ammonia and crystalline cyanate of silver; with the second, acetate of ammonia and carbonate of lead. With hyponitrous acid it is instantly decomposed into nitrogen and carbonic acid gases, which are evolved in equal volumes; with chlorine it forms hydrochloric acid, nitrogen and carbonic acid. When fused with the hydrated alkalies, or heated in concentrated sulphuric acid, it is decomposed together with the constituents of 3 eq. of water into carbonic acid and ammonia. Urea contains the elements of cyanate of ammonia (NH_4O+C_4NO); it may also be considered, according

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* Henry.

Caution.

† Since the urine contains metallic chlorides, which with the nitric acid by the aid of heat are decomposed, and give rise to the production of chlorine and nitrous acid, both of which act powerfully in destroying urea, all increase of temperature must be most carefully avoided.

‡ Wöhler.

§ Berzelius.

to Dumas, as a second compound of carbonic oxide and amide,* in which the quantity of the latter is double that in oxamide $C_2O_2+2NH_2$.

Nitrate of urea.

1747. *Nitrate of Urea.* This compound, when recently precipitated from urine, appears in the form of fine crystalline plates of a brown colour and mother-of-pearl lustre; the purer they are, the more they lose this appearance; a solution of pure urea treated with nitric acid gives a granular white crystalline precipitate, which is soluble in 8 parts of cold, but more freely in hot water, from which it crystallizes in broad, scarcely translucent plates; is sparingly soluble in nitric acid, with which it may be boiled without decomposition. Is composed of 1 eq. of nitric acid, 1 of urea, and 1 of water.†

Cyanate of potassa.

1748. *Cyanate of Potassa.* KOCyO; eq. = 81.54. By roasting at a red heat dry ferrocyanuret of potassium in fine powder upon an iron plate, the powder being constantly stirred; the cyanuret of potassium contained in the salt is thus converted, by absorbing the oxygen of the air, into cyanate of potassa. As soon as it is baked into one mass, owing to the fusion of the cyanate of potassa forming, it must be reduced to a fine powder and digested in boiling alcohol, from which, as the solution cools, crystals of the cyanate are deposited.

Process.

A mixture of two parts of ferrocyanuret of potassium, and one of peroxide of manganese, may be treated in the same way. This mixture may be kindled by a red-hot body, when it smoulders away into a brown mass which contains cyanate of potassa, carbonate of potassa, and sesquioxide of manganese. This salt may also be procured of great purity, but not so economically, by fusing the hydrate of potassa in a silver vessel, and adding melam, ammelin, or ammelid in successive portions as long as they are dissolved; the fused transparent mass congeals, on cooling, to a pure crystalline cyanate of potassa.

Properties.

1749. Crystallizes from the alcoholic solution in transparent anhydrous plates, which closely resemble chlorate of potassa, but by exposure to a moist air are gradually converted, without any change of form, into bicarbonate of potassa, while ammonia is evolved. It is dissolved by cold water, in which it decomposes into bicarbonate of potassa and ammonia; a change accelerated by heat. Fuses at a high temperature without loss of weight to a clear liquid, which, upon cooling, forms an opaque crystalline mass. If a concentrated solution be partially decomposed by acetic acid, or a dilute mineral acid, the acid cyanuret of potassa is precipitated.

Cyanates of oxides of silver and lead.

1750. *Cyanates of oxides of silver and lead,* AgOCyO, and PbOCyO, are white anhydrous salts, which are insoluble in water, and are obtained by precipitating the cyanate of potassa by a neutral salt of lead or silver. Both consist of an eq. of acid and one of metallic oxide; the silver salt is soluble in ammonia, with which it forms a white crystalline compound, but by heat the ammonia is again evolved, and the pure cyanate of silver remains; decomposed by heat when dry, with a slight explosion, into cyanic acid, carbonic acid, nitrogen and dicyanuret of silver.

Products of decomposition.

Fulminic acid.

1751. *Fulminic Acid,* Cy_2O_2; eq. = 68.78, the constituent of the fulminating silver and mercury discovered by Howard.

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*This term has been already explained (1563). "It signifies an anhydrous ammoniacal salt, deprived (if an expression apparently contradictory may be allowed) of an atom of water." T. 590.

† Regnault.

Preparation. This acid is formed when nitrate of silver or protoxide of mercury, with an excess of nitric acid, is boiled in alcohol; aldehyd* with nitric ether is evolved, and a white crystalline precipitate, the fulminate of silver or mercury, is deposited from the hot solution. By the action of the nitric acid upon the alcohol, hyponitrous acid on the one hand, and aldehyd and oxalic acid on the other, are produced. The presence of the oxide of silver or mercury, effects a reaction between two eq. of hyponitrous acid and one of ether in the alcohol, by which they are converted into water and fulminic acid.

$$\overset{\text{2 eq. hyponitrous acid.}}{N_2O_6} + \overset{\text{Ether.}}{C_4H_5O} = \overset{\text{Fulminic acid.}}{N_2C_4O_2} + \overset{\text{Water.}}{2HO}$$

1752. If a stream of hyponitrous acid vapour be conducted into a solution of nitrate of silver in alcohol, a copious precipitate of fulminate of silver is instantly formed.

Properties. This is a bibasic acid; it cannot be obtained in a free state from any of its salts, being decomposed at the moment of its separation by any other acid into hydrocyanic acid and a new product.

Fulminates. 1753. *Fulminates.* The salts of fulminic acid contain either 2 atoms of a fixed base (neutral salts) or 1 atom of a fixed base and 1 atom of water (acid salts).† If, as Liebig supposes, the salts are considered as compounds of metals with certain radicals, which arise from the union of the oxygen of the base with the constituents of the anhydrous acid; when it so happens that the affinity of the metal for the oxygen with which it is united predominates, it is impossible that the radical should be formed, or, what is the same thing, that its decomposition must follow whenever an attempt is made to separate a metallic oxide, which is easily reduced, by one holding its oxygen by a powerful affinity.

Fulminate of protoxide of mercury. **Process.** 1754. *Fulminate of Protoxide of Mercury*, $2HgO,Cy_2O_2$; eq. = 488.78, discovered by Howard, is prepared by dissolving 1 part of mercury in 12 parts of nitric acid of sp. gr. 1.36, and adding to the solution 11 parts of alcohol of 80—85 per cent.; the mixture must be heated in a water-bath. The fluid soon enters into powerful chemical action; metallic mercury is precipitated, and nitric ether vapours evolved, the latter carrying off along with them a considerable portion of the former; after a short time, hard opaque crystals of fulminate of mercury are deposited. These are carefully washed and dried at common temperatures on paper. It is freed from the admixture of metallic mercury by being re-dissolved in boiling water, from which it is deposited in white fine acicular crystals of a soft silky appearance. Explodes with great violence when struck or

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* Aldehyd, from *alcohol dehydratus*; a remarkable substance obtained from alcohol, it is a colourless liquid, very volatile, with a peculiar etherial and penetrating odour.

† The two atoms of fixed base must either be two atoms of the same or of two different metallic oxides, which are readily reduced, (2 eq. of CuO, 2 of HgO, 2 of AgO, or 1 eq. of CuO and 1 eq. of AgO, &c.) or 1 eq. of an easily reduced oxide with 1 eq. of an alkali, (1 eq. AgO and 1 eq. KO or BaO, or HOZnO, &c.) Fulminates with two atoms of a difficultly reduced metallic oxide cannot be obtained. From this it follows that when a salt of the first class,—such, therefore, as contain 2 eq. of oxides of silver, mercury, or copper,—are brought into contact with an alkali, only one half of the metallic oxide is replaced by its equivalent of the alkali; the other half remains in the new compound. This remarkable property seems to indicate a more intimate connexion between the acid and the oxygen of the metallic oxide which is combined with it, than is usually considered to exist. L. 761.

rubbed between two hard substances; placed on a red-hot coal, it burns with a slight explosion and a blue flame.

Use.

1755. It is used for firing percussion guns: for this purpose, 10 parts of the salt are reduced to a fine powder by rubbing it with a wooden pestle on a marble slab with 30 parts of water; and this, when mixed with 6 parts of nitre, forms a paste, with which the copper caps are filled.

Fulminate of silver. Process.

1756. *Fulminate of Silver.* $2AgO+Cy_2O_2$. Prepared by dissolving 1 part of silver in 10 of nitric acid of sp. gr. 1.36—1.38 at a gentle heat, adding the mixture to 20 parts of alcohol of 85 to 90 per cent., and heating the mixture gently; as soon as the fluid begins to boil, it is removed from the fire, and placed aside to cool. The solution loses its transparency, and deposits the fulminate of silver in fine acicular crystals of a snow-white colour and of great lustre; when washed and dried, their weight should equal that of the silver used.

Properties.

1757. The fulminate of silver is sparingly soluble in cold, but perfectly soluble in 36 parts of boiling water; is not decomposed by nitric acid; more readily exploded than the mercurial salt by friction, a blow, or by contact with concentrated sulphuric acid. Caustic alkalies separate half the silver as oxide, chloride of barium or potassium, as chloride; crystalline salts with two bases are obtained, from which the acid fulminate of silver may be separated by nitric acid; the latter salt may be obtained in crystals, and is more soluble than the neutral fulminate of silver.

Fulminate of copper.

1758. *Fulminate of Copper*, $2CuO,Cy_2O_2$, is prepared by digesting the fulminates of silver or mercury with metallic copper. It may be obtained in green crystals, which are very soluble, and explode with a green flame.

Fulminate of zinc.

1759. *Fulminate of Zinc* is obtained, according to E. Davy, by digesting the fulminate of mercury with metallic zinc. From the solution, which no longer contains a trace of mercury, baryta precipitates half the zinc, and the fulminate of zinc and baryta $\left.\begin{array}{l}ZnO\\BaO\end{array}\right\}Cy_2O_2$ is obtained; from this the baryta may be precipitated by free sulphuric acid, and the acid fulminate of zinc remains in solution, which has been described by E. Davy as pure fulminic acid, but the presence of the zinc may be shown after the decomposition of the fulminic acid by the sulphuret of ammonium and the known reagents.*

Hydro-chloro-cyanic acid.

1760. *Hydro-chloro-cyanic Acid*, is the product of the decomposition of fulminate of silver by hydrochloric acid. This substance has a biting but sweetish acid taste, does not precipitate silver salts, and is decomposed by heat into carbonate of ammonia and other new products. It contains 5 eq. of chlorine, and its constitution is most probably represented by the formula $C_2NCl_5+H_2$.

Cyanuric acid.

1761. *Cyanuric Acid.* Described by Scheele as pyrouric acid, by Serullas as cyanure, but its nature was first pointed out by Wöhler and Liebig.

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* On the preparation of this acid, see Fehling in *Lond. and Edin. Philos. Jour.* July, 1839.

It is a product of the decomposition of the solid chloride of cyanogen by water, of the soluble cyanates by dilute acids (acetic, &c.), of urea by heat, of uric acid by the destructive distillation, and of melam, melamin, ammelid, and ammelin by acids.

Process.

It is best prepared by dissolving dry melam in strong sulphuric acid, by aid of a gentle heat, throwing the solution into 20—30 parts of water; the mixture must be kept for several days at near its boiling heat, until upon trial it no longer gives a white precipitate with ammonia, when the solution may be evaporated to crystallize; the crystals should be purified by a second crystallization. Or it may be made by heating urea beyond its point of fusion, until it is converted with the evolution of ammonia into a white or grayish-white dry mass; this must then be dissolved in concentrated sulphuric acid, the solution treated with nitric acid added drop by drop until it becomes colourless, and then added to an equal volume of water; when cold, crystals of pure cyanuric acid are deposited.

Explanation.

1762. By dissolving melam in strong sulphuric acid it is converted into ammelid, which, by being further heated, is converted into ammonia and cyanuric acid. Three atoms of urea contain the elements of 1 eq. of cyanuric acid, and 3 eq. of ammonia; at a high temperature the greater part of the ammonia is evolved as a gas, while a small portion remains in combination with the cyanuric acid.

Properties,

1763. Colourless, inodorous, a slight taste, reddens litmus feebly, sparingly soluble in cold, but taken up by 24 parts of boiling water; the crystals from the aqueous solution contain 21.66 per cent. = 4 eq. water, which they lose at common temperature when exposed to the air, but more rapidly when heated, and fall into powder. They are oblique rhombic prisms. The dry acid contains 3 eq. of water; it may be obtained in crystals free from water of crystallization from a hot saturated solution in nitric or hydrochloric acid. The hydrate when heated is converted into 3 eq. of hydrated cyanic acid, the constituents of which it contains. It is soluble in the strongest acids without decomposition, but by long-continued boiling is converted into ammonia and carbonic acid.

It is a tribasic acid; its hydrate is Cy_3O_3+3HO; eq. = 130.17.

Cyanurates.

1764. *Cyanurates.* The salts of cyanuric acid contain three atoms of base, which are represented in the hydrate by three atoms of water. All cyanurets are decomposed by hydrochloric, nitric acids, &c.; the cyanuric acid crystallizes out of the solutions without retaining a trace of the metallic oxide with which it was united. Its alkaline salts fuse when heated, leaving a cyanate of the alkali, while cyanate of ammonia, cyanic and carbonic acids, are evolved.

Cyanurate of potassa.

1765. *Cyanurate of Potassa.* The salt $\left\{\begin{matrix}2HO\\KO\end{matrix}\right\}+Cy_3O_3$ is made by neutralizing a boiling saturated solution of cyanuric acid by potassa; it falls in the form of white brilliant cubes. If these crystals be dissolved in a solution of caustic potassa, the addition of alcohol precipitates the cyanurate of potassa with two equivalents of fixed base, $\left\{\begin{matrix}HO\\2KO\end{matrix}\right\}+Cy_3O_3$, in white acicular crystals. On being redissolved in water and evaporated, it is decomposed into free potassa and the former salt.

Cyanurate of silver.

1766. *Cyanurate of Silver.* If nitrate of silver be added to either of the above salts of potassa, a white precipitate is obtained, which is cyanurate of silver, with 2 eq. oxide of silver and 1 eq. water,

$\left.\begin{matrix}HO\\2AgO\end{matrix}\right\}Cy_3O_3$; this salt heated in the dry state evolves hydrated cyanic acid. But if a solution of silver be added to a boiling solution of cyanurate of ammonia, containing ammonia in excess, the cyanurate with 3 eq. of oxide of silver is formed, $3AgO,Cy_3O_3$; it is insoluble in water; very sparingly soluble in dilute nitric acid; may be heated to 600° without decomposition; is white, is not blackened by light, emits carbonic acid and nitrogen gases, at a red heat, leaving the cyanuret of silver as a residue.

Cyamelid.

1767. *Cyamelid*, or *Insoluble Cyanuric Acid.* Probable formula C_2O_2+NH; eq. $= 43.39$. The hydrate of cyanuric acid, when free from water of crystallization, hardens shortly after its preparation into a white porcelain-like body, which is insoluble in water, dilute acids, alcohol, and ether; but is dissolved with decomposition by the caustic alkalies; ammonia is evolved, and cyanate and cyanurate of the alkali formed. Concentrated sulphuric acid dissolves it with the aid of heat, when with the elements of 2 eq. water it is decomposed into carbonic acid and ammonia; submitted to the destructive distillation, it is converted into hydrated cyanic, a change which is very readily accounted for, since its composition is the same as that of the hydrated acid.

Cyanogen and Hydrogen.

Prussic acid.

1768. *Hydrocyanic Acid, Prussic Acid.* Discovered by Scheele; for a knowledge of its nature and chemical properties we are indebted to Gay-Lussac: it is a constituent of the water distilled from the leaves and blossoms of several stone-fruits; is formed by the destructive distillation of many substances containing nitrogen, by the decomposition of formate of ammonia by heat, and of the metallic cyanurets by acids.

Anhydrous Hydrocyanic acid. Process,

1769. *Anhydrous Hydrocyanic Acid.* Fifteen parts of crystalline ferrocyanuret of potassium are distilled in a retort, at a very gentle heat, with a mixture of 9 parts of sulphuric acid and 9 parts of water, and the products collected in a well-cooled receiver, containing 5 parts of chloride of calcium in coarse fragments: the mixture of acid and water should not be used till perfectly cold. The distillation is stopped as soon as the chloride of calcium is perfectly covered by the fluid collected in the receiver. It is then poured off into a strong glass vessel with a good stopper.*

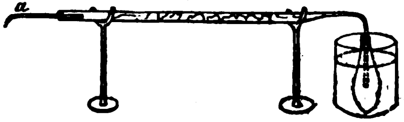
Explained.

The ferrocyanuret of potassium contains the cyanuret of potassium, which is decomposed by the hydrous sulphuric acid into sulphate of potassa and hydrocyanic acid; the latter passes over with a little water into the receiver, but this is absorbed by the chloride of calcium. It can also be prepared by decomposing the bicyanuret of mercury by strong hydrochloric or dry hydrosulphuric acid gas. L. 766.

Process.

The bicyanuret may be heated gently in a tube of about 18 inches in length and at least half an inch in diameter internally, nearly filled with that substance, and placed horizontally, as in the cut (Fig. 189). The gas is passed over until the contents of the tube have become black; none of the gas escaping from the other extremity of the tube, till all the bicyanuret is decom-

Fig. 189.



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* Trautwein.

posed. Whenever the odour of the gas is perceived at the mouth of the receiver, the tube *a*, connected with the apparatus in which the gas is produced, is withdrawn, and the extremity of the tube closed with plaster of Paris. It is heated gently when the lute has set, and the hydrocyanic acid which has been formed is volatilized and condensed in a small receiver placed in a freezing mixture.

Properties. 1770. At common temperatures, a clear limpid fluid, very combustible, burning with a reddish flame, of sp. gr. = 0.6969 at 64°. It congeals at 5° to a solid fibrous mass, boils at 80°, may be mixed in every proportion with water, ether, and alcohol; the sp. gr. of the vapour is 0.9476: scarcely reddens litmus paper. It has a peculiar penetrating odour, similar to that of bitter almonds, checks the breathing, and causes a flow of tears; it possesses a penetrating taste, which is somewhat burning, and strongly bitter; its vapour, when inhaled, acts instantly as a most powerful poison. The antidotes are ammonia, as likewise chlorine, which, however, must be administered with caution.

Freezing point. 1771. The congelation of the acid at 5° is, according to Schulz, owing to small quantities of water; he states the perfectly anhydrous acid as still liquid at—64°.

Decomposed by light, &c. 1772. Decomposes when perfectly pure with the greatest facility under the influence of light, with the formation of a brown substance and ammonia; small quantities of acids prevent this decomposition; by concentrated mineral acids it is very rapidly converted, together with the elements of water, into formic acid and ammonia; 3 eq. of water and 1 of hydrocyanic acid, a strong acid being present, suffer mutual decomposition, and are converted into ammonia which unites with the acid, and into formic acid.

$$\left.\begin{array}{ll}\text{1 eq. hydrocy. acid} & NC_2H \\ \text{3 eq. water} & H_3O_3 \\ \hline & NC_2H_4O_3\end{array}\right\} = \left\{\begin{array}{ll}\text{1 eq. amm.} & N\ H_3 \\ \text{1 eq. formic acid} & C_2H\,O_3 \\ \hline & NC_2H_4O_3\end{array}\right.$$

Action of potassium. 1773. Potassium heated in the vapour of the acid unites with the cyanogen, and liberates the hydrogen; lime and baryta, when heated in the vapour, also liberate hydrogen and give rise to cyanates; it is decomposed by chlorine with the formation of hydrochloric acid and chloride of cyanogen.

Hdyrous hydrocyanic acid. Process. 1774. *Hydrous Hydrocyanic Acid.* CyH, eq. 27.39. One part of bicyanuret of mercury dissolved in 8 parts of water is treated with a stream of hydrosulphuric acid gas till the latter is in slight excess; the free hydrosulphuric acid removed by a little carbonate of lead, and filtered. The clear liquid contains $\frac{1}{10}$ of anhydrous hydrocyanic acid. By the decomposition of the bicyanuret of mercury the fluid becomes black like ink, and it frequently only becomes clear after the addition of a small quantity of a free mineral acid; it contains too, very generally, small quantities of hydro-sulphocyanic acid.

1775. It may be prepared of the same strength and perfectly pure, according to Geiger,

By distilling 4 parts of crystallized ferrocyanuret of potassium with 18 parts of water and 2 of strong sulphuric acid; 20 parts of water are placed in the receiver, and the distillation is conducted until 38 parts have collected. The distillation is best conducted in a chloride of calcium bath, and the vapours should be condensed by a condensing apparatus of glass. The product is collected in a cylindrical bottle, which is marked at the point corresponding to 38 parts.

Sect. III.

Clark's process.

1776. According to Clark, it may be prepared by dissolving 1 part of tartaric acid in 40 parts of water, and adding 2⅔ parts of pure cyanuret of potassium in coarse fragments to the solution. The fluid must be kept very cold, and shaken from time to time; this acid contains 3 per cent. anhydrous acid, and 2½ to 3 grs. of bitartrate of potassa in the ounce.*

Magendie's acid.

1777. Magendie states that the medicinal hydrocyanic acid is prepared by mixing 1 part by volume of the anhydrous acid with 6 parts of water; or by weight, 1 part of the acid with 8½ of water.

Strength not uniform.

1778. All methods in which hydrocyanic acid is obtained by distillation never yield this energetic preparation of the same quality and strength; even with the application of every possible precaution, the product never contains more than four fifths of the small quantity of acid which, according to the calculation, ought to be procured; this arises, when ferrocyanuret of potassium is used, from a portion of the cyanuret entering into combination with the protocyanuret of iron during the decomposition of the yellow salt, or from the impossibility of effecting an absolute condensation of so volatile a substance during the distillation.

How insured.

1779. It is therefore greatly preferable to prepare a stronger acid in the first instance, to determine by experiment the quantity of anhydrous acid contained in it; and by the addition of water to bring it to that degree of dilution which is prescribed by the physician, or by the medical laws of the land.† The method described in the note may be used for testing the strength of any solution of hydrocyanic acid; 100 grains of an acid which contains 3 per cent. anhydrous prussic acid should, when precipitated by the nitrate of silver, give 15 grains of the cyanuret. This method is independent of all accidents which can possibly have an influence upon the activity of the preparation; it is so very simple that it will yield accurate results in every hand. The peroxide of mercury, which is readily dissolved as cyanide at common temperatures, may also be used to test the strength of the aqueous acid; a drop or two of caustic potassa is ad-

Strength tested.

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* Glasgow *Med. Jour.* 14.

Method of testing.

† For example 2 parts of crystalline ferrocyanuret of potassium are distilled with 1 part of sulphuric acid and 2 of water to dryness in a chloride of calcium bath; and the product, well cooled by the condensing tube apparatus, collected in a narrow-mouthed bottle, into which 2 parts of water have been placed. The quantity obtained generally amounts to 4—4½ parts by weight of liquid, containing, according to the more or less perfect cooling, from 17—20 per cent. of anhydrous hydrocyanic acid. The exact quantity is determined in the following manner:—One drachm=60 grs. of the dilute acid is added to a carefully balanced glass vessel, which contains a dilute solution of nitrate of silver,* and the increase of weight accurately determined; by way of precaution, a trial is made to see whether the addition of the silver solution causes a further precipitation, the precipitate collected upon a weighed filter, washed, dried, and the quantity of cyanuret of silver determined by a second weighing. Five parts of the precipitate correspond to 1 part of the hydrocyanic acid. If, for example 52 grains of cyanuret of silver be obtained, the 60 grains of dilute acid would have consisted of 10.4 grains of anhydrous acid, and of 49.7 grains of water. Were it desired, according to the prescription of any pharmacopœia, to make a hydrocyanic acid containing 3 per cent. of anhydrous acid, and consequently 97 per cent. of water, it is done in the following manner:—3 hydrocyanic acid is to 97 water as 10.4 acid is to X = 336.2 water: to 10.4 grains of anhydrous acid 336.2 grains of water must be added, in order to form a mixture which shall contain 3 per cent. of anhydrous acid. To each drachm of the product, therefore, since it consists of 10.4 grains of anhydrous acid and 49.6 of water, 336.2—49.6 = 286.6 grains of water must be added.

* Nitrate of silver is an exceedingly delicate test of the presence of this acid.

ded to the solution, which is then treated with a known weight of the peroxide in fine powder; every 4 parts of the oxide dissolved corresponds to one of the anhydrous acid.

Properties. 1780. The properties of the aqueous acid are similar to those of the concentrated, with the difference of taste, odour, and poisonous and combustible properties, which are dependent on a higher or lower degree of concentration; it decomposes when perfectly pure as readily as the anhydrous acid, becoming brown, and at last black.

How preserved. 1781. Like the anhydrous acid, however, it may be preserved by adding a trace of a strong mineral acid; a slight permanent reddening of litmus paper should not therefore be considered a sufficient reason for rejecting an acid; it should be clear and colourless, leave no residue on evaporation, nor be precipitated or blackened by hydrosulphuric acid gas (lead or mercury). Treated with ammonia, and evaporated in a water-bath, the dry residue should not exceed one quarter per cent.; nor should it become brown when heated, this indicating the presence of formic acid, which may also be detected by the tests hereafter to be mentioned. Sulphuric acid is detected by baryta; hydrochloric acid by evaporating in a water-bath till all odour of prussic acid is gone, and then adding a salt of silver. By careful rectification over chalk, an excess of mineral acids may readily be corrected; but in this case a trace of hydrochloric or sulphuric acid must be added afterwards, to give stability to the acid. L. 769.

Detection of hydrocyanic acid. 1782. As this acid is a very powerful poison, all experiments with it must be performed with the greatest caution. Several fatal accidents have occurred; even the fumes, incautiously inhaled, produce severe head-ache, nausea, and fainting. A single drop introduced into the throat of a large dog, kills the animal. According to Herbst, the best antidote is the cold affusion.

1783. The presence of the free acid is recognized by its odour. Its presence in the stomach after death may be detected in several ways. The sulphate of copper forms when rendered alkaline by a little potassa, a greenish precipitate, which becomes nearly white, on the addition of hydrochloric acid, but this is of less value than the formation of Prussian blue as proposed by Scheele:

Scheele's process. To the liquid supposed to contain hydrocyanic acid, add a solution of green vitriol,* throw down the protoxide of iron by a slight excess of pure potassa, and acidulate with hydrochloric or sulphuric acid, so as to redissolve the precipitate. Prussian blue will then make its appearance, if hydrocyanic acid had been originally present. The presence of *protoxide* of iron is essential.

Lassaigne's process. 1784. The subject has been investigated experimentally by Leuret and Lassaigne, and the process they have recommended is the following:

> The stomach or other substances to be examined are cut into small fragments, and introduced into a retort along with water, the liquid being slightly acidulated with sulphuric acid. The distillation is then conducted by the heat of boiling water, till about one eighth part of the water has passed over into the receiver. To the distilled liquid add a drop of caustic potassa, and immediately after a very small quantity of the solution of sulphate of copper. A small quantity of matter will be disengaged by the action of the alkali on the copper solution. Then add one or two drops of hydrochloric acid. If no hydrocyanic acid be present, the

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* Liebig disapproves of this test.

precipitate will be dissolved and the liquid become transparent; but if any of the acid is present it will remain undissolved and white. By this method $\frac{1}{20000}$ part of the acid may be detected. There is, however, a source of ambiguity; the same white precipitate will remain if the liquid should contain hydriodic acid. Sulphate of iron when substituted for sulphate of copper will detect $\frac{1}{10.000}$ of the weight of the acid, but it has the advantage of being characteristic in consequence of the formation of Prussian blue.*

Hydrocyanate of ammonia.

1785. *Hydrocyanate of Ammonia, Cyanuret of Ammonium.* NH_4Cy, eq. = 44.54. Prepared by distilling dry ammoniacal salts with metallic cyanurets, or by bringing anhydrous hydrocyanic acid into contact with ammoniacal gas, when the compound is produced in the form of bright crystalline plates. It is almost as volatile as the acid itself; decomposes very rapidly in water, is poisonous, and has a strong peculiar smell.

Hydrocyanic acid with metallic oxides,

1786. On bringing hydrocyanic acid into contact with metallic oxides which retain their oxygen by a feeble affinity, as in the oxides of mercury, silver, palladium, they suffer mutual decomposition, giving rise to the formation of water and a metallic cyanuret; if no water be present, the decomposition is accompanied by so great an evolution of heat as to cause an explosion. The alkaline oxides unite with the acid without decomposition; in this class of compounds also the decomposition of the acid and alkali is instantly effected, when the solution is treated with another metallic cyanuret, with which they form a double compound. With many peroxides, as, for example, with the peroxide of copper, the hydrocyanic acid gives rise to a corresponding percyanuret; but this is decomposed either instantly, or after a short time, into cyanogen gas, and a protocyanuret; with the peroxide of lead the protocyanuret is formed, and cyanogen liberated.

With silver, &c.

1787. The compounds of cyanogen with silver, mercury, and most heavy metals, are not decomposed by dilute ox-acids, and are with difficulty decomposed by concentrated nitric acid at a boiling temperature; many of them with great facility by hydrosulphuric and hydrochloric acid into hydrocyanic acid, and a metallic sulphuret or chloride (cyanurets of mercury, silver). The cyanurets of the precious metals (silver, mercury) are decomposed by heat like the corresponding oxides into cyanogen and metal; the cyanurets of the heavy metals into a carburet and free nitrogen; the cyanurets of the alkaline metals, if protected from the action of the air and moisture, will bear a very high temperature without decomposition.

Insoluble cyanurets

1788. All insoluble cyanurets of the heavy metals may be formed by adding hydrocyanic acid to the acetate. They are decomposed on being heated in a large excess of hydrochloric acid or in hydrate of potassa into a metallic chloride, or into an oxide, ammonia, and formic acid; the latter is the case with the alkaline cyanurets when boiled in an excess of alkali. All metallic cyanurets, the corresponding oxides of which do not retain carbonic acid at a red heat, evolve, when burnt with oxide of copper, nitrogen and carbonic acid gases in the proportion 1 : 2 by volume.

Cyanuret of potassium,

1789. *Cyanuret of Potassium.* KCy eq. 65.54. Formed, when potassium is heated in cyanogen gas with the appearance of com-

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* *Ann. de Chim. et Phys.* xxvii. 200.

bustion, by heating potassium with anhydrous substances containing nitrogen, by heating the carbonate of potassa to redness with matter containing carbon and nitrogen.

Prepared. By adding hydrocyanic acid in excess to a recently prepared concentrated solution of caustic potassa, evaporating the solution in a retort at a boiling heat till crystallization commences, when it must be poured into a porcelain dish and fused at a low red heat. Or a saturated alcoholic solution of hydrate of potassa is treated with strong hydrocyanic acid in successive portions as long as it throws down a white crystalline precipitate, which should be washed with alcohol and dried. An additional quantity is obtained by evaporating the liquid in a retort. Or better by heating the ferrocyanuret of potassium, carefully dried and reduced to a fine powder, in an iron vessel or well-closed crucible to a strong red heat, exposure to the air being carefully avoided till quite cold; the semi-fused or black porous mass must then be reduced to a fine powder, placed in a funnel, moistened with a little alcohol, and then washed with cold water. The first concentrated colourless solution which passes off, is rapidly brought to dryness and fused in a porcelain dish. The pounded fused mass may also be boiled in spirit when the cyanuret is deposited in crystals on cooling. Alcohol of 60 per cent. dissolves at the boiling temperature a considerable quantity of the cyanuret, almost the whole of which is again deposited as the solution cools; if it be stronger or weaker, this does not occur. The application of warm water in the preparation must be altogether avoided, as when air is present it at once colours the solution yellow, owing to the reproduction of the ferrocyanuret of potassium.

Properties. 1790. Colourless, crystallizes in transparent cubes, or other forms of the octohedral system, without odour, but of a sharp biting alkaline and bitter-almond taste; fuses readily to a clear transparent liquid, and will bear a white heat without decomposition in close vessels; exposed to oxygen, on the contrary, it is converted into cyanate of potassa. On exposure the crystals become opaque, deliquesce in a moist atmosphere, are very soluble in water, the solution is decomposed even by the carbonic acid of the air, and smells of prussic acid. Even kept in close vessels it decomposes in a shorter or longer time.

Action of water. 1791. The cyanuret of potassium is converted, when dissolved in water, into hydrocyanate of potassa; if the solution be evaporated with an excess of potassa, the whole of the nitrogen is evolved as ammonia, and formate of potassa remains. Effervescence on the addition of an acid proves the presence of carbonic acid; a yellow colour, that of iron; and a blackening when heated, the admixture of salts of formic acid. It may be used instead of the hydrocyanic acid.

Cyanuret of iron. 1792. *Cyanuret of Iron.* FeCy; eq.=54.39. This compound, remarkable from its tendency to form a very peculiar class of double compounds by uniting with other cyanurets, would appear as incapable of existing in a free state as the corresponding protoxide. On adding a proto-salt of iron to a solution of cyanuret of potassium, a yellowish-red precipitate is formed, which is redissolved by an excess of the cyanuret into a yellow liquid, the ferrocyanuret of potassium. On heating dry ferrocyanuret of ammonium, cyanuret of ammonium is evolved, and a gray insoluble powder, which has been considered as this compound, is the residue obtained. It is also produced, according to Robiquet, by pouring a saturated solution of hydrosulphuric acid over recently precipitated Prussian blue contained in a well-stoppered vessel; the Prussian blue becomes white, and the solution contains hydrocyanic acid.* The properties of these preparations differ too widely to allow of their being considered as identical.†

Bicyanuret of mercury.

1793. *Bicyanuret of Mercury.* $HgCy_2$, eq.=254.78. An aqueous solution of prussic acid is treated with finely powdered peroxide of mercury until all odour of the former disappears; the liquid yields on evaporation perfectly pure crystals of the bicyanuret.

Process,

For this purpose the acid prepared as recommended by Geiger is most convenient; it should be introduced into a well-stopped bottle, and the combination with the oxide of mercury promoted by frequent agitation. It must always be remembered, that the compound can only be produced when water is present in sufficient quantity to dissolve the whole of the cyanuret; water must therefore be added, should it be observed that the liquid smells of prussic acid, while any portion of the oxide of mercury remains undissolved. Or by adding to a solution of 2 parts of ferrocyanuret of potassium in 15 parts of boiling water, 3 parts of perfectly dry bisulphate of the peroxide of mercury; boil the mixture for a quarter of an hour, and separate the clear liquid while boiling hot from the precipitate by filtration; as the solution cools, the bicyanuret crystallizes. The mother-liquor yields a second crop of crystals by further concentration; or it may be evaporated to dryness, and the cyanuret obtained from the residue by boiling alcohol. The first crystals from the aqueous solution are purified by a second crystallization.

Explained.

1794. The formation of the cyanide in this process is owing to the mutual decomposition between the 2 eq. of cyanuret of potassium of the ferrocyanuret and 2 eq. of persulphate of mercury into bicyanuret of mercury and sulphate of potassa, while the cyanuret of iron is precipitated.

Properties.

1795. Crystallizes in colourless transparent regular four or six-sided prisms; they are anhydrous, permanent in the air, of a very disagreeable metallic taste, and are very poisonous. Is dissolved by 8 parts of water at 60°, but is more soluble in boiling water, and in alcohol.

Peroxide of mercury decomposes all soluble metallic cyanurets with the formation of an oxide and double cyanurets of mercury and other metals.‡

Cyanuret of silver.

1796. *Cyanuret of Silver.* AgCy, eq. 134.39. Falls, on mixing a soluble salt of silver with hydrocyanic acid, in the form of a brilliant white curdy precipitate; is decomposed by all hydracids, but with great difficulty by other mineral acids; strong boiling nitric acid alone can dissolve it; suffers no change by the caustic fixed alkalies, is readily dissolved by ammonia. Is soluble in a concentrated solution of the nitrate of silver, forming with it a compound, which may be obtained in crystals, but is not permanent in water. It gives rise to double compounds with all cyanurets of the alkaline metals.

Cyanuret of palladium.

1797. *Cyanuret of Palladium.* PdCy, eq. 79.69. The affinity of palladium for cyanogen surpasses that of all other metals; they

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* Berzelius.

† *Sesqui, and Proto-cyanurets of Iron,* $FeCy+Fe_2Cy_3+4$ aq.

‡ If the bicyanuret be boiled with an excess of peroxide of mercury, the latter is dissolved in large quantity (3 eq. Kühn), and the solution on evaporation deposits a compound in fine acicular crystals; these are more soluble in cold water than the bicyanuret, and have an alkaline reaction on vegetable colours. The formation of this compound, during the preparation of the bicyanuret, must be carefully avoided, or only a white saline mass may be obtained. This is best done by the careful addition of hydrocyanic acid until its odour is slightly perceptible.

combine, whenever hydrocyanic acid or any soluble cyanuret is added to a salt of the oxide of palladium, in the form of a light chestnut precipitate, which has a greenish tint if copper be present; gives rise to double salts with ammonia, cyanuret of potassium, and nitrate of the oxide of palladium.

Percyanuret of gold.

1798. *Percyanuret of Gold.* $AuCy_3$, eq.$=278.17$. This compound has recently been used medicinally.

A solution of gold in aqua regia, carefully deprived of all free acid by evaporation, is precipitated by a recently prepared solution of caustic potassa to which hydrocyanic acid has been added in excess; care must be taken that a small quantity of the chloride of gold remain in the solution. The yellowish-white precipitate is collected, washed, and dried. An excess of cyanuret of potassium dissolves the precipitate, and the solution has a yellowish-red colour, but in this case it is re-precipitated by the addition of an acid. It may also be prepared by adding to 16 parts of gold dissolved in aqua regia by the aid of heat a boiling solution of 24 parts of bicyanuret of mercury, evaporating to dryness, and washing with pure water.

Double cyanurets of the metals.

1799. All insoluble metallic cyanurets (the heavy metals) combine with the soluble (the alkaline metals) to peculiar generally crystallizable double compounds, which are very similar in their general properties to the combinations of the soluble and insoluble metallic sulphurets. On mixing a double cyanuret of potassium or sodium with a metallic salt, the basis of which is an oxide of a heavy metal, a new double compound is generally formed, arising from the replacement of the alkali by its equivalent of the heavy metal. The double cyanuret of silver and potassium, $KCy+AgCy$, forms, with acetate of lead, $PbO\bar{A}$, the double cyanuret of silver and lead, $PbCy+AgCy$, and acetate of potassa.

Constitution of the double compounds of iron and cyanogen.

1800. The composition of these compounds is best explained by supposing the existence of a radical, which contains 1 eq. of iron in combination with carbon and nitrogen in the same proportion as they exist in cyanogen, but in such quantity as would form 3 eq. of the latter, and which, by uniting with 2 eq. of hydrogen, form a bibasic acid. The radical itself may be called ferrocyanogen; the acid, hydro-ferrocyanic acid; and the compounds of the radical with the metals by the same adjuncts to ferrocyanuret as are used for the corresponding oxides.

The ferrocyanogen is composed of

$$\left.\begin{array}{l}\text{6 eq. carbon}\\ \text{3 eq. nitrogen}\end{array}\right\}=\text{3 eq. cyanogen}+\text{1 eq. iron}=\text{1 eq. ferrocyanogen; symb. } Cfy.$$

Compounds of Ferrocyanogen.

Hydro-ferrocyanic acid.

1801. *Hydro-Ferrocyanic Acid.* $Cfy+2H$, eq.$=109.17$. Discovered by Porrett.

Process.

Prepared by decomposing recently precipitated ferrocyanuret of lead or copper by sulphuretted hydrogen; filter to separate the metallic sulphuret, and evaporate over sulphuric acid in vacuo.* Or by mixing pure Prussian blue with ten times its volume of concentrated hydrochloric acid, and as soon as the blue colour has disappeared, and the insoluble portions have become yellow or brown, washing it well with fresh portions of the concentrated acid; the moist mass should be spread out upon a clean tile, placed under a bell-jar with quick lime, and when dry dissolved in alcohol, and the solution spontaneously evaporated.†

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* Berzelius.

† Robiquet.

Properties.

1802. A white distinctly crystalline mass, or small granular, sometimes acicular crystals, which acquire a blue colour by exposure to the air. The aqueous solution is decomposed by boiling into hydrocyanic acid, and a white, but after exposure in open vessels blue, precipitate. The hypothetical radical of the acid can (probably) not be isolated.

Ferrocyanuret of ammonium.

1803. *Ferrocyanuret of Ammonium.* It may be formed by digesting at a gentle heat the ferrocyanuret of lead with carbonate of ammonia; filtering to separate the carbonate of lead, and evaporating to crystallization. It is isomorphous with the ferrocyanuret of potassium; the crystals are white, or yellowish-white, transparent, permanent in the air, very soluble in cold, but decomposed by boiling water into cyanuret of ammonium and cyanuret of iron, insoluble in alcohol. It forms with sal ammoniac a double salt, which is obtained by boiling a solution of equal parts of ferrocyanuret of potassium and sal ammoniac in 6 parts of water, when it forms, on cooling, large lemon-yellow crystals, which are very brittle and permanent in the air. They are composed of an eq. of ferrocyanuret of ammonium, 1 of sal ammoniac, and 3 eq. water.*

Hydro-ferrocyanic acid and metallic oxides.

1804. On bringing the hydro-ferrocyanic acid into contact with metallic oxides, the latter are reduced by the hydrogen of the acid, water, and a compound of the metal with the radical of the acid being formed; as 1 eq. of the acid contains 2 eq. of hydrogen, it follows as a necessary consequence that it decomposes 2 eq. of the most numerous class of oxides, in which 1 eq. of oxygen is present in 1 eq. of the oxide.

Decomposed by heat.

1805. The ferrocyanurets are, without exception, decomposed when exposed to a red heat in close vessels; those which contain an alkaline metal give rise to the formation of the cyanuret of that metal, a carburet of iron, and the evolution of nitrogen gas; all others yield mixtures of metals and metallic carburets, with or without the evolution of cyanogen. All the soluble ferrocyanurets are decomposed by being boiled with peroxide of mercury into perycyanuret of mercury, free alkali, and oxy-cyanuret of iron. The ferrocyanurets of potassium and sodium are converted by being calcined in open vessels into alkaline cyanates, and the black oxide or carburet of iron.

Properties.

1806. Most of the ferrocyanurets contain water of crystallization, which they lose when heated. Those of zinc, copper, and mercury unite with ammonia to peculiar crystalline double compounds.† Most of them are soluble in concentrated sulphuric acid without decomposition; or they unite with it, when they lose their colour, to saline combinations in which the ferrocyanuret acts the part of a base. By nitric acid they are decomposed, many of them with the evolution of cyanogen and the formation of metallic ferrid-cyanurets. When those which are soluble in water are boiled with dilute acids, the hydro-ferrocyanic acid is separated, and at that temperature decomposed into hydrocyanic acid which escapes, and into the white but impure protocyanuret of iron, which, on exposure to the air, absorbs oxygen and becomes blue.

Ferrocyanuret of potassium.

1807. *Ferrocyanuret of Potassium.* In crystals K_2Cfy+3 aq., eq. $=185.47$. This compound occurs of great purity in commerce, and is

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* Bunsen.

† Ibid.

Chap VI.

Process. prepared on a large scale by fusing substances which are rich in nitrogen, as horn, hoof, and dried blood, with 2—3 parts of carbonate of potassa in iron vessels; the mass after perfect fusion is allowed to cool, the soluble parts removed by boiling water from which the ferrocyanuret is obtained by crystallization. It may be obtained on a small scale by boiling Prussian blue in carbonate of potassa.

Explained. 1808. By the fusion of substances containing carbon and nitrogen with carbonate of potassa at a red heat, the potassa is reduced by a portion of the carbon to potassium, by the reaction of which on the rest of the materials cyanuret of potassium as the principal product is formed. The red-hot fused mass does not contain a particle of the ferrocyanuret, but it contains, in the form of a black slime, a large quantity of finely divided metallic and carburetted iron. If the mass be treated with cold water, and the solution evaporated, no ferrocyanuret is obtained; but if, while covered with water, it is freely exposed to the air and gently warmed for some hours, oxygen is rapidly absorbed, and a yellow solution is obtained, which is rich in ferrocyanuret of potassium; this arises from the solution of pure cyanuret of potassium dissolving iron when oxygen is present with the formation of potassa; the potassium, therefore, of the cyanuret, by uniting with oxygen, gives the cyanogen to the iron, by which the latter is converted into cyanuret, and thus acquires the property of uniting with undecomposed cyanuret of potassium to the ferrocyanuret.

Effect of air.

Air excluded. 1809. In close vessels the solution of iron by cyanuret of potassium is attended with the evolution of hydrogen, owing to the decomposition of water, the oxygen of which unites with the potassium, while the cyanogen passes over to the iron. The fused mass contains a large quantity of free potassa, which, by being boiled with the cyanuret of potassium, causes the decomposition of the latter into formate of potassa and ammonia; if the animal substances be fused in open vessels with the potassa, a portion of the cyanuret of potassium is burnt into cyanate of potassa, the solution of which is decomposed by boiling into ammonia and bicarbonate of potassa. The ammonia arises in every case from the decomposition of the cyanuret of potassium; its formation is consequently always accompanied by a corresponding loss, and should be most carefully avoided.*

Properties. 1810. Crystallizes in large quadrangular tables or short prisms with truncated edges and angles, which belong to the square prismatic system; is of a lemon-yellow colour, of sp. gr. 1.832; has at first a sweetish bitter, but afterwards saline taste; is permanent in the air, loses at 212° 12.82 per cent.=3 eq. of water, and becomes white; is soluble in 4 parts of cold and in 2 parts of boiling water; is insoluble in alcohol, by which it is precipitated from its aqueous

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Protosulphate of iron useful. * It is best to treat one third either by volume or weight of a cold solution of the raw mass with protosulphate of iron as long as a precipitate falls, then add the remaining two thirds of the solution, and bring the whole to the boiling point; it must always be remembered that the solution must contain free potassa. In this manner sulphate of potassa is obtained, and all the cyanuret of potassium is converted without any loss into the ferrocyanuret; the solution can be evaporated without decomposition, and the sulphate of potassa is easily separated by crystallization. The raw solution generally contains some sulphocyanuret of potassium, sulphuret of potassium, formate and carbonate of potassa, all of which remain in the mother liquor.

solution in brilliant yellow flakes. Is converted by nitric acid, with the escape of cyanogen, and by chlorine, into the ferrid-cyanuret of potassium. At a red heat it is decomposed into the carburet of iron and cyanuret of potassium, but by the action of atmospheric air the latter is converted into cyanate of potassa.

Use.

1811. The ferrocyanuret of potassium forms double compounds with other ferrocyanurets. It is used as a test for the oxide of iron in solution. When thus employed, however, it must be remembered that the solution must not have an alkaline reaction, for all solutions of oxide of iron which contain free ammonia are not precipitated by the ferrocynnuret of iron.

It is used for the preparation of hydrocyanic acid, percyanuret of mercury, Prussian blue, &c.; taken in large doses is purgative and not poisonous.*

Ferrocyanuret of mercury.

1812. *Ferrocyanuret of Mercury.* On mixing a solution either of pro- or peroxide of mercury with ferrocyanuret of potassium a white precipitate falls, which spontaneously decomposes into cyanuret of mercury which is re-dissolved, and into cyanuret of iron. This change is rendered more rapid by the aid of heat, and metallic mercury is separated when a proto-salt of mercury has been used.

Colour of precipitates by K_2Cfy.

1813. Ferrocyanuret of potassium produces white precipitates with the salts of silver, zinc, and bismuth, a greenish-white with those of nickel, and green with cobalt; but the latter, by taking up water, become reddish-gray; with salts of protoxide of manganese a white precipitate is first formed, but it afterwards acquires the colour of peach-blossoms.

Prussian blue.

1814. *Sesqui-ferrocyanuret of Iron.* Discovered by Diesbach in Berlin in 1710, from which it became generally known as Prussian or Berlin blue. It is formed whenever a salt of peroxide of iron is added to a soluble metallic ferrocyanuret; compounds similar in colour, but different in constitution, although likewise known by the name of Prussian blue, may be obtained by precipitating the ferrid-cyanuret of potassium by a salt of the protoxide of iron, or by precipitating the ferrocyanuret of potassium by a proto-salt of iron, adding an acid, and exposing the precipitate to the air until it becomes blue.

Process.

By precipitating a solution of perchloride or pernitrate of iron by ferrocyanuret of potassium, care being taken to avoid an excess of the latter. Or by dissolving 6 parts of green vitriol and 6 parts of ferrocyanuret of potassium each by itself in 15 parts of water, mixing the two solutions, and then adding to them 1 part of concentrated sulphuric acid and 24 parts of fuming hydrochloric acid under constant stirring. After some hours the whole should be treated with a clear solution of 1 part of bleaching-powder in 80 of water, added in successive portions, care being taken to stop the addition of the bleaching liquid as soon as an effervescence arising from the escape of chlorine gas is observed. After standing some hours, the precipitate, should be thoroughly washed† and dried, either at common or high temperatures. Or the precipitate may be treated with dilute nitric acid till it is rendered of a deep blue colour. This yields the finest product.‡

Properties.

1815. Prussian blue dried at common temperatures is a light porous body of a deep velvet-blue colour; dried, on the contrary, at high temperatures, it has a deep copper-red colour, but the powder

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* For other ferrocyanurets see Liebig and Turner's *Elements*, 780.

† Hochstätter.

‡ For details of the manufacture, see Ure's *Dict. Arts and Manuf.* 1040.

is blue; it is tasteless, insoluble in water and dilute acids, and is not poisonous. The painter's Prussian blue of commerce contains variable quantities of earthy matter. When heated in close vessels, water, hydrocyanic acid, and carbonate of ammonia are evolved, and carburet of iron is the residue; it may be kindled in the air by a red-hot body, when it burns slowly to oxide of iron; it is decomposed by fuming nitric acid, but strong sulphuric acid unites with it, forming a white mass of the consistence of paste. Concentrated hydrocyanic acid deprives it of its iron, and liberates the hydro-ferrocyanic acid; sulphuretted hydrogen whitens it, but the colour returns on exposure to the air; metallic zinc and iron have a similar action. By peroxide of mercury it is decomposed into percyanuret of mercury, and an insoluble mixture of oxide and cyanuret of iron; by alkalies, into soluble ferrocyanurets and peroxide of iron.

Chemical constitution.

1816. In reference to the constitution of this compound, it is known with certainty that it differs from all other ferrocyanurets. It contains hydrogen and oxygen, which cannot be separated without the decomposition of the compound, so that it must be considered as formed by the union of hydro-ferrocyanic acid with the peroxide of iron combined without reduction. According to the experiments of Berzelius, the weight of the iron of the hydro-ferrocyanic acid is to that of the oxide as 3 : 4; from this it may be concluded that its formation is owing to the decomposition of 3 eq. of ferrocyanuret of potassium, and 2 eq. of peroxide of iron, into 6 eq. of a potassa salt and into Prussian blue.

$$\left.\begin{matrix} 3Cfy+6K \\ 2Fe_2+6O \end{matrix}\right\} = (3Cfy+2Fe_2)+6KO.$$

Effect of light.

1817. Prussian blue becomes white in the direct rays of the sun, and cyanogen is evolved; but in the dark it absorbs oxygen and recovers its colour.* This change of colour in substances dyed with Prussian blue in solar light, arises from a peculiar decomposition; the recovery of the colour is owing to the formation of the so-called basic Prussian blue.

Ferrocyanurets with two basic metals.

1818. When concentrated solutions of the salts of baryta, strontia, lime, magnesia, protoxide of iron, protoxide of manganese, copper, &c., are added to a solution of the ferrocyanurets of potassium, white bulky, frequently crystalline, precipitates are formed, which arise from the replacement of 1 eq. of potassium by 1 eq. of the other metal. These double ferrocyanurets which contain an alkaline metal, although with difficulty, are nevertheless soluble in water; they contain water of crystallization; when dried at a high temperature they glow with a brilliant light, and cyanate of potassa is formed.†

Ferrocyanuret of potassium and iron.

1819. *Ferrocyanuret of Potassium and Iron* is obtained in the form of a bluish-white precipitate when a salt of the protoxide of iron is added to a solution of the ferrocyanuret of potassium. By the action of chlorine or nitric acid 3 eq. of potassium and 1 eq. of iron are removed from 3 eq. of the compound; Prussian blue is left. Exposed to the air it absorbs oxygen and becomes blue; when washed, the ferrocyanuret of potassium is dissolved, and after all soluble salts are removed the following compound is left.

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* Chevreul.

† Campbell.

Basic sesqui-ferrocyanuret of iron.

1820. *Basic Sesqui-ferrocyanuret of Iron.* By continued washing the preceding salt dissolves, without leaving any residue of oxide of iron, to a beautiful deep blue solution, which may be again evaporated to dryness without decomposition. The addition of any salt causes the separation of the compound; the precipitate may be redissolved in pure water, and is not thrown down by alcohol.* The formation of this soluble salt is prevented by the presence of a strong acid, which unites with the peroxide of iron, and Prussian blue is left.

Ferrocyanuret of potassium.

1821. *Ferrocyanuret of Potassium—Sesqui-ferrocyanuret of Iron.* The blue precipitate which falls when a salt of the peroxide of iron is added to a solution of ferrocyanuret of potassium, always contains, when the iron salt is in excess, variable quantities of the ferrocyanuret of potassium; the latter may, by continued washing with water, gradually, although with great difficulty, be removed, which accounts for the constant presence of potassium in the Prussian blue of commerce; it varies from 2 to 9 per cent.†

Ferrocyanuret of zinc.

1822. *Ferrocyanuret of Potassium—Ferrocyanuret of Zinc*, is obtained by precipitating any salt of zinc, which is free from iron, by ferrocyanuret of potassium, and then washing and drying the precipitate. It is a white, tasteless powder, is insoluble in dilute acids, and contains 2 eq. of ferrocyanogen, 1 eq. potassium, 3 eq. of zinc, and 12 eq. of water $= 2Cfy + \left\{\begin{matrix}K\\3Zn\end{matrix}\right\} + 12$ aq. A blue tint shows the presence of Prussian blue. It is used in medicine.

Ferrid-cyanogen.

1823. *Ferrid-cyanogen.* By treating a solution of ferrocyanuret of potassium with chlorine a new compound of potassium is formed, the radical of which contains twice as much cyanogen and iron as exists in ferrocyanogen. It may be called ferrid-cyanogen; it unites with 3 eq. of hydrogen and forms a tribasic acid.

Its formula is $6Cy+2Fe$; symb.$=$Cfdy; eq.$=214.34$.

The formula of hydro-ferridcyanic acid is	$Cfdy + 3H$
ferridcyanuret of potassium	$Cfdy + 3K$
ferridcyanuret of iron (Prussian blue)	$Cfdy + 3Fe$

Hydro-ferridcyanic acid and metallic oxides.

1824. *Hydro-ferridcyanic Acid* unites with metallic oxides, forming water and a metallic ferridcyanuret; of these the compounds with the metals of the alkaline earths, as also that corresponding to the peroxide of iron, are soluble in water; all others are insoluble

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* Two eq. ferrocyanuret of potassium and iron contain 1 eq. of ferrocyanuret of potassium and 3 eq. of ferrocyanuret of iron ($6Fe+3Cfy$); of these 6 eq. of iron, 2 are converted into peroxide by the absorption of oxygen, and the ferrocyanuret of potassium is dissolved; so that the soluble blue compound must be represented by the formula $\left\{\begin{matrix}2Fe_2\\Fe_2O_3\end{matrix}\right\} + 3\,Cfy$, which corresponds to a compound of 1 eq. of Prussian blue and 1 eq. of peroxide of iron.

† If, instead of the salt of peroxide of iron, the ferrocyanuret of potassium be in excess, the precipitate is likewise blue, but it is a mixture of Prussian blue with a compound composed of Prussian blue and ferrocyanuret of potasssium eq. to eq. $2Cfy+\left\{\begin{matrix}Fe_2\\K\end{matrix}\right\}$. On washing, the latter is dissolved, giving a deep blue solution, which may be evaporated without decomposition, when it is obtained as a deep blue mass possessed of a strong lustre. It is precipitated by the addition of a salt to its solution, without however losing its solubility in pure water; it is distinguished from the soluble basic Prussian blue by being precipitated from its solution by alcohol.

in water. The latter may be prepared by the mutual decomposition of a soluble ferridcyanuret and the corresponding metallic salt.

Ferridcyanuret of potassium.

1825. *Ferridcyanuret of Potassium.* K_3Cfdy; eq.=331.79. Discovered by L. Gmelin, is prepared by passing a stream of chlorine gas through a solution of ferrocyanuret of potassium, until it no longer gives a blue precipitate with salts of the peroxide of iron; the solution is then evaporated, and the crystals obtained by cooling purified from the admixture of chloride of potassium by re-crystallization.*

Properties.

1826. They are transparent right rhombic prisms of a red colour and high lustre, anhydrous, permanent in the air, and soluble in 3.8 parts of cold, but more freely in hot water; burn when held in the flame of a candle with brilliant scintillations; heated in close vessels, cyanogen and nitrogen gases are evolved, a mixture of carburet of iron and ferrocyanuret of potassium is the residue. The aqueous solution is decomposed by hydrochloric or sulphuric acid; in the last case, sulphur and cyanuret of iron are precipitated, and ferrocyanuret of potassium and prussic acid are formed. It is one of the most delicate tests for the protoxide of iron, with which it forms a precipitate similar to Prussian blue; peroxide of iron is not precipitated.

Ferrid-cyanuret of iron.

1827. *Ferridcyanuret of Iron.* This compound is likewise sold in commerce as Prussian blue, but it is of a lighter colour and differs from it altogether in constitution. It is prepared by precipitating a solution of the protosulphate of iron by ferridcyanuret of potassium, or by a mixture of ferrocyanuret of potassium and hypochlorite of soda, to which a certain quantity of hydrochloric acid has been added. In this kind of Prussian blue the three equivalents of potassium of the ferridcyanuret of potassium are replaced by 3 eq. of iron.

Turnbull's blue.

1828. The peculiarly beautiful Prussian blue sold in commerce under the name of Turnbull's blue, is the ferridcyanuret of iron; it is easily recognised by its action on ferrocyanuret of potassium, for being boiled in a solution of the latter it is decomposed into ferridcyanuret of potassium, which is dissolved, and into an insoluble gray residue of ferrocyanuret of iron and ferrocyanuret of potassium.†

Constitution of the ferrocyanurets according to Berzelius,

1829. According to Berzelius, the cyanurets form, by uniting with each other, double compounds similar to the double salts, which are produced by the oxacids; in these compounds, therefore, 1 eq. of cyanuret of iron is united with 2 eq. of another cyanuret, the constitution being such, if the metals be considered united with oxygen, as would be expressed by saying that the oxygen in the protoxide of iron is equal to one half that in the other metallic oxides.

According to Graham.

1830. According to Graham, the ferrocyanurets are formed from a peculiar acid, the eq. of which is triple of that of the hydrocyanic acid; it contains 3 eq. of cyanogen, which constitutes a radical called prussine in combination with 3 eq. of hydrogen. This acid is accordingly a tribasic hydracid corresponding to the cyanuric acid; in uniting with a metallic oxide three eq. of hydrogen are replaced by their eq. of the metals.

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* Its formation is owing to the decomposition of 2 eq. of ferrocyanuret of potassium, 2 Cfy + 4 K, by 1. eq. of chlorine into 1 eq. of ferridcyanuret, Cfdy + 3 K, and 1 eq. of chloride of potassium, KCl.

† Cambell. For *Cobalto-Cyanurets*, see T. and L. *Elem.* 786.

1831. *Chloride of Cyanogen.* Two compounds of chlorine with cyanogen are known, and these are isomeric in their constitution. The one, which at common temperatures is gaseous, was discovered by Gay-Lussac; the other, which is a crystalline solid, by Serullas. **Sect. III.** **Chloride of Cyanogen.**

1832. *Gaseous Chloride of Cyanogen,* CyCl? is formed when chlorine gas is transmitted into hydrated prussic acid, when moist bicyanuret is placed in an atmosphere of chlorine in the dark, or when mellon is heated in dry chlorine gas. **Gaseous chloride of cyanogen.**

1833. This compound, which is gaseous at common temperatures, has a most powerful penetrating odour, excites the eyes to a copious flow of tears, becomes solid at 0°, and forms long acicular needles, which fuse at 5° and boil at 10°; but, under a pressure of four atmospheres, it is still liquid at 70.° If the liquid be introduced into glass tubes and hermetically sealed, it is gradually converted into the solid chloride, and regular crystals of the following compound are obtained. **Properties.**

1834. Water dissolves 25, alcohol 100, and ether 50 times its volume of the gas without change. It is decomposed by the alkalies; salts of the protoxide of iron are rendered of a deep green colour when an alkali is added to the mixture. **Action of water, &c.**

1835. If moistened bicyanuret of mercury in chlorine gas be exposed to solar light, a heavy oily liquid of a yellow colour is formed, which is insoluble in water, and has the same odour as the gaseous chloride; the same substance appears to be formed by the action of chlorine upon the fulminate of silver. If it be dissolved in alcohol, and its solution thrown into water, a crystalline substance like camphor is precipitated; on exposing a mixture of moist chlorine and chloride of cyanogen gases to the sun's rays, two other solid compounds appear to be formed. **Of light.**

1836. *Solid Chloride of Cyanogen.* Discovered by Serullas. It is formed by exposing dry chlorine gas and anhydrous hydrocyanic acid to the sun's light; hydrochloric acid and the solid chloride, which is deposited in crystals, are formed. It may also be formed by heating sulphocyanuret of potassium in a stream of dry chlorine gas. **Solid chloride of cyanogen.**

1837. In the pure state it is white, sublimes in long transparent crystals, has a penetrating odour similar to the excrement of mice, and a sweet biting taste; its sp. gr.=1.32; fuses at 284°, sublimes at 374°. By digestion in water at a gentle heat, it is decomposed into cyanuric and hydrochloric acids, from which its constitution must be represented by the formula Cy_3Cl_3. It is soluble in absolute alcohol and ether without decomposition. **Properties.**

1838. *Iodide of Cyanogen.* CyI. Formed by heating dry cyanuret of mercury or silver with iodine;* most conveniently by heating a mixture of bicyanuret of mercury, iodine, and water, in a retort,† when at a gentle temperature the iodide sublimes, and collects in the neck of the retort as a fine crystalline snow, or in long needles. The crystals have a penetrating odour, which excites a flow of tears, may be dissolved in alcohol, ether, and water without decomposition, and are perfectly volatilized at 100°. **Iodide of cyanogen.**

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* Wöhler.

† Mitscherlich.

Cyanogen and sulphur.

1839. *Cyanogen and Sulphur.—Sulpho-cyanogen, Bisulphuret of Cyanogen.* $Cy+2S$, Symb.=Csy; eq.=58.59. Discovered by Liebig. Prepared by saturating a concentrated solution of a metallic sulphocyanuret with chlorine, or by heating it with nitric acid; it falls in the form of a deep yellow, amorphous powder, which retains its colour when dry; is light, porous; is insoluble in water, alcohol, and ether, but is dissolved by strong sulphuric acid from which it is precipitated by water. It is decomposed by nitric acid and by potassium with the aid of heat, giving rise to the formation of the sulphuret, cyanuret, and sulphocyanuret of potassium. Its decomposition by the action of heat is peculiarly remarkable, the products of its destructive distillation being sulphuret of carbon, sulphur, and the residue mellon, which at a high temperature is decomposed into nitrogen and cyanogen gases.

Hydro-sulphocyanic acid.

1840. *Hydro-sulphocyanic Acid.* $Csy+H$, eq. 59.53. Discovered by Rink. Occurs in the seeds and blossoms of the Cruciferæ (Senapis, &c.), and in the saliva of man and sheep.

Obtained.

1841. By decomposing the basic sulphocyanuret of lead by dilute sulphuric acid, care being taken to leave some lead in the solution, which is afterwards separated by hydrosulphuric acid gas; or by decomposing sulphocyanuret of silver in 10 volumes of water by the same gas.

Properties.

1842. A colourless fluid of a pure acid taste, which by the action of the air, and on being heated, readily decomposes into a variety of products; one of these deposits itself from the acid as a lemon-yellow, in water insoluble, powder. It cannot exist without water; on treating the aqueous acid with chlorine or nitric acid, it is deprived of hydrogen, and sulpho-cyanogen is precipitated: by a further action cyanic and sulphuric acids are formed, but the former is at once decomposed into carbonic acid and ammonia. It colours the salts of peroxide of iron blood-red, and is not poisonous.

Sulphocyanuret of ammonium.

1843. *Hydro-sulphocyanic Acid and Ammonia—Sulphocyanuret of Ammonium.* NH_4+CyS_2; eq.=75.74. By saturating the acid with ammonia and gently evaporating, a semi-fluid saline mass is obtained, which, at a higher temperature, suffers a peculiar decomposition. At first, ammoniacal gas is evolved, then sulphuret of carbon, and at last the protosulphuret of ammonium is sublimed. The residue, when the heat has not been driven too far, consists of melam, or of a mixture of melam with mellon.

Sulphocyanuret of ammonium is also formed by adding sulphuret of carbon to alcohol, which has been saturated with ammonia.

Metallic sulphocyanurets.

1844. *Metallic sulphocyanurets.* The hydro-sulphocyanic acid must be considered as a compound analogous in its constitution to the hydrated cyanic acid, the oxygen of the latter having been replaced by its equivalent of sulphur. Considered as a hydracid, the formula of the hydrated cyanic acid would be

CyO_2+H, corresponding to that of the hydro-sulphocyanic acid, CyS_2+H.

On its being brought into contact with the metallic oxides, the hydrogen is replaced by 1 eq. of the metal. The soluble metallic sulphocyanuret may be formed:—by the action of the acid on the metallic oxide, by heating the higher sulphurets of the alkaline metals to redness in cyanogen gas, or by conducting cyanogen gas into their solution, by heating or fusing the soluble metallic cyanurets with sulphur, or the insoluble cyanurets with the soluble sulphuret.

Properties of soluble metallic sulphocyanurets.

1845. The soluble metallic sulphocyanurets colour the salts of peroxide of iron blood-red; are decomposed, when heated in dry hydrochloric acid gas, into metallic chlorides and anhydrous hydrosulphocyanic acid, but the latter instantly decomposes into other products. The sulphocyanurets of the alkaline metals, when dry, bear a strong heat without decomposition, but, if oxygen be present, they are converted, with the evolution of sulphurous acid, into salts of cyanic and sulphuric acids; those of the heavy metals are decomposed by the red heat into mixtures of metallic sulphurets and mellon, this change being generally accompanied by the evolution of sulphuret of carbon and sulphur; at a higher temperature the residue evolves cyanogen and nitrogen gases in the proportion of 3 : 1.

Action of chlorine.

Heated to redness in chlorine gas, they give rise to metallic chlorides, mellon, chlorides of sulphur and cyanogen, and a small quantity of the sulphuret sublimes unchanged; they are most of them soluble in alcohol. The proto-salts of mercury are decomposed by the soluble sulphocyanurets into metallic mercury which is deposited, and into the soluble bisulphocyanuret. All the soluble sulphocyanurets form with the bicyanuret of mercury double compounds, which are readily obtained in crystals.

Sulphocyanuret of potassium.

1846. *Sulphocyanuret of Potassium.* KCsy; eq. 97.74. Ferrocyanuret of potassium, gently roasted to drive off water of crystallization, is mixed in the form of a fine powder with half its weight of flowers of sulphur, and the mixture fused in an iron vessel at a low red heat, until the bubbles of gas which escape through the melted mass inflame in the air and burn with a red light. The mass when cold is dissolved in boiling water, and treated with a solution of carbonate of potassa as long as a turbidity is produced; the whole is then boiled for a quarter of an hour, and the clear liquid separated from the precipitated iron by filtration. On evaporation crystals are obtained, which are separated from the admixture of carbonate of potassa by being re-dissolved in alcohol.

Properties.

1847. Crystallizes in long striated colourless prisms, which are anhydrous, of a cooling, somewhat biting taste, fuse much below the red heat to a clear liquid; deliquesces in a moist atmosphere, very soluble in hot alcohol, from which it crystallizes on cooling.*

Products of the decomposition of cyanogen and its compounds.

1848. *Cyanogen and Water.* A solution of cyanogen in water acquires rapidly in the light, but more slowly in the dark, a brown colour, and a brown flocculent precipitate falls; the solution is then found to contain carbonic acid, prussic acid, ammonia, urea, and oxalate of ammonia.†

Cyanogen and water.

1849. The different products, which arise from the reaction of cyanogen and water, are without doubt the results of several perfectly independent decompositions. One eq. of cyanogen and 3 eq. water contain the elements of 1 eq. of anhydrous oxalate of ammonia; 2 eq. cyanogen and 1 eq. water, the elements of 1 eq. of cyanic and 1 eq. of hydrocyanic acid. Carbonate of ammonia is formed from the

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* For others, see T. and L. 794.

† Wöhler.

decomposition of cyanic acid, and three equivalents of water; urea, by the union of cyanic acid with ammonia and water.

Cyanogen and ammonia.

1850. *Cyanogen and Ammonia.* If cyanogen gas be conducted into liquid ammonia, a decomposition similar to that produced by water ensues, but in a much shorter time. A large quantity of a brown substance, which contains ammonia in chemical combination, is deposited.

By heating this brown precipitate to redness, paracyanogen, water, and carbonate of ammonia are obtained; this decomposition is readily explained, when it is considered that this product may be considered as a compound of cyanogen (C_4N_2) with ammonia and cyanic acid; the latter of which, by decomposing with 3 eq. water, forms 2 eq. of carbonic acid and 1 eq. of ammonia.

Paracyanogen.

1851. *Paracyanogen.* Discovered by Johnston. Formed by heating to redness the brown precipitate formed by the decomposition of cyanogen with water or ammonia; left in small quantity on decomposing bicyanuret of mercury in a retort by heat.*

Cyanilic acid.

1852. *Cyanilic Acid.* By a long-continued boiling of mellon in dilute nitric acid, a solution is effected with the evolution of gaseous products, and the liquid yields on evaporation colourless, transparent, octohedral crystals; by resolution in hot water, hydrated cyanilic acid in soft tabular crystals of a mother-of-pearl lustre are obtained. This acid has the same composition as the crystalline cyanuric acid; contains, like the latter, 4 eq. water of crystallization, which it loses at 212°, when it becomes opaque and falls to a white powder. By the destructive distillation it is converted into hydrated cyanic acid; by solution in sulphuric acid and caustic potassa into cyanuric acid.

Cyanogen and hydrosulphuric acid.

1853. *Cyanogen and Hydrosulphuric Acid.* $Cy_2S_6H_4 + aq.$ Two compounds of cyanogen and hydrosulphuric acid are known, neither of which are formed when the gases are mixed in a dry state, but are generated by the direct combination of the gases when water is present. The one discovered by Gay-Lussac is obtained by mixing one volume of cyanogen with one and a half volume of sulphuretted hydrogen, a small quantity of water being present; both the gases are absorbed by the water, and on evaporation it deposits long yellow acicular crystals, a solution of which is not precipitated by salts of lead. The other compound was discovered by Wöhler.

Prepared.

It is prepared by conducting sulphuretted hydrogen into a saturated solution of cyanogen in alcohol, by which the latter is rendered yellow, and on being artificially cooled deposits this compound of cyanogen and sulphuretted hydrogen in bright orange-red crystals.

Properties,

1854. Insoluble in cold, slightly soluble in boiling water. Very soluble in hot alcohol, from which it may again be obtained in crystals; soluble by alkalies in the cold, and precipitated unchanged from the solution by acids; but on the application of heat a mixture of a metallic sulphuret and a sulphocyanuret is formed; its solution precipitates salts of silver, lead, and copper.

Hydrosulphocyanic acid and hydrosulphuric acid.

1855. *Hydro-sulphocyanic Acid and Hydrosulphuric Acid.* Discovered by Zeise. Prepared by saturating 1 volume of absolute alcohol at the temperature of 50° with ammoniacal gas, and adding

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* For products of the decomposition of sulphocyanogen, mellon (1726), hydromellonic acid, &c. see T. and L. *Elem.* 796.

to the solution a mixture of 0.16 vol. of bisulphuret of carbon, and 0.4 vol. of alcohol; the whole should be placed in a well-stopped glass vessel, which is kept perfectly full at the temperature of 60°. Two products are thus produced, of which the one is a compound of ammonia with an acid formed of sulphuret of carbon and sulphuretted hydrogen; this ammoniacal salt separates in the course of some hours as a crystalline deposit, and the residual liquid contains another ammoniacal salt, the acid of which may be considered as a compound of hydro-sulphocyanic acid and hydro-sulphuric acid.

SECTION IV. *Hypothetical Compounds of Cyanogen and Carbonic Oxide.*

Hypothetical compounds of cyanogen and carbonic oxides.

1856. Under these compounds the uric acid and the products of its decomposition are described. These substances are distinctly separated from all known bodies by their chemical relations; an explanation of their formation can only be developed by making certain hypotheses, of which the assumption that they contain cyanogen and carbonic oxide is a deduction drawn from their analyses. The compounds belonging to this group are uril, uric acid, alloxan, alloxantin, and uramil. (Liebig, 804.)

Uril.

1857. The uril, or urilic acid, which may from its composition be also called the cyan-oxalic acid, is an hypothetical compound of nitrogen, carbon, and oxygen, according to the formula $C_8N_2O_4$; it may be considered as a compound of cyanogen and carbonic oxide $2Cy+4CO$, or as oxalic acid, in which the oxygen which unites with the radical, carbonic oxide, has been replaced by its eq. of cyanogen.

C_2O_2+O . . . Oxalic acid.
$2(C_2O_2+Cy)$ . . . Cyan-oxalic acid.

If this acid be represented by the symbol Ul, the compounds are represented by the formula:

Rational formula.			Empirical formula.
2Ul+1 eq. urea .	=Uric acid .	=	$C_{10}N_4H_4O_6$
$2Ul+O^2+4$ aq. .	=Alloxan .	=	$C_8N_2H_4O_{10}$
2Ul+O +5 aq. .	=Alloxantin .	=	$C_8N_2H_5O_{10}$
2Ul+1 eq. amm.+2 aq.	=Uramil .	=	$C_8N_3H_5O_6$

Uric acid.

1858. *Uric Acid.* $C_{10}N_4H_4O_6$, or $2\,Ul+(C_2O_2+2NH_2)$. Discovered by Scheele; first pointed out as existing in the excrement of snakes by Vauquelin, in the excrement of silkworms by Brugnatelli, and in cantharides by Robiquet. Is a product of secretion of all carnivorous animals, of birds, and of many insects; is deposited from human urine generally in combination with ammonia, as it cools, as a yellow or brownish powder; the stone-like concretions in the joints of persons labouring under gout contain uric acid in combination with soda or ammonia; it is the basis of most calcareous deposits in the human bladder. The semi-fluid urine of serpents and birds is principally composed of urate of ammonia. The guano (the decomposed excrement of aquatic birds, which covers the surface of many of the smaller islands of the South Sea, and is used as manure,) is also composed in greater part of urate of ammonia.

Guano.

Process.

1859. Urinary calculi, or the white chalk-like excrement of serpents, is reduced to a fine powder and dissolved in a solution of caustic potassa by boiling; the solution is treated with hydrochloric acid in excess, boiled for one quarter of an hour, and the precipitate well washed. It is obtained perfectly pure by decomposing a saturated boiling solution of urate of potassa by hydrochloric acid.

Properties.

1860. Crystallizes in fine scales of a brilliant white colour and silky lustre, is tasteless and inodorous, heavier than water, almost insoluble in cold, slightly soluble, in small quantity, in boiling water; the solution reddens feebly the vegetable colours. It is dissolved by concentrated sulphuric acid, from which it is precipitated by water; in strong hydrochloric acid, it is somewhat more soluble than in pure water.

Product of destructive distillation.

1861. Exposed to the destructive distillation, the products of the decomposition of urea are obtained, namely, urea, cyanuric acid, and cyamelid (the insoluble cyanuric acid); also, hydrocyanic acid, a litle carbonate of ammonia, and, as a residue, a brown carbonaceous substance which is rich in nitrogen. In this decomposition the hydrated cyanic acid in combination with ammonia is deposited in the neck of the retort as urea; the cyamelid dissolved in potassa forms cyanurate of potassa.

Action of nitric acid.

1862. Dissolves in dilute nitric acid with the evolution of equal volumes of pure carbonic acid and nitrogen; the solution contains alloxan, alloxantin, parabanic acid, and ammonia; evaporated and treated with ammonia in excess, it acquires a purple-red colour, a test by which uric acid may be recognised. Fused with hydrate of potassa, carbonic acid, and cyanate of potassa, and cyanuret of potassium are obtained; boiled with peroxide of lead in water, it is decomposed into allantoin and oxalic acid, and urea is separated. Is insoluble in ether and alcohol. With sulphuric acid it forms a crystalline compound.[*]

Uric acid and metallic oxides.

1863. *Uric Acid and the Metallic Oxides.* The uric acid appears to unite with the metallic oxides without, as in the other acids, the separation of an eq. of water; its salts, with the fixed alkalies and alkaline earths, are sparingly dissolved by cold, but more freely by boiling water; with ammonia and the other oxides, insoluble compounds, generally of a white colour, are formed. All urates are decomposed by other acids, even by acetic acid; the uric acid is at first separated as a bulky gelatinous mass, but it shortly afterwards changes into a fine crystalline powder.

Urate of potassa.

1864. *Urate of Potassa.* Impure urate of ammonia (the excrement of serpents) is dissolved by boiling in a dilute solution of caustic potassa; and the clear liquid, obtained by separating the insoluble portions by filtration, is evaporated. On cooling, the urate of potassa separates as a white crystalline mass, which, when washed by cold water and dried, yields a powder composed of fine acicular crystals of a silky lustre; these crystals are very sparingly soluble in cold water, and the alkaline reaction is scarcely perceptible. Uric acid is more soluble in carbonate of potassa than in pure water; and one half of the carbonate is decomposed.

Urate of soda.

1865. *Urate of Soda.* The action of uric acid upon pure and carbonate of soda is the same as above described for potassa; this

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[*] Fritszche.

salt may also be formed by boiling uric acid in a solution of borax; it is the principal constituent of gouty concretions.*

Allantoin.

1866. *Allantoin.* Frequently called allantoic acid. Occurs ready formed in the allantoic fluid of the cow;† it is formed when uric acid is boiled in water with peroxide of lead.‡

Process.

One part of uric acid is boiled in 20 parts of water, and recently prepared and well-washed peroxide of lead is added in successive portions to the boiling liquid as long as its colour is observed to change. The hot liquid should be filtered, and evaporated until crystals are observed to form upon its surface. The crystals which have deposited when the solution has become quite cold, are purified by recrystallization. Or the allantoic fluid of the cow may be evaporated to one quarter its volume, and the crystals formed on cooling and long standing are purified by animal charcoal.

Properties.

1867. Small transparent and colourless prisms of the right rhombic system, which have a glassy lustre, are tasteless, have no action on vegetable colours, and are soluble in 160 parts of cold, but more freely in hot water. It is soluble in nitric acid, and is decomposed by it when the solution is boiled without the evolution of nitrous fumes. Its composition is such, that it contains the elements of anhydrous oxalate of ammonia minus 3 eq. water; this explains its decomposition by the alkalies, by which it is reduced at the boiling heat into an oxalate and ammonia.

Action of sulphuric acid, heat,

1868. Gently heated in concentrated sulphuric acid, it is decomposed into carbonic oxide, carbonic acid and ammonia; but if a strong heat be rapidly applied, the acid is blackened. It is soluble in caustic and carbonated alkalies by the aid of a gentle heat, and may be again obtained unchanged by crystallization. A solution of allantoin in hot water, to which a little ammonia has been added, produces, with the nitrate of silver, a white precipitate, which contains 43.56 per cent. of oxide of silver, and is composed as represented by the formula, $C_8N_4H_5O_5+AgO$; it consequently contains 2 eq. allantoin, $C_8N_4H_6O_6$—1 eq. water, HO+1 eq. oxide of silver.

Explained.

1869. In the decomposition of uric acid by the peroxide of lead, 2 eq. of oxygen derived from 2 eq. of the peroxide, and 3 eq. water, attach themselves to the constituents of the cyanoxalic acid, by which the latter is decomposed into 2 eq. oxalic acid and 1 eq. allantoin, and the urea is set free.

$$\begin{array}{l} 2PbO+\begin{array}{c}C_4O_4+N_2C_4\\ O_2+H_3O_3\end{array}=\left\{\begin{array}{l}\text{1 eq. cyanoxalic acid}\\ \text{1 eq. urea}\end{array}\right\}=\text{1 eq. uric acid.}\\ \hline \text{2 eq. oxalate of lead+1 eq. allantoin+1 eq. urea.}\end{array}$$

Its formula is $C_4\,H_3\,N_2\,O_3$, or $2\,Cy+3HO$.

Alloxan.

1870. *Alloxan.* The erythric acid of Brugnatelli; rediscovered by Wöhler and Liebig. One of the products of the decomposition of uric acid by nitric acid.

Process.

One part of dry uric acid is added in successive portions to 4 parts of nitric acid of sp. gr. 1.45 to 1.5, by which it is dissolved with effervescence and the production of heat; the production of a high temperature must be avoided as much as possible by artificial cooling, and by adding the uric acid slowly. Small granular crystals of a strong lustre are thus formed, and by degrees the whole liquid is converted into a solid mass. This should then be placed in a glass funnel; and after the fluid parts have thus drained off, it should be spread upon a porous tile, where it is rendered perfectly dry. It is purified by solution in hot water and recrystallization.

Properties.

1871. On the cooling of a warm but not perfectly saturated solu-

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* Wollaston. † Vauquelin and Buniva. ‡ Wöhler and Liebig.

tion of alloxan, it is obtained in large colourless and transparent crystals of the right prismatic system, and of a strong adamantine lustre; these crystals effloresce rapidly, losing 25 per cent.=6 eq. water, and are converted when gently warmed, with the loss of water, into anhydrous alloxan. If a hot saturated solution be allowed to crystallize in a warm place, anhydrous alloxan is deposited directly from the solution in oblique prisms, on the extremities of which truncated rhomboidal octohedrons are seen.

Solubility. 1872. It is very soluble in water, has a disagreeable odour, and a slightly saline astringent taste, reddens vegetable colours, and causes a purple stain on the skin. Treated with alkalies, alloxanic acid is formed; but on boiling it is decomposed into urea and mesoxalic acid. Heated with peroxide of lead, it is decomposed into urea and carbonate of lead, with which a few traces of oxalate of lead are mixed.

Action of zinc, &c. 1873. When brought into contact with zinc and hydrochloric acid, with chloride of zinc or sulphuretted hydrogen, alloxantin is produced; it is decomposed by free ammonia into mykomelinic acid, by nitric acid into parabanic acid, by sulphuric and hydrochloric acids into alloxantin, by sulphurous acid and ammonia into thionurate of ammonia, with alloxantin and ammonia into murexid. With a protosalt of iron and an alkali, it forms an indigo-blue solution. Does not unite without decomposition with the metallic oxides.

Theory. 1874. The formation of alloxan and the other products which arise at the same time, is dependent upon two perfectly independent decompositions; namely, upon the conversion of cyanoxalic acid into alloxan, and upon the mutual decomposition of urea and hyponitrous acid. To 1 eq. of cyanoxalic acid are added the elements of 4 eq. water, and 2 eq. oxygen from 1 eq. nitric acid, by which 1 eq. alloxan and 1 eq. hyponitrous acid are formed. The latter combines with the ammonia of the urea, and liberates cyanic acid; the hyponitrite of ammonia is decomposed by heat into nitrogen and water, and the cyanic acid with water is resolved into carbonic acid and ammonia, which unites with the free nitric acid.

$$
\begin{array}{ll}
\text{Cyanoxalic acid} = & C_8N_2\quad O_4 \\
\text{4 eq. water} & \qquad H_4O_4 \\
\text{2 eq. oxygen} & \qquad\quad O_2 \\
\hline
\text{1 eq. alloxan} = & C_8N_2H_4O_{10}
\end{array}
$$

$$
\begin{array}{ll}
\text{Urea} & = C_2N_2H_4O_2 \\
\text{Hyponitrous acid} = & \quad N \quad O_3 \\
\hline
\end{array}
$$

$$
\begin{array}{ccccc}
C_2N_3H_4O_5 = C_2O_4 + & N_2 + & NH_3 + & HO \\
\text{Carbonic acid.} & \text{Nitrogen.} & \text{Ammonia.} & \text{Water.}
\end{array}
$$

It frequently happens that on dissolving the impure alloxan, for the purpose of purifying by a second crystallization, a portion of alloxantin is obtained; it may be easily separated from the alloxantin by cold water. (See *Alloxantin.*)

Alloxanic acid. 1875. *Alloxanic Acid.* $C_8N_2H_2O_8$+2 eq. Discovered by Wöhler and Liebig. Produced by the decomposition of alloxan by alkalies. It is prepared by decomposing alloxanate of baryta by sulphuric acid. A strongly acid fluid is obtained, which by gentle evaporation crystallizes in radiated groups of acicular crystals; it is a bibasic acid, dissolves zinc with the evolution of hydrogen, is unchanged by sulphuretted hydrogen, and precipitates the salts of silver, baryta, and lime. The anhydrous alloxanic acid contains the constituents of half an equivalent of alloxan minus 1 eq. water.

Alloxanic acid and metallic oxides.

1876. Alloxanic acid neutralizes the alkalies perfectly, decomposes the carbonates, and forms, when neutralized by ammonia, with the salts of silver a white precipitate, which by boiling becomes first yellow and then black, the change being accompanied by a rapid effervescence; treated with ammonia in excess, it produces white gelatinous precipitates with the salts of lime, strontia, and baryta; but the precipitate is redissolved by a large excess of water, and readily by an acid. The solutions of the neutral alloxanate of lime, strontia, and baryta, become turbid when boiled, the bases are precipitated, and urea and mesoxalic acid are formed.*

Mesoxalic acid.

1877. *Mesoxalic Acid.* When a saturated solution of alloxanate of baryta or strontia is heated to the boiling point, a precipitate falls consisting of the carbonate, mesoxalate, and alloxanate of baryta or strontia. The solution, on evaporation, yields a crystalline crust, from which urea is separated by treating it with alcohol, and mesoxalate of baryta remains. If a solution of alloxan be added, drop by drop, to a boiling solution of acetate of lead, a very heavy granular precipitate of mesoxalate of lead is formed, and urea remains as the only other product in the solution. The mesoxalic acid may be obtained by decomposing this lead salt by sulphuric acid; it is a strongly acid solution, reddens vegetable colours, and forms, like the alloxanic acid, on the addition of ammonia, precipitates with the salts of baryta and lime, which are soluble in acids and a large excess of water; it may be boiled and evaporated without change. Its action on the salts of silver is characteristic; it forms with them, after being neutralized by ammonia, a yellow precipitate, which on being gently heated is reduced to the metal with a rapid effervescence.

Analysis and composition.

1878. The above-mentioned lead salt yields, on analysis, 80.4 per cent. of oxide of lead; it contains a slight admixture of a substance containing nitrogen, probably cyanate or cyanurate of lead, from which it cannot be perfectly purified. The composition of the lead salt is very probably expressed by the formula C^3O^4+2PbO, in which case its formation from alloxan and alloxanic acid admits of a ready explanation. From 1 eq. alloxan 1 eq. urea is separated, by which 2 eq. of anhydrous mesoxalic acid is left.

$$\begin{array}{ll}
\text{1 eq. alloxan} & = C_8N_2H_4O_{10} \\
-\text{1 eq. urea} & = C_2N_2H_4O_2 \\
\hline
= \text{2 eq. mesoxalic acid} & = C_6 \qquad O_8
\end{array}$$

The above-mentioned mesoxalate of baryta contains 56 per cent. of baryta, from which its constitution is probably represented by the formula $C_3O_4+\left\{\begin{matrix}BaO\\HO\end{matrix}\right.$

Mykomelinic acid.

1879. *Mykomelinic Acid.* $C_8N_4H_5O_5$? Discovered by Wöhler and Liebig. Product of the decomposition of alloxan by ammonia.

Process.

It is prepared by heating to 212° a solution of alloxan with an excess of ammonia, then neutralizing with an excess of dilute sulphuric acid and boiling for a few minutes. The mykomelinic acid falls as a yellow gelatinous precipitate, which dries to a yellow porous powder; it is with difficulty dissolved by cold, but more readily by hot water.

1880. Its solution has a distinctly acid reaction; it decomposes the carbonated alkalies and is easily dissolved by the caustic alkalies, but on being boiled with them is decomposed with the evolution of ammonia; it forms, with the oxide of silver, a yellow compound,

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* For *Alloxanates*, see T. and L. 810.

which is insoluble in water. It is produced by the decomposition of 1 eq. alloxan and 2 eq. ammonia into 1 eq. mykomelinic acid and 5 eq. water.

Parabanic acid. 1881. *Parabanic Acid.* $C_6N_2O_4+2$ aq. Discovered by Wöhler and Liebig. Product of the decomposition of uric acid and alloxan by nitric acid. Prepared by treating 1 part of uric acid, or 1 part of alloxan, in 8 parts of pretty strong nitric acid, evaporating to the consistence of a syrup, and allowing it to stand for some time, when it yields colourless crystals which may be purified by a second crystallization.

Properties. 1882. Colourless, transparent, thin, hexagonal prisms; has a strong acid taste, very similar to that of oxalic acid; is very soluble in water, does not effloresce either in the air or in a warm room; fuses if heated, when a portion sublimes unchanged, but another part decomposes with the evolution of hydrocyanic acid. The cold solution neutralized by ammonia, produces a white precipitate in the salts of silver, which contains 70.62 per cent. of the oxide; when treated with ammonia it is converted into oxaluric acid.

Theory. 1883. It is formed by the decomposition of 1 eq. of uric acid, which, by the addition of 2 eq. of water and 4 eq. oxygen from the nitric acid, is resolved into 2 eq. carbonic acid, 1 eq. parabanic acid, and 1 eq. urea; the latter is decomposed as before-mentioned by the hyponitrous acid. One eq. alloxan with 2 eq. oxygen is resolved into 2 eq. carbonic acid, 4 eq. water, and 1 eq. parabanic acid.

Oxaluric acid. 1884. *Oxaluric Acid.* $C_6N_2H_3O_7+$aq. Discovered by Wöhler and Liebig. Produced by the decomposition of parabanic acid.

Prepared by adding dilute sulphuric or hydrochloric acid to a saturated solution of oxalurate of ammonia in hot water, and rapidly cooling the mixture when the oxaluric acid falls as a white crystalline powder; this should be washed with cold water as long as the washing, when neutralized by ammonia, causes with the salts of lime a precipitate which is perfectly redissolved by heat, or by an additional quantity of water.

Properties. 1885. It is a white, or slightly yellow crystalline powder of an acid taste, reddens the vegetable colours, and, when neutralized by ammonia, forms with silver salts a white precipitate which is perfectly redissolved by boiling. By boiling in water it is completely decomposed into free oxalic acid and oxalate of urea.

Theory. 1886. The oxaluric acid is formed by the addition of 2 eq. water to the constituents of the parabanic acid. It contains further the elements of 2 equivalents of oxalic acid and 1 eq. urea; it may be considered as uric acid in which the cyanoxalic acid has been replaced by the oxalic acid.

Oxalurate of ammonia. 1887. *Oxalurate of Ammonia*, $NH_4O+C_6N_2H_3O_7$, may be formed

Process. by heating a solution of parabanic acid with ammonia, or more advantageously by treating a recently prepared solution of uric acid in dilute nitric acid with an excess of ammonia and evaporating. The liquid acquires at first a purple colour, which disappears during the evaporation, and if allowed to cool when arrived at a certain degree of concentration, it deposits radiated groups of hard acicular yellow crystals; they are obtained colourless by charcoal and recrystallization.

Properties. 1888. The oxalurate of ammonia crystallizes in radiated groups of fine acicular crystals, which have a silky lustre, and are readily dissolved by hot, but with difficulty by cold water; the solution has no reaction on vegetable colours, and may be boiled and evaporated without change; the dry salt loses no weight at 250°, but at a higher temperature it is decomposed with the rapid evolution of hydrocyanic acid. Acids separate from a concentrated solution the oxaluric acid as a crystalline powder.

Oxaluric acid and metallic oxides.

1889. The oxaluric acid forms with the alkalies very soluble, but with the alkaline earths sparingly soluble salts. If concentrated solutions of oxalurate of ammonia, chloride of calcium or barium be mixed with each other, after standing some time, brilliant transparent scales or needles of oxalurate of baryta or lime will be deposited; a solution of the latter in water when treated with an excess of ammonia gives a basic salt in the form of a transparent gelatinous precipitate, which is redissolved by a large quantity of water.

Thionuric acid.

1890. *Thionuric Acid.* $C_8N_3H_7O_{14}S_2$. A bibasic acid. Discovered by Wöhler and Liebig. Is formed by the action of sulphurous acid on alloxan. It is prepared by decomposing the thionurate of lead by hydrosulphuric acid. A white crystalline mass, is permanent in the air, and readily dissolved by water; of an acid taste, reddens vegetable blues strongly; its saturated solution, when heated to the boiling point, congeals to a semi-fluid crystalline mass of uramil, and the fluid when this has deposited is found to contain free sulphuric acid.

Theory.

1891. The thionuric acid contains the elements of 1 eq. alloxan, 1 eq. ammonia, and 2 eq. sulphurous acid; the uramil may be considered as a compound of ammonia with alloxan minus 2 eq. oxygen, or of cyanoxalic acid with 1 eq. ammonia and 2 eq. water. On heating the solution of thionuric acid 2 eq. oxygen are given by 1 eq. alloxan to the 2 eq. of sulphurous acid, which is thus converted into sulphuric acid, while the elements of cyanoxalic acid, ammonia, and water combine to uramil.

Thionuric acid and metallic oxides.

1892. Thionuric acid forms with the alkalies very soluble salts; with the alkaline earths either insoluble or sparingly soluble salts, which are however readily dissolved by dilute acids; they generally are formed of 1 eq. of acid and 2 eq. of the metallic oxide. All these salts evolve sulphurous acid abundantly when treated with concentrated sulphuric acid; when fused with hydrate of potassa, sulphite of potassa is formed.

Uramil.

1893. *Uramil.* $C_8N_3H_5O_6$; eq.=144.41. Discovered by Wöhler and Liebig. A product of the decomposition of thionuric acid.

A cold saturated solution of thionurate of ammonia is made boiling hot, and then treated with hydrochloric acid till it has a strongly acid reaction, when it is again heated till a slight turbidity is observed, and allowed to cool slowly; or a boiling saturated solution of the same salt may be mixed with hydrochloric or dilute sulphuric acid, and then kept boiling until the whole is converted to a semifluid mass. It is obtained in a plume-form aggregation of fine but hard needles, or as a fine porous powder, consisting of fine needles which have a silky lustre, and are permanent in the air, but acquire a pink tint when heated.

Properties.

1894. It is insoluble in cold, but taken up in small quantity by boiling water; soluble in ammonia and the caustic alkalies in the cold, from which it is precipitated by acids unchanged. The solution of uramil in ammonia and caustic potassa acquires a purple colour by exposure to the air, and deposits green acicular crystals, of a brilliant metallic lustre; if boiled in the caustic potassa, it is decomposed into uramilic acid with the evolution of ammonia. It is soluble in concentrated sulphuric acid, from which it is again precipitated by water; by boiling in dilute acids it suffers the same change as in caustic potassa. By boiling with the oxides of silver and mercury it is converted into murexid, and the oxide is reduced.

Action of nitric acid.

1895. With concentrated nitric acid it is resolved into alloxan, with the evolution of hyponitrous acid, and the formation of nitrate of ammonia. The above decomposition of the thionurate of ammonia consists in the separation of the elements of 2 eq. of sulphate of ammonia. Uramil may be considered as uric acid, in which the urea is replaced by 1 eq. ammonia and 2 eq. water.

Uramilic acid.

1896. *Uramilic Acid.* $C_{16}N_5H_{10}O_{15}$. Discovered by Wöhler and Liebig. A product of the decomposition of uramil.

Preparation.

A saturated solution of thionurate of ammonia in cold water is added to a small quantity of sulphuric acid, and the mixture evaporated in a water-bath, when the uramilic acid is slowly deposited in transparent prisms of a glassy lustre. If a white amorphous deposit, which is soluble in hot water, be at the same time obtained, it arises from the presence of undecomposed acid thionurate of ammonia; this is again dissolved in water mixed with sulphuric acid, and treated as before.

Properties.

1897. Colourless four-sided prisms, or fine silky needles; is soluble in 6—8 parts of cold, and in 3 parts of boiling water; loses no weight when heated to 212°, but acquires a slightly pink colour; the solution has a feeble acid reaction. It is soluble in concentrated sulphuric acid with effervescence, but without colouring the acid. By boiling in strong nitric acid, a yellow solution is obtained, which yields on evaporation white crystalline and sparingly soluble scales or granular crystals; they are dissolved by alkalies, and again precipitated by acetic acid. In its formation 2 eq. of uramil lose the elements of 1 eq. of ammonia, which are replaced by 3 eq. of water.

Salts of uramilic acid.

1898. The uramilic acid forms with ammonia and the fixed alkalies soluble crystallizable salts; lime and baryta are not thrown down from their saline solution by the free acid; but on the addition of ammonia a white precipitate is formed, which again disappears in a large quantity of water. Uramilate of ammonia produces with nitrate of silver a dense white precipitate, which contains from 63—64 per cent. of silver.

Alloxantin.

1899. *Alloxantin.* $C_3N_2H_5O_{10}$; eq.$=$162.26. First observed by Prout as a product of the decomposition of uric acid by nitric acid; it is also formed by the action of chlorine on uric acid, as likewise from alloxan by the action of deoxidizing agents.

Preparation.

1900. *From uric acid:* one part of uric acid is added to 32 parts of water, which is brought to the boiling point, and then treated with dilute nitric acid in successive portions till a perfect solution is obtained; it should then be evaporated to two thirds of its volume, when, after standing for some hours, or a day, crystals of alloxantin will be deposited, which should be purified by recrystallization.

From alloxan: it is obtained in large quantity by transmitting a stream of hydrosulphuric acid gas through a solution of alloxan, when first sulphur, and then a crystalline mass of alloxantin is deposited; it is separated from the sulphur by solution in hot water, which yields by evaporation and cooling pure crystals of alloxantin. It may also be formed by adding zinc and hydrochloric acid to a solution of alloxan, but here an excess of acid must be carefully avoided; or by boiling alloxan in moderately strong sulphuric acid, when it is deposited as the solution cools. If a solution of alloxan be exposed to the action of a galvanic battery, oxygen is evolved at the positive electrode, while the negative is covered with a crystalline crust of alloxantin.

Properties.

1901. Short oblique four-sided prisms of the oblique prismatic system, the obtuse angle of the prism being 105°. The crystals are colourless, or have a slightly yellow tint; in an ammoniacal atmosphere they become red, acquire a greenish metallic lustre, and are readily reduced to powder; exposed to 212° they undergo no change of weight, but at 300° lose 15.4 per cent.=3 eq. water; sparingly soluble in cold, more freely in boiling water. The solution reddens litmus; is converted into alloxan by being warmed with nitric acid, or by a solution of chlorine; forms with the salts of silver a black precipitate of metallic silver; it is decomposed by alkalies; barytic water causes a violet-blue precipitate, which is first rendered colourless by heat and then disappears; by adding an excess of baryta to this solution a brilliant white precipitate is formed.

1902. If a solution of alloxan, instead of being left in contact with zinc and hydrochloric acid at common temperature, be heated to the boiling point, and kept at that temperature for some time, it deposits, on cooling, yellow granular crystals of a brilliant lustre and sparing solubility in boiling water, and of characters essentially different from alloxantin.

Products of the decomposition of alloxantin.

1903. If a stream of hydrosulphuric acid gas be passed through a boiling solution of alloxantin, a further precipitation of sulphur ensues, and the solution acquires a strongly acid reaction; if neutralized by carbonate of ammonia, it deposits on cooling an abundant crop of white silky acicular crystals of an ammoniacal salt, which, when heated to 212° in the air, becomes of a blood-red colour; its composition is represented by the formula $C_8N_3H_2O_8$, and it may therefore be considered to be a compound of cyanoxalic acid with 1 eq. ammonia and 4 eq. water. The acid in this salt appears in the moment of its separation from the ammonia with which it was combined to be decomposed into a variety of new products. It is proposed to call this acid the dialuric acid, since its properties appear to differ from those of the cyanoxalic.

Action of ammonia.

1904. If a hot saturated solution of alloxantin be treated with a solution of sal ammoniac, it instantly acquires a purple-red colour, which disappears after a few moments, while the solution becomes turbid, and deposits brilliant white scales of uramil, but they are pink when dried; the same occurs with the acetate, the oxalate, and other ammoniacal salts; the solution contains, after the decomposition, alloxan and free hydrochloric acid.

Theory.

1905. Two eq. alloxantin and 1 eq. ammonia contain the elements of 1 eq. uramil, 1 eq. alloxan, and 4 eq. water. By heating a solution of alloxantin in pure ammonia, the products first formed are uramil and mykomelinate of ammonia, both of which suffer further changes by the continued action of ammonia and the atmospheric air. If a solution of alloxantin in ammonia, which has been prepared in the cold, be spontaneously evaporated by exposure to the air, oxygen is absorbed, and crystals of the oxalurate of ammonia are obtained: 3 eq. alloxantin, 7 eq. oxygen, and 6 eq. ammonia, contain the elements of 4 eq. oxalurate of ammonia and 5 eq. water.

Action of oxide of silver.

1906. If oxide of silver be heated in a solution of alloxantin, a portion of the former is reduced with effervescence, and the solution contains pure oxalurate of silver. In this reaction 3 eq. oxygen from the oxide of silver decompose 1 eq. alloxantin into 1 eq. water, 2 eq. carbonic acid, and 1 eq. oxaluric acid, which last unites with some undecomposed oxide of silver.

Murexid.

1907. *Murexid.* $C_{12}N_5H_6O_8$; eq.=197.19. The *purpurate of ammonia* discovered by Prout.

Processes.

By heating a mixture of equal parts of peroxide of mercury and uramilic acid in 36—40 parts of water, with the addition of an exceedingly small quantity of ammonia; as soon as the liquid has acquired a deep purple colour, it is filtered and allowed to rest, when the murexid crystallizes; or by dissolving uramil by the aid of heat in ammonia, and when the solution has cooled to 160°, alloxan is added until a very slight alkaline reaction is observed.

Or a solution of uric acid in dilute nitric acid is evaporated until it acquires a flesh-red colour, when it is allowed to cool to 160°, and is then treated with a dilute aqueous solution of ammonia, till the presence of free ammonia is remarked by the odour; the solution is then diluted with half its volume of boiling water, and allowed to cool.*

Or a boiling saturated solution of alloxantin in water is treated with ammonia in excess till the precipitated uramil is redissolved, when a solution of alloxan is added, so that only a slight alkaline reaction is left, and the whole is allowed to cool.

Or by heating alloxantin with sal ammoniac or oxalate of ammonia, and after the formation of uramil adding ammonia till the former is redissolved, and then alloxan. Murexid may be formed by a number of other processes, by bringing together many of the products of uric acid with ammonia, with or without the presence of atmospheric air.

Theory.

1908. When the oxygen from 1½ eq. of peroxide of mercury is added to 2 eq. uramil, they may give rise to the formation of 1 eq. murexid, 1 eq. alloxanic acid, and 3 eq. water. Alloxan appears to have the same action upon a solution of uramil in ammonia as the peroxide of mercury. One eq. alloxan, 2 eq. alloxantin, and 4 eq. ammonia, contain the elements of 2 eq. murexid and 14 eq. water. The solution of uric acid in dilute nitric acid contains principally alloxantin, urea, and nitrate of ammonia: evaporated until the flesh-red colour appears, a portion of the alloxantin is converted by the action of free nitric acid into alloxan, a portion of which, by a further action, gives rise to parabanic acid. But when alloxan and alloxantin are simultaneously present in a solution, an excess of ammonia produces a deep purple-red liquid from which murexid is deposited. If the solution contain an excess of alloxantin, the crystals of murexid are mixed with uramil; with an excess of alloxan, mykomelinate of ammonia is formed, which also falls with the murexid. The parabanic acid present passes, when the solution of uric acid is saturated with ammonia, into oxaluric, which is obtained in crystals of oxalurate of ammonia by evaporating the mother-liquor.

Properties.

1909. Murexid crystallizes in short four-sided prisms, two faces of which, like the upper wings of the cantharides, reflect a green metallic lustre. The crystals are transparent, and by transmitted light are of a garnet-red colour. It forms a brownish-red powder, which, under the polishing steel, acquires a brilliant metallic green colour. It is insoluble in ether and alcohol; sparingly soluble in cold, but more readily in boiling water, on the cooling of which it crystallizes unchanged; insoluble in a saturated solution of carbonate of ammonia, soluble in caustic potassa with a beautiful indigo-blue colour, which disappears on the application of heat with the evolution of ammonia.

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* In applying this method of preparation, it is advisable to test a small quantity of the solution of uric acid from time to time by saturating it with ammonia; if it be rendered turbid by the ammonia, and a red powder falls, a small quantity of nitric acid must be added to the hot solution of the uric acid; but if a yellow slimy precipitate be formed, the solution will only give rise to the formation of murexid after a stream of hydrosulphuric acid gas has been transmitted through it.

1910. It is decomposed either in the solid state or in solution by all the mineral acids, with the separation of brilliant scales of murexan; the liquid contains ammonia, alloxantin, alloxan, and urea. The instant the murexid is brought into contact with hydrosulphuric acid it is decomposed into alloxantin, dialuric acid, and murexan, with the separation of sulphur. An equivalent of alloxan, alloxantin, murexan, and urea, together with 2 eq. ammonia, contain the elements of 2 eq. murexid and 11 eq. water. **Decomposed.**

1911. *Murexan.* $C_6N_2H_4O_5$; eq.=109.02. The *purpuric acid* discovered by Prout as the product of the decomposition of murexid. Prepared by dissolving murexid in caustic potassa by the aid of heat, which is applied till the blue colour disappears, when dilute sulphuric acid is added in excess. **Murexan.**

1912. It falls in crystalline scales of a silky lustre; is insoluble in water and dilute acids, but is taken up by ammonia and the fixed alkalies in the cold without neutralizing them. It is dissolved by concentrated sulphuric acid, from which it is again precipitated unchanged by water. If a solution of murexan in ammonia be exposed to the air, it acquires a purple-red colour, and deposits the brilliant crystals of murexid; with an excess of ammonia the solution again becomes colourless, and is then found to contain oxalurate of ammonia.

1913. Two eq. murexan, 1 eq. ammonia, and 3 eq. oxygen, contain the elements of 1 eq. murexid and 3 eq. water; 1 eq. murexan, 3 eq. oxygen, and 1 eq. ammonia, are the constituents of 1 eq. oxalurate of ammonia. **Theory.**

1914. *Uric Oxide, or Xanthic Oxide.* $C_5N_2H_2O_2$. A rare constituent of urinary calculi; first discovered by Marcet. **Uric Oxide, or Xanthic oxide.**

1915. Urinary calculi, which contain this ingredient, are dissolved in caustic potassa and the solution saturated with carbonic acid, when the uric oxide is precipitated.

1916. A white precipitate; when dried, it forms a pale yellow hard mass, which acquires a waxy lustre by friction: it is dissolved by the pure and carbonated alkalies; in small quantity by hot water, hydrochloric and oxalic acids. It is soluble in concentrated sulphuric acid with a yellow colour; no precipitation is caused by the addition of water to the solution. It is dissolved in nitric acid without effervescence; on evaporating to dryness, a lemon-yellow residue is left, which is not reddened by ammonia, is partially soluble in water, but perfectly and easily in potassa; the solution has a light reddish-yellow colour, and leaves on evaporation a red residue. **Properties.**

1917. Exposed to the destructive distillation, it evolves an odour of urine, hydrocyanic acid, and carbonate of ammonia, but no urea. The calculi, which contain uric oxide, have a light brown, or bright brown surface; the fracture is scaly, of a strong lustre, and also of a brown or deep flesh colour; by friction the lustre becomes resinous. **Destructive distillation.**

1918. *Cystic Oxide.* Discovered by Wollaston; a rare constituent of urinary calculi; an organic base. **Cystic Oxide.**

1919. The calculus is dissolved in aqueous ammonia, and the filtered solution evaporated in the air, when the cystic oxide crystallizes.

1920. In the calculus it exists as a yellowish-white confused crystalline mass of a brilliant lustre: crystallizes from its solution in potassa, on the addition of acetic acid, in hexagonal plates; from ammonia, in white transparent scales. It is decomposed by heat, with the evolution of sulphurous and ammoniacal products of an offensive odour. It is readily dissolved by mineral acids, with which it forms crystalline compounds.

Salt of.

1921. It forms with hydrochloric acid an anhydrous salt which is composed of 1 eq. of the base and acid. The salt with nitric acid is formed of 1 eq. of acid, 1 eq. of base, and 2 eq. water, the half of which is separated by a temperature of 105°. It is soluble in the pure and carbonated alkalies; but if the solution be heated it is decomposed at first with the evolution of ammonia, but as the evaporation proceeds, a very combustible gas, which burns with a blue flame, and smells like sulphuret of carbon, is given off. The occurrence of the cystic oxide is so rare, that it is impossible to institute any investigation of this remarkable substance.

According to the analysis of Thaulow, its formula is $C_6NH_6O_4S_2$. L. 823.

CHAPTER VII.

SECTION I. *Vegetable Alkalies.*[*]

Vegetable alkalies.

1922. These alkaline bodies have been discovered since the year 1817, and their number is daily increasing. The most important only can be comprised in this chapter. Almost all plants, which are remarkable for their poisonous or medicinal properties, when subjected to a chemical examination, have been found to contain an alkaline principle.

Precipitated by tannin.

1923. It has been found that all the vegetable alkalies are precipitated by tannin, or infusion of nutgalls. These precipitates are usually white powders, bitannates of the alkali, insoluble in cold water, and easily decomposed by an alkaline or earthy base. Henry has proposed infusion of nutgalls as an excellent reagent for obtaining these alkalies. His process is as follows:

> Digest the plant containing the alkali in warm water, acidulated with sulphuric acid. Neutralize the clear liquor by potassa, and add a concentrated infusion of nutgalls as long as a precipitate falls. Separate the precipitate, wash it with cold water, and mix intimately with a slight excess of slaked lime. Dry the mixture over the vapour-bath till it is reduced to powder. Digest this powder in alcohol or ether. Filter, distil off the alcohol or ether. Set the residue aside for some days. The alkali will be deposited in crystals.[†]

How distinguished.

1924. These bodies have been distinguished by names terminating in *a*, that they might resemble potassa, soda, and ammonia, and the name of the neutral principles with which they are associated in vegetables has been made to terminate in *ine* or *in*. They are all compounds of carbon, hydrogen, nitrogen, and oxygen.

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[*] The materials for this chapter have been principally derived from Thomson's *Chem of Org. Bodies*, to which the student must be referred for the description of many of the less important substances.

[†] *Jour. de Pharm.* xxi. 213.

Cinchonia.

1925. *Cinchonia.* $C_{20}H_{12}NO1\frac{1}{2}$*, = 158.0, was detected by Pelletier and Caventou in 1820, in the gray Peruvian bark, which is considered as the bark of the *cinchona nitida* or the *cinchona condaminea*, and is not much esteemed for its medical properties. But there is reason to suspect that the *cinchona lancifolia* of Loxa, the most celebrated of all the varieties contains the same principle.

It is obtained from the pale bark by digesting it in dilute hydrochloric acid, precipitation by an alkali or earth, solution in alcohol and crystallization.†

Crystalline form and solubility.

1926. It crystallizes in prismatic needles, and requires 2500 times its weight of water for solution. It is very soluble in alcohol; has a bitter taste, is not altered by exposure to the air. Its alkaline properties are well marked.

Characters of its salts.

1927. The salts of cinchonia have a bitter taste; are precipitated by oxalates, tartrates and gallates, and by the infusion of gallnuts. It combines with acids forming neutral salts and disalts, or salts composed of two atoms base united to 1 atom acid. T.

Quinia.

1928. *Quinia.* $C_{20}H_{12}NO_2 = 162.0$. In 1820 Pelletier and Caventou pointed out the alkaline character of this substance, and showed it might be obtained in a separate state.‡ Since that period sulphate of quinia has come into general use as a medicine, and has almost superseded the use of bark.

1929. Quinia may be extracted from the *yellow* bark usually considered as the *cinchona cordifolia.*

Process.

The bark is boiled in water acidulated with sulphuric acid: the solution of sulphate of quinia thus formed is decomposed by lime; sulphate of lime is formed, and the quinia mixes mechanically with it, as it is precipitated. Alcohol dissolves the quinia and leaves the sulphate of lime. The alcohol being evaporated, the quinia is procured by itself; neutralized by dilute sulphuric acid, and boiled with animal charcoal to destroy the colouring matter, a solution is procured, which gives crystals of the sulphate on evaporation.

Obtained from the sulphate.

1930. As sulphate of quinia is prepared on a large scale, it is more convenient to obtain quinia from that salt. Nothing more is necessary than to dissolve the sulphate in water, and to mix the solution with a dilute solution of ammonia. The quinia falls in white flocks, which become a little coloured during drying.

Characters.

1931. It crystallizes with difficulty from hot alcohol in fine needles and then is in the state of a hydrate. Exposed to heat, it softens and falls down as a white powder; at 302°, or a few degrees higher, it melts and loses the whole of its water (T.). Suddenly cooled, it becomes yellow and brittle; slowly cooled, it assumes a fibrous texture, and becomes opaque. By friction it becomes negatively electric.

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* The atomic composition is given as stated by Thomson.

Pelletier and Caventou's process.

† The following process was adopted by Pelletier and Caventou for the extraction of cinchonia. Two kilogrammes (4 2-5 lbs. avoirdupois) of gray bark in powder were digested in 6 kil. (13 1-5 lbs.) of alcohol. This treatment was repeated four times. The alcoholic tinctures were all united, and the alcohol was distilled off after the addition of two litres (122 cubic inches) of water. The residual liquor was filtered, and it left on the filter a reddish matter apparently resinous, which was washed with water containing a little potassa till the liquid passed without colour. The matter remaining on the filter, after being well washed with distilled water is greenish white, very fusible, soluble in alcohol, and capable of crystallizing. It was cinchonia with foreign matter. It was purified by the action of hydrochloric acid, magnesia, and repeated boiling in alcohol which dissolved the cinchonia.

‡ *Ann. de Chim. et Phys.* xv. 346.

1932. When freed from water and placed in that liquid, quinia swells and absorbs it. Its taste is intensely bitter. It is soluble in 200 times its weight of boiling water; very soluble in alcohol and in ether.

Its salts distinguished.

1933. The salts of quinia are distinguished by a strong bitter taste; those in crystals have a pearly lustre; most of them are soluble in water, and several in alcohol and in ether. These solutions are precipitated by oxalic, tartaric, and gallic acids, and also by infusion of nutgalls.

Sulphate of quinia.

1934. *Sulphate of Quinia.* The powerfully febrifuge properties of this salt have introduced it into general use as a medicine, and it has become an important article of manufacture, especially in France.[*] The process usually followed is the following of M. Henri, junior, with some slight modifications.[†]

Adulteration detected.

1935. Sulphate of quinia, from its commercial value, is frequently adulterated. The substances commonly employed for the purpose are water, sugar, gum, starch, ammoniacal salts, and earthy salts, such as sulphate of lime and magnesia, or acetate of lime. Pure sulphate of quinia, when deprived of its water of crystallization by a heat of 212°, should lose only from 8 to 10 per cent. of water. Sugar may be detected by dissolving the suspected salt in water, and adding precisely so much carbonate of potassa as will precipitate the quinia. The taste of the sugar, no longer obscured by the intense bitter of the quinia, will generally be perceived; and it may be separated from the sulphate of potassa, by evaporating gently to dryness, and dissolving the sugar by boiling alcohol. Gum and starch are left when the impure sulphate of quinia is digested in strong alcohol. Ammoniacal salts are discovered by the strong odour of ammonia, which may be observed when the sulphate is put into a warm solution of potassa. Earthy salts may be detected by burning a portion of the sulphate.[‡]

Disulphate.

1936. *Disulphate of Quinia* effloresces; is soluble in 740 times its weight of water at 55°, and in 30 times its weight of boiling water. It dissolves in 80 times its weight of alcohol of sp. gr. 0.85. It crystallizes in tufts composed of fine needles of a pearly lustre. It fuses and then resembles liquid wax: at a higher temperature it assumes a fine red colour, and burns without leaving any residue.

Composition.

From Liebig's analysis, as quoted by Thomson, it is composed of 85 quinia, 10 sulphuric acid, and 4.17 water.

Neutral sulphate.

1937. *Neutral sulphate of quinia* may be formed by adding a little sulphuric acid to the solution of the disulphate.[§]

1938. *Salicin*, $C_4H_8O_2$,=43.0, although not alkaline is analogous to

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[*] The annual produce in Paris exceeds 1200,00 ounces per annum. T.

[†] For details of which, see T. *Org. Bodies*, 233, and Ure's *Dict. Arts and Manuf.* 1054.

[‡] Several of the preceding directions are taken from a paper on the subject by Phillips, *Phil. Mag. and Ann.* iii. 111. (Turner.) According to Thomson, margaric acid and boracic acid are employed; the former may be separated by weak hydrochloric acid which dissolves sulphate of quinia but leaves the margaric acid; the boracic acid is discovered by incinerating a portion of the suspected salt.

[§] *Hydro-ferrocyanate of Quinia* has been found a more powerful febrifuge than the sulphate, but is liable to decomposition. For the method of preparing this, and the other salts of quinia, see T. *Org. Bodies*, 236.

Salicin,

Use.

the alkalies from cinchona. It is obtained from the bark of the willow (*salix helix*), and exists in several species, also in the bark of the poplar (*populus tremula*). It is white, very bitter, soluble in water and alcohol. With concentrated sulphuric acid it becomes of a beautiful red colour; this holds with solutions containing only $\frac{1}{600}$ of their weight of it; and the presence of salicin in any bark may thus be ascertained. It has been employed as a substitute for quinia.

Veratria.

Characters.

1939. *Veratria*, $C_{34}H_{22}NO_6$,=288, the alkaline principle of *veratrum album*, white hellebore, and *colchicum autumnale*, meadow saffron, has the aspect of resin, is white and fusible at about 240°. Alcohol and ether dissolve it. It has no smell, but when drawn into the nostrils, even in minute quantity, it produces violent and long-continued sneezing. Its taste is excessively acrid, it occasions frightful vomiting, and a few grains are fatal.[*]

Strychnia.

Characters.

1940. *Strychnia* exists in the seeds or fruits of several species of *strychnos*, particularly in the *nux vomica*. It was found also in the poisonous matter called *upas*. It is intensely bitter, and requires 2500 times its weight of boiling, and 6667 times its weight of cold water for solution. It is highly poisonous; occasioning violent contractions of the muscles, and tetanus; the best antidote is infusion of nutgalls, or warm tea. In very small doses it has been employed in paralysis, and it is said sometimes with success.

1941. *Brucia* resembles the foregoing, and has been found to accompany it in the different vegetable bodies which contain it.[†]

Narcotina.

1942. *Narcotina*. $C_{40}H_{20}NO_{12}$, = 370.24. Discovered by Desrone in 1803.[‡] It is obtained from opium.

Process.

Digest opium in water, filter and evaporate to the consistence of an extract. Ether digested on this extract dissolves the narcotina together with some other substances. Distil off the ether, and dissolve the residual matter in hot water or boiling alcohol, digest the solution with animal charcoal. Decant the clear liquid and precipitate the narcotina by ammonia. If not white, the narcotina may be dissolved in hydrochloric acid, and the solution be again treated with animal charcoal, thrown down by ammonia, washed and dried.

Characters.

1943. Narcotina is white, and is deposited from boiling ether or alcohol in needle-form crystals of a pearly lustre. It does not restore the blue colour of litmus paper reddened by acids; but as it combines with and neutralizes acids must be considered as an alkali.

Action of hyponitrous acid.

1944. Its taste is not bitter. In contact with hyponitrous acid it assumes a carmine-red colour and gives out red vapours. In about half a minute the action increases, the narcotina catches fire and burns with a large white flame. There remains a blackish spongy matter consisting partly of charcoal and partly of bitter principle of Welter, or carbazotic acid.[§] It is insoluble in cold water, very little soluble in boiling water, but readily soluble in ether and in fixed oils.

Salts obtained.

1945. The salts of narcotina may be obtained by dissolving it in dilute acids and concentration.

Effect on animals.

1946. It may be introduced into the stomach without producing any deleterious or even sensible effect. Orfila administered it to the

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[*] *Delphinia* exists in the *delphinium staphysagria*, or stavesacre.

Emetia.

[†] *Emetia* or *Emetina* is obtained from the various roots sold under the name of ipecacuanha. These are the roots of the *cephælis emetica*, *callicocca ipecacuanha*, and *viola emetica*. T. 263.

[‡] *Ann. de Chim*. xlv. 257.

[§] *Jour. de Pharm*. xxii. 382.

amount of several drachms a day, without perceiving any action whatever. It was speedily fatal however to dogs.

Morphia.

1947. *Morphia—Morphina.* $C_{34}H_{18}NO_6$, = 284. This is one of the most important of the vegetable alkalies, and the principle on which the narcotic properties of opium depend; insoluble in cold water; boiling water dissolves about $\frac{1}{100}$ of its weight of it; dissolved by boiling alcohol, crystallizing in six and four-sided prisms, tasteless when pure. Extremely bitter when rendered soluble by alcohol or an acid.

Action of nitric acid and heat.

1948. Nitric acid changes its colour to orange-red, which gradually passes into yellow. By heat the transparent crystals lose $6\frac{1}{3}$ per cent. of water and become opaque and white. If the heat is increased the morphia melts, and forms a yellow liquid, which becomes white and crystalline on cooling: by continuing the heat, it gives out a resinous odour, and burns with a red flame.

Process.

1949. Morphia is obtained by various processes;* the following is recommended by Thomson:

> Macerate opium in twice its weight of water for 24 hours, agitating the mixture occasionally to promote solution. Decant and pour over the undissolved portion a new quantity of distilled water, equal to the portion first employed. Repeat this process four times, or till everything soluble in cold water be taken up. If the opium be of good quality, about three fourths of it will be dissolved and the remaining fourth remains in a solid state. Filter the solutions thus obtained, and evaporate the whole to dryness in a low heat to prevent any portion of the residue from being decomposed or injured. Pour distilled water upon this dry residue. The whole will dissolve except a brilliant crystalline matter, which is narcotina. Heat the solution to the temperature of 212° and add to it ammonia in slight excess. Boil the mixture for ten minutes, to drive off this excess, and then allow the liquid to cool. The morphia precipitates in crystals, pretty pure; but a portion of it swims on the surface, mixed with impurity. If the morphia thus obtained be digested in sulphuric ether, a portion of narcotina is dissolved, and the morphia is rendered more pure. It may be rendered quite pure by dissolving it in boiling alcohol, digesting the solution with ivory black, filtering and crystallizing. This process should be repeated three or four times, in order to free the morphia from all impurity. An easier mode of purifying it is to dissolve it in sulphuric acid, taking care to avoid an excess of acid. By evaporation the sulphate of morphia is obtained in crystals. Let this salt be decomposed by digesting it with magnesia. The sulphate of magnesia is washed off, and the morphia, which is mixed with the excess of magnesia employed, is to be dissolved in boiling alcohol, and crystallized.

Opium yields at an average about $\frac{1}{16}$ of its weight of pure morphia.

Action on animals.

1950. When pure, owing to its insolubility, it is almost inert; for Orfila gave twelve grains of it to a dog without its being followed by any sensible effect. In a state of solution, on the contrary, it acts on the animal system with great energy, Sertuerner having noticed alarming symptoms from so small a quantity as half a grain. From this it appears to follow that the effects of an over-dose of a salt of morphia may be prevented or diminished by giving a dilute solution of ammonia, or an alkaline carbonate, so as to precipitate the vegetable alkali.

Detection of morphia,

1951. Many experiments have been made to discover a ready mode of detecting morphia, and distinguishing it from other bodies. When this alkaline substance, or any of its salts, is placed in contact

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* For which see B. ii. 539; *Edin. Med. and Surg. Jour.* Nos. 107 and 111; *Amer. Jour.* xiii. 27.

with a neutral solution of a *neutral* salt of peroxide of iron, it strikes a blue colour. The addition of a slight excess of acid causes this colour to disappear immediately. The addition of too much water causes the blue colour to pass into red.

Lassaigne's method.

1952. When opium is administered as a poison, its presence is rendered obvious by the peculiar odour of that drug, as well as by the red tint given to persalts of iron by the meconic acid of the opium; but when death is occasioned by a salt of morphia, it becomes necessary to eliminate the morphia, a practical process of considerable delicacy. The method suggested by Lassaigne for detecting acetate of morphia, may be applied to its saline combinations in general.[*]

The suspected solution is evaporated by a temperature of 212°, and the residue treated with alcohol, by which the salt of morphia, together with osmazome and some salts, is dissolved. The alcohol is next evaporated, and water added to separate fatty matter. The aqueous solution is then set aside for spontaneous evaporation, during which the salt of morphia is generally deposited in crystals. From an aqueous solution of the salt, ammonia throws down a crystalline precipitate, which may be recognised as morphia by the combination of the following characters:—By the figure of its crystals; its bitter taste; solubility in alcohol; alkalinity; by the orange-red tint developed by nitric acid; and by the peculiar action of iodic acid. The last character is particularly valuable in distinguishing morphia from other vegetable alkalies: the latter combine with iodic acid and form iodates; but morphia decomposes iodic acid, and sets iodine free, which may then be detected by starch. A grain of morphia in 7000 grains of water may be discovered by this test.[†] T.

Hydrochlorate.

1953. *Hydrochlorate of Morphia.* This salt is much employed in Edinburgh as a medicine.[‡] It crystallizes in needles, and dissolves in from 15 to 20 times its weight of cold, and in less than its weight of boiling water.

Acetate.

1954. *Acetate of Morphia* is less convenient in medical practice than the foregoing salt, being variable in constitution. It is apt to lose a portion of its acid, even when kept in crystals; and during

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[*] *Ann. de Chim. et de Phys.* xxv. 102.

[†] Serullas. Robinet, in *Jour. de Pharm.* xiii. 24. For Hare's method of detecting minute quantities of opium, see *Amer. Jour.* xii. 290.

Gregory's process for hydrochlorate of morphia.

[‡] The method of preparing it now in general use was suggested by Robertson, and improved by Gregory and Robiquet, *Edin. Med. and Surg. Jour.* Nos. 107 and 111, and *Jour. de Pharm.* xix. 156. The aqueous solution of opium is concentrated in a vessel of tinned iron, to the consistence of a thin syrup, when a slight excess of chloride of calcium, neutral, and quite free from iron, is added. The mixture is boiled for a few minutes, and then poured into an evaporating basin. Resinous flocks, meconate of lime, and colouring matter precipitate. But this last matter does not separate well unless the liquid has been sufficiently concentrated. After this deposit has subsided, the clear liquid is evaporated on the sand-bath. During the evaporation a new deposition takes place, which must be separated before the liquid be allowed to crystallize. The concentrated liquid is now to be allowed to cool, under constant agitation. The crystals of hydrochlorate of morphia are deposited in abundance. They are to be put into a stout cloth, and subjected to pressure, which squeezes out a black liquid, containing various impurities. The crystals are now to be dissolved in water, at 70°, filtered through cloth, mixed with a little chloride of calcium, crystallized and compressed as before. These crystals are again dissolved in water, the liquid is saturated with chalk and animal charcoal being added, the whole is digested for 24 hours at 194°. It is then filtered and concentrated. The crystals are deposited rapidly, and when freed from the mother water they are white and neutral. The salt thus obtained is dried at a temperature of 150°. It usually amounts to about one tenth of the weight of opium employed, and consists of hydrochlorate of morphia and a little hydrochlorate of codeina; from which it might probably be freed by digesting in ether. T. *Org. Bodies*, 271.

the evaporation crystals of morphia are sometimes deposited. It is readily formed by dissolving morphia in acetic acid.*

Codeia. 1955. *Codeia* was discovered in 1832, by Robiquet, in the hydrochlorate of morphia made by Gregory's process. (1953 n.) Ammonia added to a solution of this substance in water precipitates the morphia, leaving the codeia in solution, which can be separated by crystallization. It has an alkaline reaction, fuses when heated to 300°, does not render nitric acid red, and is more soluble in water than morphia.

1956. In doses of from 4 to 6 grains it produces an excitement similar to intoxication, which is followed by depression, nausea, and vomiting.

Narceia. 1957. *Narceia*† is another alkali discovered by Pelletier in the watery infusion of opium. It is white and crystalline, melting at about 200°. Its salts are blue when dissolved in a particular quantity of water, the colour changing to violet and red as it is increased.

Thebaia. 1958. *Thebaia* is the name of an alkaline principle found in opium, which is considered the same as the *paramorphine* of Pelletier. It is white, crystalline, soluble in ether, and fuses at 266°.

Meconia. 1959. *Meconia.* $C_{10}H_5O_4$. This is another constituent of opium, but is not possessed of alkaline properties, and contains no nitrogen. It is found in minute quantity, opium yielding but about $\frac{1}{2000}$ of its **Characters.** weight of meconia. It is white, has no odour, and when first put into the mouth has no taste, but soon imparts an impression of acridity. It is soluble in water, alcohol and ether. It fuses at 194°. It resembles fat in appearance.‡

Brucia. 1960. *Brucia* or *Brucina* resembles strychnia (1940), and may be procured from the *nux vomica* in small quantity, and also from the *Brucia anti-dysenterica.*§ Like morphia, it strikes a deep red tint with nitric acid, and strychnia, which produces this effect, is considered as containing a small portion of brucia. It acts upon animals like strychnia, but is a less active poison. It is intensely bitter.

Conia. 1961. *Conia* is the active principle of *conium maculatum*, or hemlock, and next to hydrocyanic acid, the most virulent poison known.||

Parillia. 1962. *Parillia* or *Parillina* exists in the root of *smilax sasaparilla*, common sasaparilla of commerce. It is white, of a peculiar odour,

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* The basis of Battley's *sedative liquor* is supposed to be acetate of morphia.

† Probably from *ναρκη*, *torpor*.

‡ From 40 lbs. of opium Couerbe obtained

50	ounces of	morphia,
1½	"	codeia,
1	"	thebaia,
1	"	meconia,
⅜	"	narceia.

Colour produced by agitating the preceding substances with sulphuric acid mixed with a little nitric acid:

Morphia	gives a	brownish	colour.
Codeia	"	green	"
Thebaia	"	yellow rose	"
Meconia	"	turmeric yellow and then a red	
Narceia	"	chocolate	"

(Reid.)

§ *False angustura*, the seeds of which were brought from Abyssinia by the traveller Bruce.

|| See Christison in *Trans. Edin. Roy. Soc.* xiii.

a sharp bitter taste, and nauseous. When swallowed to the extent of 13 grains, it occasions nausea, vomiting, diminishes the rapidity of the pulse, and acts as a sudorific.

Nicotina. 1963. *Nicotina* exists in the leaves and seeds of tobacco. At common temperatures it is a liquid of the consistence of honey, of an acrid taste and a brown colour. It is a virulent poison. Its salts are distinguished by their taste of tobacco and their acrid causticity.[*]

Section II. *Intermediate Bodies.*

1964. In this class, which is merely temporary, Thomson has placed all the vegetable principles which seem capable of entering into definite compounds with other bodies, and which have not as yet been proved by satisfactory experiments to be either acid or alkaline.

Alcohol and its Compounds.

Alcohol. 1965. *Alcohol*, C_4H_5O+HO, eq. 46.00, is the intoxicating ingredient of all spirituous and vinous liquors. It does not exist ready formed in plants, but is a product of the vinous fermentation.

Spirit of wine. 1966. Common alcohol or *spirit of wine* is prepared by distilling whiskey or some ardent spirit, and the rectified spirit of wine is procured by a second distillation. The former has a sp. gr. of about 0.867, and the latter of 0.835 or 0.84. In this state it contains a quantity of water, from which it may be freed by the action of substances which have a strong affinity for that liquid.

Purified. Thus, when carbonate of potassa heated to 300° is mixed with spirit of wine, the alkali unites with the water, forming a dense solution, which, on standing, separates from the alcohol, so that the latter may be removed by decantation. To the alcohol, thus deprived of part of its water, fresh portions of the dry carbonate are successively added, until it falls through the spirit without being moistened. Other substances, which have a powerful attraction for water, may be substituted for carbonate of potassa. Gay-Lussac recommends the use of pure lime and baryta;[†] and dry alumina may also be employed.

A very convenient process is to mix the alcohol with chloride of calcium in powder, or with quicklime, and draw off the stronger portions by distillation. Another process, which has been recommended for depriving alcohol of water, is to put it into the bladder of an ox, and suspend it over a sand-bath.

The strongest alcohol which can be procured by any of these processes has a sp. gr. of 0.796 at 60° F. This is called *absolute* alcohol, to denote its entire freedom from water.

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[*] The following table exhibits the quantity of this substance yielded by 1000 parts of various kinds of tobacco:

Cuba	8.64
Maryland	5.28
Virginia	10.00
Ile de Vilain	11.20
Lot	6.48
North	11.28
Lot-et Garonn	8.20
For smoking	3.86

T. *Organic Bodies*, 286.

Several other principles analogous to the foregoing, have been obtained from various plants, on which their activity depends. These have been particularly described together with the processes for obtaining them in Thomson's late volume.

[†] *An. de Ch.* lxxxvi.

[‡] *Jour de Sci.* xviii.

Chap. VII.

Absolute alcohol.

1967. An elegant and easy process for procuring absolute alcohol, has been proposed by Graham.* A large shallow basin is covered to a small depth with quicklime in coarse powder, and a smaller one containing three or four ounces of commercial alcohol is supported just above it. The whole is placed upon the plate of an air-pump, covered by a low receiver, and the air withdrawn until the alcohol evinces signs of ebullition. Little alcohol evaporates, as its vapour is not condensed by lime, but all the water evaporates and its vapour is absorbed by the lime. Common alcohol is in this way entirely deprived of water in the course of about five days. The temperature should be preserved as uniform as possible during the process. Sulphuric acid cannot be substituted for quicklime, since both vapours are absorbed by this liquid.

Soemering's experiments.

1968. According to Söemering when spirit of wine is enclosed in a bladder, and exposed for some time to the air, it is converted into alcohol, the water only escaping through the coats of the bladder.† But the recent experiments of Christison do not confirm this, who found that spirit, whatever its strength, became weaker when thus exposed. They however confirm the results obtained by Graham, and absolute alcohol of the density of .796 was obtained in two months by exposing rectified spirit in an open cup enclosed in a confined space with quicklime.‡

Christison's experiments.

Properties.

1969. Alcohol, obtained by slow and careful distillation, is a limpid, colourless liquid, of an agreeable smell, and a strong pungent flavour. Its specific gravity varies with its purity; the purest obtained by rectification over chloride of calcium being .791; as it usually occurs it is .820 at 60°. If rendered as pure as possible by simple distillation, it can scarcely be obtained of a lower specific gravity than .825, at 60°. Absolute alcohol boils at 168½° F.§

Effect of cold.

1970. Hutton is said to have succeeded in freezing alcohol, but the fact is doubtful, as the means by which he effected its congelation were never disclosed. Walker exposed it to a temperature of —91 but no congelation took place. Even when diluted with an equal weight of water, it requires a cold of 6° below 0 to congeal it. When of a specific gravity of .810, it boils at the temperature of 173.5°, the barometrical pressure being 30 inches. In the vacuum of an air-pump it boils at common temperatures.

1971. Alcohol may be mixed in all proportions, with water, and the specific gravity of the mixture is greater than the mean of the two liquids, in consequence of a diminution of bulk that occurs on mixture, as may be shown by the following experiment:

Fig. 190.

Fig. 190 represents a tube with two bulbs, communicating with each other, the upper one being supplied with a well ground glass stopper. Fill the tube and lower bulb with water, pour alcohol slowly into the upper bulb, and when full put in the stopper. The vessel will now be completely filled, the alcohol lying upon the water; if it be inverted, the alcohol and water will slowly mix and the

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* *Edin. Phil. Trans.* 1828.

† *Quart. Jour.* viii. 381, and Henderson's *Hist. of Wines*, Lond. 1824.

‡ *Edin. Phil. Jour.* July, 1839.

§ Ure.

condensation that ensues will be indicated by the empty space in the tube. A considerable rise of temperature takes place in this experiment in consequence of the condensation.

Strength how ascertained.

1972. The strength of such spirituous liquors as consist of little else than water and alcohol, is of course ascertained by their specific gravity; and for the purpose of levying duties upon them, this is ascertained by the hydrometer.* But the only correct mode of ascertaining the specific gravity of liquids, is by weighing them in a delicate balance against an equal volume of pure water, of a similar temperature.† *Proof spirit* contains equal weights of alcohol and water; sp. gr. 0.917.

1873. There are other methods of judging of the strength of spirituous liquors, which, though useful, are not accurate, such as the taste, the size and appearance of the bubbles when shaken, the sinking or floating of olive oil in it, and the appearances exhibited when burned; if it burns away perfectly to dryness, and inflames gunpowder or a piece of cotton immersed in it, it is considered as alcohol: the different spirituous liquors leave variable proportions of water when thus burned in a graduated vessel.

Combustion of alcohol.

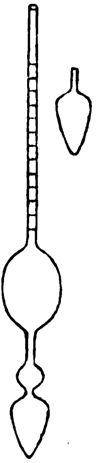
1974. Alcohol is extremely inflammable, and burns with a pale blue flame, scarcely visible in bright daylight. It occasions no fuliginous deposition upon substances held over it, and the products of its combustion are carbonic acid and water, the weight of the water considerably exceeding that of the alcohol consumed. According to Saussure, jun., 100 parts of alcohol afford, when burned, 136 parts of water, the production of which may be shown by substituting the flame of alcohol for that of hydrogen, in the apparatus described in Chapter iii., under the article *Water* (403), and if the tube at its extremity be turned down into a glass jar, it will be found that a current of carbonic acid passes out of it, which may be rendered evident by lime water.

There are some substances which communicate colour to the flame of alcohol; from boracic acid it acquires a greenish-yellow tint; nitre and the soluble salts of baryta cause it to burn yellow, and those of strontia give it a beautiful rose colour; cupreous salts impart a fine green tinge.

Use as a solvent.

1975. Alcohol dissolves pure soda and potassa, but it does not act upon their carbonates: consequently, if the

Fig. 191.



Bate's hydrometer.

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* The hydrometer of Bate, constructed for the Commissioners of Great Britain, has a scale of 4 inches in length divided into 100 parts and 9 weights, giving a range of 900 divisions, and expresses specific gravities at the temperature of 62° F. To render this instrument so accurate as to involve no error of appreciable amount, the weights are constructed so that each successive weight has an increase of bulk over the preceding weight equal to that part of the stem occupied by the scale, and an increase of weight sufficient to take the whole of the scale, and no more, down to the liquid. Fig. 191 represents this instrument and two of its nine ballast weights. It comprehends all specific gravities between 820 and 1000 and indicates true sp. gr. with almost perfect accuracy at 62° F. Ure's *Dict. Arts and Manuf.* 23.

In France the *alcoomètre* of Gay-Lussac is employed, for which see *Ibid.* In the United States the hydrometer of Dicas is used.

† In the *Phil. Trans.* for 1794, Gilpin has given a copious and valuable series of tables of the specific gravity of mixtures of alcohol and water, and of the condensation that ensues, with several other particulars. Other tables by Tralles and Gay-Lussac, will be found in Ure's *Dict. Arts and Manuf.* 18—24.

latter be mixed with alcohol containing water, the liquor separates into two portions, the upper being alcohol deprived to a considerable extent, of water, and the lower the aqueous solution of the carbonate. The alcoholic solution of caustic potassa was known in old pharmacy under the name of Van Helmont's *Tincture of Tartar*. Its use in purifying potassa has already been stated (845).

Tincture of tartar.

1976. The greater number of sulphates are insoluble in this menstruum, but it dissolves many of the hydrochlorates and nitrates. It also dissolves the greater number of the acids. It absorbs many gaseous bodies. It dissolves the vegetable acids, the volatile oils, the resins, tan, and extractive matter, and many of the soaps; the greater number of the fixed oils are taken up by it in small quantities only, but some dissolve largely.*

Alcohates.

1977. Graham has shown that alcohol may in many instances be combined with saline bodies, performing as it were the part of water of crystallization. Such combinations may be termed *alcohates*. They are obtained by dissolving the substances by heat in absolute alcohol, and are deposited as the solution cools, more or less regularly crystallized. They appear to be definite compounds, and in some of them the alcohol is retained by an attraction so powerful, as not to be evolved at a temperature of 400° or 500°.†

Decomposition.

1978. When the vapour of alcohol is passed through a red-hot copper tube, it is decomposed, a portion of charcoal is deposited, and a large quantity of carburetted hydrogen gas is evolved.

Alcohol in wine.

1979. Alcohol exists ready formed in wine and spirituous liquors, and may be collected without heat. Brande‡ procured it from wine by precipitating the acid and extractive colouring matters by subacetate of lead, and then depriving the alcohol of water by dry carbonate of potassa: the pure alcohol may then be measured in a graduated tube. Gay-Lussac obtained alcohol from wine by distilling it *in vacuo* at the temperature of 60° F. He also succeeded in separating the alcohol by the method of Brande; but he suggests the employment of litharge in fine powder, instead of subacetate of lead, for precipitating the colouring matter.§

Brande's results.

1980. The preceding researches of Brande led him to examine the quantity of alcohol contained in spirituous and fermented liquors. According to his experiments, brandy, rum, gin, and whiskey, contain from 51 to 54 per cent. of alcohol, of specific gravity 0.825. The stronger wines, such as Lissa, Raisin wine, Marsala, Port, Madeira, Sherry, Teneriffe, Constantia, Malaga, Bucellas, Calcavella, and Vidonia, contain from between 18 or 19 to 25 per cent. of alcohol. In Claret, Sauterne, Burgundy, Hock, Champagne, Hermitage, and Gooseberry wine, the quantity is from 12 to 17 per cent. In cider, perry, ale, and porter, the quantity varies from 4 to near 10 per cent. In all spirits, such as brandy or whiskey, the alcohol is simply combined with water; whereas in wine it is in combination with

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* It may be remarked that many errors exist in the published estimates of the solubility of substances in alcohol, arising from the existence of water either in the solvent or substance dissolved.

† Graham has examined the alcoholic combinations of chloride of calcium, nitrate of magnesia, &c. see *Quart. Jour.*, N. S., Dec. 1828.

‡ *Phil. Trans.* 1811 and 1813.

§ *Mem. d'Arcueil*, vol. iii.

mucilaginous, saccharine, and other vegetable principles, a condition which tends to diminish the action of the alcohol upon the system.*

Christison's recent experiments.

1981. From recent experiments Christison is of opinion that the alcoholic strength of many wines has been overrated. The following table shows some of his results; the first column gives the per-centage of absolute alcohol of sp. gr. 793.9, by weight, and the second the per-centage of proof-spirit sp. gr. 920 by volume.

	Alcohol p. c. By Wg't.	*P. Sp. p. c.* By Vol.
Port—weakest	14.97	30.56
mean of 7 wines	16.20	33.91
strongest	17.10	37.27
white port	14 97	31.31
Sherry—weakest	13.98	30.84
mean of 13 wines, excluding those very long kept in casks	15.37	33.59
strongest	16.17	35.12
mean of 9 wines very long in cask in the East Indies	14.72	32.30
Madre da Xeres	16.90	37.06
Madeira { all long in cask in the East Indies } strongest	14.09	30.80
weakest	16.90	36.81
Teneriffe, long in cask at Calcutta	13.84	30.21
Cercial	15.45	33.65
Dry Lisbon	16.14	34.71
Claret, a first growth of 1811	7.72	16.95
Chateau-Latour, first growth 1825	7.78	17. 6
Ordinary Claret, a superior "vin ordinaire"	8.99	18.96
Malmsey	12.86	28.37
Rudesheimer, superior quality	8.40	18.44
Do. inferior	6.90	15.19
Giles' Edin. Ale before bottling	5.70	12.60
Same ale 2 years in bottle	6.06	13.40
Superior London Porter 4 months bottled	5.36	11.91†

Composition of alcohol vapour according to Thomson,

1982. The composition of alcohol in the state of vapour is thus stated by Thomson:

1 vol. olefiant gas	0.9722 sp. gr.
1 " vapour of water	0.6250 "
	1.5972 "

condensed into 1 vol.; so that its sp. gr. is 1.5972 when in the state of vapour.

1983. Olefiant gas is a compound, 2 vols. carbon vapour, and 2 vols. hydrogen gas united together, and condensed into 1 volume. So that a vol. of it is equivalent to 2 atoms of carbon, and 2 atoms hydrogen.

Liebig's view.

1984. Liebig has given another view of the composition of alcohol, founded upon the experiments lately made to determine the composition of ether. According to him, ether contains no water, but is composed of C_4H_5+O, or it is an oxide of (C_4H_5). Alcohol is a hydrate of ether, or it consists of $(C_4H_5O)+HO$. This view recommends itself by its simplicity, and by the facility which it presents to us in explaining the nature of the numerous compounds formed by means of alcohol.‡

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* For Brande's table of proportion of alcohol in wines, see his *Chem.* ii. 565.

† *Edin. Philos. Jour.* July, 1839.

‡ Thomson, *Org. Bodies*, 300.

Chap. VII.

Aldehyde. 1185. *Aldehyde.** This remarkable substance was first noticed by Dobereiner, but has been particularly examined by Liebig.†

Obtained. 1986. It is a colourless liquid, having a peculiar ethereal smell and is obtained by passing the vapour of ether through a large glass tube heated to redness. The products being introduced into sulphuric ether, the aldehyde is retained in combination. Dry ammoniacal gas is then passed into the solution, which forms a crystalline compound with the aldehyde, termed *ammonia aldehyde.* From this compound it is procured by adding an equal weight of water, and then diluted sulphuric acid to unite with the ammonia, heating it afterwards in a retort.‡ The product of distillation is hydrated aldehyde, which is separated from the water by distilling it from chloride of calcium.

By spongy platinum. 1987. Aldehyde may also be formed by the action of spongy platinum with air and alcohol, or by distillation from 4 parts of water and 4 of alcohol, mixed with 6 of peroxide of manganese, and 6 of aqueous sulphuric acid.

Properties. 1988. It is very volatile, of sp. gr. 0.790, and boiling at 71½°. Its vapour when inhaled produces a kind of cramp in the stomach. It combines with water in all proportions, with evolution of heat. It takes fire readily, burning with a pale flame and much light. Kept in a vessel full of air it absorbs oxygen, and is converted into very concentrated acetic acid; this is promoted by spongy platinum.

A solvent. 1989. Aldehyde dissolves sulphur, phosphorus, and iodine; absorbs chlorine and bromine with production of hydrochloric and hydrobromic acids.§

Action on oxide of silver. 1990. When heated with water and oxide of silver, at first moderately and then raised to the boiling temperature, in a glass tube, the silver is revived and covers the glass with a brilliant coating. The oxide of silver is also reduced when a few drops of ammonia are added to aqueous aldehyde and it is heated with the oxide, affording an easy method of ascertaining the presence of the smallest quantity of aldehyde in any liquid.

Liebig's analysis. 1991. When kept in vessels to which air has access, oxygen is absorbed, and prismatic crystals are formed, which fuse at 212°, and at a higher temperature sublime. They are hard, inflammable, and soluble in alcohol and ether.

1992. Liebig analysed aldehyde by heating it with oxide of copper; the result was as follows:

Carbon - -	53 67	or 4 atoms	= 3.0	or per cent.	54.55
Hydrogen -	8.97	or 4 "	= 0.5	or "	9.09
Oxygen - -	37.36	or 2 "	= 2.	or "	36.36
	100.00		5.5		100.00

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* From *alcohol dehydratus.*

† *Ann. de. Chim. et Phys.* lix. 296, and *Ann. de Pharm.* xiv. 133.

‡ For minute details, see T. *Organic Bodies,* 301.

§ Liebig is of opinion that in these reactions the aldehyde is changed into *chloral* and *bromal.*

The density of its vapour he found 1.532.*

Aldehyde resin.

1993. *Aldehyde resin* is produced when potassa is dissolved in alcohol, and most speedily when the access of air is permitted. It is to the presence of this substance that the alcoholic solution of potassa owes its reddish-brown colour. It is produced also when a solution of potassa in alcohol and acetal is exposed to the air. This is a useful character to enable us to distinguish acetal from acetic ether and other ethereal liquids. All the liquids containing aldehyde assume a reddish-brown colour when heated with potassa; and when diluted with water the resin of aldehyde separates in brown flocks.†

Acetal.

1994. *Acetal* was obtained by Dobereiner by the following process:

Process.

Place alcohol of sp. gr. 0.8631 upon a saucer and in the saucer a support, the top of which is raised a few lines above the alcohol; upon the support place a number of watch-glasses having a quantity of spongy platinum in each. Cover the whole with a bell glass, open above, standing in the saucer so that the vapours which condense may fall back into the alcohol. The apparatus is left in a place not too cool till the alcohol acquires a very acid taste. The whole is then distilled over carbonate of lime. To the product of this distillation add chloride of calcium in powder, which causes the separation of an ethereal liquor, to which Liebig has given the name of *acetal*.

Properties.

1995. Acetal is colourless, and of sp. gr. 0.823; it boils at 203°; burns with a bright flame, and by the action of spongy platinum is converted into acetic acid. It may be considered as $C_4H_4 + H_{\frac{1}{2}}O1\frac{1}{2}$.‡

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* If we consider the vapour as composed of 4 vols. carbon vapour, 4 vols. hydrogen gas, and 1 vol. oxygen gas, condensed into 2 vols, we have

4 vols. carbon vapour = 1.6666
4 " hydrogen gas = 0.2777
1 vol. oxygen " = 1.1111

2)2.9555

1.4777 = sp. gr.

of aldehyde vapour. The vapour then is composed of 4 vols. carbon, 4 vols. hydrogen and 1 vol. oxygen condensed into 2 vols.

It is easy to see how, by means of oxygen, aldehyde is converted with such facility into acetic acid,

Acetic acid - - $C_4H_3O_3$
Aldehyde - - - $C_4H_4O_2$

If, therefore, the oxygen combine with one of the atoms of hydrogen, and convert it into water, while another atom of oxygen replaces the hydrogen, it is obvious that aldehyde will become acetic acid. Liebig is of opinion that there exists an unknown basis composed of C_4H_3, to which he has given the name of *alde-hyden*. The oxide of this basis is C_4H_3O, and when this oxide is combined with an atom of water, it constitutes aldehyde, the true formula for which is C_4H_3O+HO. Acetic acid is $C_4H_3O_3 + HO$. It is obvious also that aldehyde and alcohol differ from each other merely by the aldehyde containing 2 atoms less hydrogen than alcohol.

Alcohol is - - $C_4H_6O_2$
Aldehyde is - - $C_4H_4O_2$ (Thomson, 304.)

Aldehydic acid.

† *Aldehydic Acid* is prepared from aldehyde and oxide of silver, and is composed of $C_4H_4O_3$. It differs from acetic acid merely in containing an additional atom of hydrogen.

Bromide and Iodide of Aldehyden have been discovered, for which see T. 307.

‡ For some other compounds see T. *Org. Bodies*, 310. Thomson has given the name of *deutocarbohydrogen* to olefiant gas, and shown its relation to aldehyden as follows:

Aldehyden . . C_4H_3
Chloride of " . . . $C_4H_3 + Cl$
Bromide of " - . . $C_4H_3 + Br$

Chloral. 1996. *Chloral** was discovered by Liebig. It is obtained by passing a current of dry chlorine gas through absolute alcohol. A prodigious quantity of chlorine is necessary and a great deal of hydrochloric acid is formed.†

Properties. 1997. It is liquid, colourless, tasteless, of a penetrating odour, and of an oily appearance. It combines with water, sulphur, bromine and iodine; is decomposed when heated with different earths and metals, metallic chlorides being formed.‡

Insoluble chloral. 1998. Liebig has given the name *of insoluble chloral* to the substance formed when chloral is left to the action of concentrated sulphuric acid at common temperatures. During the conversion of alcohol into chloral, the alcohol loses 5 atoms of hydrogen and gains 3 atoms of chlorine. For every atom of alcohol converted into chloral 10 vols. of hydrochloric acid are formed, and 3 vols of chlorine enter into chemical combination with it. T.

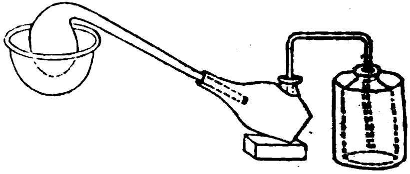
Ethal. 1999. *Ethal.*§ $C_{16}H_{17}O$, eq.=121. This substance has been described by Thomson in this place from its analogy to alcohol and sulphuric ether. It was obtained by Chevreul from spermaceti or cetine. With sulphuric acid it forms *sulphocetic acid.*

Ether. 2000. *Ether.* This name has been given to the light, volatile, inflammable, and fragrant liquids, obtained by distilling in a glass retort a mixture of alcohol and any strong acid. The different kinds of ether have been distinguished by the name of the acid employed in the process. That which is best known is sulphuric ether.

Sulphuric ether. Process. To prepare sulphuric ether, equal weights of sulphuric acid and alcohol are exposed to heat in a plain glass retort, pouring in the alcohol first and then the acid by a long glass funnel (Fig. 192), and adjusting the retort in a sand-bath already heated to the temperature of 200°, in the manner shown in Fig. 193. The acid and the alcohol should be well mixed by shaking them together in the retort, when the temperature rises considerably, and the receiver should be tubulated to convey away the atmospheric air, and any other gaseous products that may be formed towards the

192

Fig. 193.



Iodide of aldehyden . . .	$C_4H_3 + I$
Olefiant gas . .	$C_4H_3 + H$
Chloride of deutocarbohydrogen . .	$C_4H_3Cl + HCl$
Bromide of " . . .	$C_4H_3Br + HBr$
Iodide of " . . .	$C\ H_3I + HI$
Aldehyde	$C_4H_3O + HO$
Aldehydic acid	$C_4H_3O_2 + HO$
Acetic acid	$C_4H_3O_3 + HO$

Chloroform. *Chloroform* is obtained by distilling a mixture of alcohol and aqueous solution of bleaching powder, as a limpid fluid of sp. gr. 1.480. It is a compound of 1 atom bicarburet of hydrogen with 3 atoms of chlorine.

Bromoform. *Bromoform* is analogous to the last and is obtained when a mixture of bromide of lime and alcohol, or acetone, is distilled. It is an oily looking liquid, heavier than sulphuric acid, and its composition is the same as that of chloroform.

* From *chlorine* and *alcohol.*

† If we employ an avoirdupois pound of alcohol, we shall require 66.453 cubic inches, or almost 38⅓ cubic feet of chlorine gas, or 48 cubic feet of hydrochloric acid gas. T.

‡ It differs from chloroform by containing two atoms more of carbon and two atoms of oxygen.

§ From first syllables of *ether* and *alcohol.*

close of the operation. The neck of the receiver should fit closely to the neck of the retort, and the joint be rendered tight by tying it round with a piece of linen or cotton cloth spread over with paste made of flour. The bent tube fixed to the tubulure of the receiver should be made to pass into a second receiver, or to dip into a bottle in the manner represented, which is kept cold by placing it in a jar or basin with water or ice; the tube must not fit tightly to the neck of the bottle, but allow any gas that may come over to be freely disengaged. The first receiver should be tied round with a piece of linen or cotton cloth, that it may be more easily kept cold; ice or snow should always be used when it can be procured.

2001. The distillation is generally continued till a quantity of liquid has come over equal to one half the alcohol employed. More ether is said to be obtained when it is kept constantly boiling than at a lower temperature, though this has been disputed; the retort should not be filled more than half full, and great attention must be paid to the heat applied during the whole of the operation, as the mixture is apt to boil over when urged with too strong a fire.

Purified.

2002. The ether that condenses in the receiver is never obtained pure at first, being always mixed with a little alcohol that distils over unaltered, and some sulphurous acid. To remove these, it is mixed with potassa, taking five or six grains for every ounce of alcohol employed, and distilled again from a retort with a very gentle heat till five or six sevenths shall have passed over; the potassa retains the sulphurous acid, along with some water and alcohol. To separate the alcohol completely, it may be shaken with about three fourths of its bulk of water, which combines with all the alcohol and a little ether. It is then distilled by a very gentle heat, and may be rendered still stronger by distillation from chloride of lime. It should be kept in bottles with well-ground glass stopples.

On a small scale, an ounce or two of alcohol with as much sulphuric acid by weight, will be sufficient to show the process, condensing the product in a common flask.*

Properties.

2003. Ether is a colourless liquid, of a hot pungent taste and fragrant odour. It is highly exhilarating, and produces a degree of intoxication when its vapour is inhaled by the nostrils. Its sp. gr. varies with its purity. Lowitz is said to have procured it as light as .632; Brande states that he never obtained it lower than

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Phillip's process.

* The *London Pharmacop.* directs the distillation of ether with potassa, for its purification from sulphurous acid; and Phillips has given the following directions for procuring ether for pharmaceutical purposes, which answer extremely well.

"Mix with 16 ounces of sulphuric acid, an equal weight of rectified spirit, and distil about 10 fluid ounces, add 8 ounces of spirit to the residuum in the retort, and distil about 9 fluid ounces; or continue the operation until the contents of the retort begin to rise or the product becomes considerably sulphurous; mix the two products, and if the mixture consists of a light and heavy fluid, separate them; add potassa to the lighter, as long as it appears to be dissolved; separate the ether from the solution of potassa, and distil about nine tenths of it, to be preserved as *ether sulphuricus*, the specific gravity of which ought to be at most .750."

In the preparation of ether on a large scale considerable risk is incurred by fire, recourse has therefore been had to steam as the source of the required heat. In the apparatus employed at Apothecaries' Hall (Lond.) the still is of cast iron, lined with lead; the steam is conducted through the mixture of acid and alcohol by a contorted leaden pipe at the bottom of the still, and is supplied by a boiler calculated to resist the pressure of 100 lbs. on the square inch; in this way the mixture is very rapidly raised to its boiling point, and a larger relative quantity of ether is obtained. The boiler is placed in a distant apartment. The condensing apparatus and refrigeratory are of the usual construction, but abundantly supplied with cold water. Brande's *Pharmacy*, 486.

.700; as ordinarily prepared, its sp. gr. varies between .730 and .760, and as met with in commerce, it must be considered as a mixture of pure ether and alcohol.*

Volatile. 2004. It is extremely volatile, and when poured from one vessel into another, a considerable portion evaporates; during its evaporation from surfaces, it produces intense cold, as may be felt by pouring it upon the hand; and seen, by dropping it upon the bulb of a thermometer, which sinks to many degrees below the freezing point. The sp. gr. of the vapour of ether compared with atmospheric air, is, according to Gay-Lussac, as 2.586 to 1.000.† Two ounce measures of ether converted into gas at the temperature of 72.50 fill the space of a cubic foot.

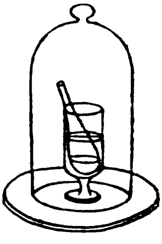
Exp. The change may be exhibited by placing a large bell glass filled with hot water on the shelf of the pneumatic trough and passing the ether from a phial up into it. The vapour will fill the jar, and may be fired with suitable precautions.

Boiling point 2005. At mean pressure, sulphuric ether, when of a sp. gr. of .730, boils at 98°, and under the exhausted receiver of an air-pump, at all temperatures above —20°; hence, were it not for atmospheric pressure, ether would only be known in the state of vapour.

In consequence of the cold produced during the vaporization of sulphuric ether, the phenomena of boiling and freezing may be exhibited in the same vessel.

Exp. For this purpose procure a very thin flask which fits loosely into a wine-glass, as shown in Fig. 194. Pour a small quantity of ether into the flask, and of water into the glass, and place the whole under the receiver of an air-pump; during exhaustion, the ether will boil, and a crust of ice will gradually form upon the exterior of the flask.‡

Fig. 194.



2006. Ether is highly inflammable, and in consequence of its volatility it is often kindled by the mere approach of a burning body; a circumstance which renders it highly dangerous to decant, or open vessels of ether near a candle.§

Exp. The inflammability of ethereal vapour may be shown by passing a small quantity into a receiver, furnished with a brass stop-cock and pipe, and inverted over water at a temperature of 100°. The receiver becomes filled with the vapour, which may be propelled and inflamed; it burns with a bright bluish-white flame.

Explodes with oxygen, 2007. When ether is admitted to any gaseous body it increases its bulk. Oxygen thus expanded, produces a highly inflammable mixture; if the quantity of oxygen be large and of ether small, the mixture is highly explosive, and produces water and carbonic acid.

Exp. Into a strong two ounce phial, filled with oxygen gas, and wrapped round with a cloth, let fall a drop of ether. On applying the flame of a candle, a violent detonation will ensue.

And with chlorine. 2008. The vapour of ether also explodes with chlorine, as is shown by the following experiment.

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* For table of sp. gr. see Henry's *Chem.* ii. 333.

† 2.5822, T. and L.

‡ After using ether, *air* should be drawn through the pump many times to get rid of the ether, as it injures the valves.

§ In spirit warehouses or druggists' laboratories where ether is distilled the *safety lamp* (Fig. 174) may be advantageously used.

Sect. I.

Exp.

Fill a bottle of the capacity of three or four pints, with chlorine gas, taking care to expel the water as completely as possible. Then throw into it about a drachm or a drachm and a half of good ether, covering its mouth immediately with a piece of light wood or paper. In a few seconds white vapour will be seen moving circularly in the bottle, and this will soon be followed by an explosion, accompanied with flame. At the same time a considerable quantity of carbon will be deposited.

When a small quantity of ether is poured into a large jar of warm chlorine, it occasionally happens that a considerable explosion ensues.

2009. Ether freezes at —46°. When exposed to light in a vessel partially filled, and which is frequently opened, it gradually absorbs oxygen, and a portion of acetic acid is generated.

Dissolves resins, &c.

2010. Ether dissolves the resins, several of the fixed oils, and nearly all the volatile oils; it also dissolves a portion of sulphur, and of phosphorus; the latter solution is beautifully luminous when poured upon warm water in a dark room. The fixed alkalies are not soluble in ether, but it combines with ammonia.

Action on oxides of gold and platinum.

It dissolves the oxides of gold and platinum, and these solutions have been employed for coating steel with those metals, with a view to ornament and as a defence from rust.*

2011. When a coil of platinum wire is heated to redness, and then suspended above the surface of ether contained in an open vessel (Fig. 53), the wire instantly begins to glow, and continues in that state until all the ether is consumed. During this slow combustion, pungent acrid fumes are emitted, which, if received in a separate vessel, condense into a colourless liquid possessed of acid properties, owing to the formation of acetic acid.

Base of ether.

2012. It has been already stated (1567) that sulphuric ether consists of C_4H_5O, and that it possesses the characters of a base, being capable of neutralizing acids, oxygen, chlorine, bromine, iodine, and fluorine. These new compounds are at present very inaccurately termed *ethers*. The base of ether is C_4H_5 to which Liebig has given the name of *ethyl*.† Common ether is an oxide of ethyl. T.

Sweet oil of wine.

2013. In preparing ether the ebullition is continued till white vapours appear, and the smell of sulphurous acid is perceived, and by continuing the heat a yellowish liquid comes over which has been called the *sweet oil of wine*.‡

Chloride of ethyl.

2014. *Chloride of Ethyl—Hydrochloric Ether.* C_4H_5Cl. This compound is generated by the action of hydrochloric acid on alcohol, and may be prepared by several processes:—by distilling alcohol previously saturated with hydrochloric acid gas, or mixed with an

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Use of ethereal solution of gold &c.

* If to a saturated solution of gold or platinum, in nitro-hydrochloric acid, there be added about three parts by measure of good sulphuric ether, it soon takes up the metals, leaving the acid nearly colourless below the ethereal solution, which is to be carefully decanted off; into this the polished steel is for an instant plunged, and immediately afterwards washed in water, or in a weak alkaline solution. Though the coating of platinum is the least beautiful, Stodardt, who has made many experiments upon this subject, considers it as the best protection from rust. Polished brass may be coated by the same process. These surfaces of gold and platinum, though very thin, are often a useful protection; with gold the experiment is particularly beautiful, and well illustrates the astonishing divisibility of the metal. The ethereal solution of gold is not permanent, but, after a time, deposits the metal in the form of a film, in which crystals of gold are often perceptible.

† From recent experiments Löwig concludes that by the action of potassium on chloride of ethyl, chloride and *ethylide* of potassium are formed, and that by the action of water upon the latter, the ethyle is set free. *Lond. and Edin. Phil. Mag.*, July, 1839.

‡ See T. *Inorg. Chem.* ii. 307, and B. ii. 592.

equal volume of strong hydrochloric acid; by heating a mixture of 5 parts of alcohol, 5 of strong sulphuric acid, and 12 of fused sea-salt in fine powder; or by distilling alcohol with the chlorides of tin, bismuth, antimony, or arsenic. The products are transmitted through tepid water, by which free alcohol and acid are absorbed, and the pure hydrochloric ether is then received in a vessel surrounded by ice or a freezing mixture.

Properties. 2015. Hydrochloric ether is a colourless liquid, of a penetrating, somewhat alliaceous, ethereal odour, and a strong rather sweet taste. It is so volatile that it boils at about 54°. When inflamed, as it issues from a small aperture, it burns with an emerald-green flame without smoke, yielding abundant vapours of hydrochloric acid.

Sulphuret of ethyl. 2016. *Sulphuret of Ethyl*, or *Mercaptan*. C_4H_5S+HS. This new substance was discovered by Zeise and named *mercaptan*, on account of its energetic action on the red oxide of mercury.[*]

Process. Althionate of baryta, lime, or potassa, was heated with a strong solution of protosulphuret of barium. There distilled over along with the water an ethereal liquid, while the althionate was changed into sulphate.

2017. The ethereal liquid was lighter than water, colourless, of a penetrating odour, resembling that of garlic. Its taste was sweet; it inflamed readily, giving out the odour of sulphurous acid. When distilled it was divided into two distinct liquids. To the first the name of *thialic ether* was given, and to the second *mercaptan*.

Mercaptan. 2018. Mercaptan acts with force upon potassium, hydrogen gas being evolved and the metal converted into a colourless salt, very soluble in water and in alcohol. These solutions give a yellow precipitate, with acetate and nitrate of mercury.[†]

There are six bodies to which the term ether has been applied, but which are not considered such by Thomson, by whom they have been constituted a distinct class, having for their base not C_4H_6 but C_4H_4 (the *tetarto-carbo-hydrogen* of Thomson), they are

Other ethers.

1	Light oil of wine	$C_4\ H_4$
2	Chloric ether	$C_4\ H_4 + Cl_2$ [‡]
3	Bromic "	$C_4\ H_4 + Br_2$
4	Iodic "	$C_4\ H_4 + I_2$
5	Acetal "	$C_4\ H_4 + H_{\frac{1}{2}}O$
6	Sulphocyanic	

The third set of bodies classed among the ethers, consists of chemical compounds of sulphuric ether and an acid. Of these Thomson enumerates twenty, for which see *Org. Bodies*, 329.

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[*] *Ann. de Chim. et de Phys.* lvi. 87.

Hydrocyanic ether. [†] *Cyanodide of Ethyl—Hydrocyanic Ether*, $C_4H_5(C_2N)$, was discovered by Pelouze, and is obtained by heating a mixture of equal parts of cyanodide of potassium and althionate of baryta.

Sulphohydric, *Sulphohydric Ether*, $C_4H_5(HS)$? was formed by Löwig by the action of oxalic ether and sulphuret of potassium. It has no action on red oxide of mercury, and by this character is distinguished from mercaptan. See T. *Org. Bodies*, 328.

Chloric ether. [‡] *Chloric Ether* is the name which has been applied to a liquid obtained by distilling a gallon from a mixture of three pounds of chloride of lime and two gallons of alcohol, sp. gr. 0.844, and rectifying the product. This was discovered by Guthrie in the United States and Souberain in France. See Guthrie's account in *Amer. Jour.* xxi. As this liquid does not contain chloric acid, Bache has proposed for it the name of *chlorine ether*.

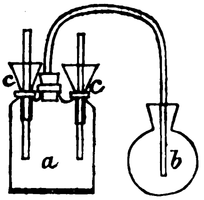
It is extremely volatile, of a sweetish taste, boiling at 166°, and having the sp. gr. of 1.486. When diluted with water it is employed as a diffusible stimulant.

Thomson's 3d set.

Nitric ether.

2019. *Nitric ether. Nitrous ether*; $C_4H_5O+NO_3$. Various processes are given for obtaining this liquid;* it is produced by the action of equal weights of nitric acid and alcohol, the acid being added in small successive quantities to the alcohol, and the mixture cooled after each addition, to prevent the violent action that would otherwise ensue. It collects on the surface of the mixture and is cautiously withdrawn.

Fig. 195.



Preparation.

1. Fig. (195) represents an arrangement proposed by Torrey—*a* a Woulfe's bottle, *b* a receiver, *c c* glass funnels ground to the necks, and glass rods ground to the funnels, the acid being in one funnel, and the alcohol in the other; by means of the glass rods the admission of either is regulated at pleasure.

2. Introduce into a sufficiently capacious retort equal weights of alcohol, (specific gravity 820) and of nitric acid of commerce (specific gravity 1.30) and connect it with five Woulfe's bottles, the first of which is empty and the remaining four half filled with a saturated solution of salt in water. Apply a gentle heat to the retort, till the liquor begins to effervesce; then withdraw the fire, and the gaseous matter passing through the bottles, which should be kept cold by ice, deposits the ether upon the saline solution, from which it is to be decanted, shaken with chalk, and redistilled at a very gentle heat.†

Caution.

2020. In all experiments with nitric acid and alcohol, great care must be taken not to mix a large quantity of acid with the alcohol at once, as the gaseous products that are immediately produced are apt to throw out the whole of the mixture with explosive violence.‡ Nitrogen, protoxide and binoxide of nitrogen, and carbonic acid gases are disengaged.

2021. The nitrous agrees with sulphuric ether in its leading properties; but it is still more volatile. When recently distilled from quicklime by a gentle heat, it is quite neutral; but it soon becomes acid by keeping. It is decomposed by potassa, and, on evaporation, crystals of the nitrite or hyponitrite of that alkali are deposited (Mem. d'Arcueil, i.) It is soluble in 48 parts of water, and in all proportions in alcohol; this last solution is the *spiritus ætheris nitrici*, or *sweet spirit of nitre* of the Pharmacopœia.§

Sweet spirit of nitre.

Oxalic ether.

2022. *Oxalic ether*. $C_4H_5O+C_2O_3$. Is obtained from 1 part of alcohol, 1 binoxalate of potassa, and 2 parts of sulphuric acid. It is purified by boiling with pounded litharge. It is an oleaginous liquid, boiling at 263°. When a current of dry ammoniacal gas is passed over it a substance is obtained which has been called by Dumas‖ *oxamethane*.¶

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* Thomson's *Inorg. Chem.* 318.

† See description of an apparatus for this process by Hare, in *Am. Jour.* vol. ii. p. 326 and xxxiii. 241.

‡ Though a small quantity of acid may be added to a large quantity of alcohol without much action, a small quantity of alcohol cannot be added to a large quantity of acid without violent action.

Process for.

§ Two lb. of nitrate of potassa and a lb. and a half of sulphuric acid are mixed in a glass retort, 9 and a half lbs. of alcohol are gradually poured in; it is digested with a gentle heat for two hours, the heat is then raised and a gallon distilled off; to this 1 pint of diluted alcohol and an ounce of carbonate of potassa are added and a gallon distilled off. *U. S. P.*

‖ *Ann. de. Chim. et de Phys.* liv. 241, and *Ann. de Pharm.* ix. 129.

¶ *Etheroxalate of Potassa.* It was shown by Leibig that oxalic ether has the pro-

Œnanthic ether.

2023. *Œnanthic ether.* $C_4H_5O+C_{14}H_{13}O_2$. It is to this remarkable ether that the peculiar odour of wines is owing.* When large quantities of wine are distilled we obtain, at the end of the process a small quantity of an oily liquid. The same liquid is obtained when the lees of wine are distilled;

Properties.

2024. It has a strong taste, is usually colourless, and is a mixture of œnanthic ether with an excess of œnanthic acid. The ether is separated by distillation. It is very liquid, has a strong odour of wine and produces intoxication when inspired.†

Thomson's 4th set.

2025. The fourth set of bodies, which have by some been classed among *ethers*, are certain acidulous salts, consisting of 1 atom of ether united to 2 atoms of an acid. They are

1 Heavy oil of wine - - -	$C_4H_5(H\frac{1}{2}O\frac{1}{2})+SO_3$
2 Althionic acid - - - -	$C_4H_5O+2(SO_3)+HO$
3 Phosphovinic acid - - -	$C_4H_5O+2(PO_2\frac{1}{2})$
4 Oxalovinic acid - - - -	$C_4H_5O+2(C_2O_3)+HO$
5 Tartrovinic acid - - - -	$C_4H_5O+2(C_4H_2O_5)+HO$
6 Racemovinic acid - - -	$C_4H_5O+2(C_4H_2O_5)+HO$
7 Camphovinic acid - - -	$C_4H_5O+2(C_{10}H7\frac{1}{2}O_5)+HO$

Pyroxylic spirit.

2026. *Pyroxylic spirit.* $C_2H_3O+HO=32$. This name has been given to the volatile liquid which is formed when wood is subjected to heat, and which is found in the aqueous liquid which comes over. This is decanted off to separate it from the tar, and when again distilled the pyroxylic spirit is in the first tenth part of the product. It is rectified over quicklime.

Properties.

2027. Pyroxylic spirit is colourless, and has a peculiar odour, alcoholic and aromatic mixed with that of acetic ether. It boils at 150°, its sp. gr. is .798 not differing much from alcohol.‡

Action of platinum sponge.

2028. When its vapour is mixed with air in contact with platinum sponge, heat is evolved and formic acid produced. If allowed to fall drop by drop on the spongy platinum, it burns and carbonic acid is produced. Its vapour explodes with dry chlorine. Distilled with chloride of calcium it gives rise to chloroform.

Action of sulphuric acid.

2029. When a mixture of 1 part of pyroxylic spirit and 4 parts of concentrated sulphuric acid is distilled, a gas comes over, which possesses the constitution of alcohol vapour. The very same thing takes place in this distillation as when we heat a mixture of alcohol and sulphuric acid. One half the water is abstracted relative to the

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Etheroxalate of potassa.

perty of combining with bases like an acid, and this salt is obtained when oxalic ether is dissolved in absolute alcohol and as much hydrate of potassa is added as is just sufficient to neutralize half the oxalic acid. *Lehrbuch der chim.* 2 Aufl. i. 644.

[*] *Ann. de Chim. et de Phys.* lxiii. 113.

[†] For the other ethers of this division see *T. Org. Bodies*, 333.

Used as a solvent, &c.

[‡] Pyroxylic spirit is extensively used by hat makers, for the purpose of dissolving shell lac and mastic to stiffen hats and render them water proof. According to Scanlan a fluid of higher sp. gr. and lower boiling point is obtained by distillation by saturating the purified acid with slacked lime, and subsequent distillation as long as the product is of less sp. gr. than water. This product is rectified in a still, consisting of a boiler and rectifier of copper of peculiar construction placed in a bath of water, and kept at such a temperature as will condense water, but retain the more volatile products in the state of vapour till they pass the last part of the apparatus where they are cooled. See *Rep. Brit. Assoc.* 1835, 40.

other ingredient, the carbo-hydrogen.* When alcohol is used olefiant gas† is converted into ether; but when pyroxylic spirit is used, the compound is C_2H_3O, or it contains an atom of olefiant gas less than ether.‡

2030. When pyroxylic spirit is made to act on the hydracids, a set of compounds is formed very analogous to the ethers which the same acids form with alcohol. Dumas and Peligot consider them as compounds of the hydracid and a base which they term *methylene.*§ Action on hydracids.

CHAPTER VIII.

Section I. *Colouring Matters.*

2031. A great number of vegetable principles are comprised under the term colouring matter, and are extensively employed in the processes of dyeing and calico-printing.¶

2032. Some of these are used as chemical re-agents and for testing the presence of acids and alkalies. The infusion of red cabbage has been already described (56 n.); the colouring matter of violets may be used for the same purpose.

2033. *Litmus* is the blue colouring matter prepared from the *lichen rocella* which grows in the Canary islands, and the *leconora tartarea* which is collected in Norway. From the latter is also prepared *cudbear*,** the colour being developed by the aid of ammonia. The colouring matter of the leconora has been termed *erythrin*, and that of archil *orcin*. Litmus.

2034. Litmus is more easily affected by acids than the colouring matter of cabbage, but is not turned to a green by alkalies. If previously reddened by acids, it may be used for detecting alkalies, the original blue tint being restored.†† Effect of acids and alkalies.

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* Carbo-hydrogen is the name applied by Thomson to the gas evolved when pyroxylic spirit is treated with aqua regia, it is composed of 1 vol. of carbon vapour and 1 vol. of hydrogen gas.

† *Deutocarbohydrogen* of T.

‡ This is the same thing in both cases as abstracting one half of the water which the spirit contained. But in reality

Alcohol is . . . . $C_4\,H_5\,O + H\,O$
While this gas is . . . $C_2\,H_2 \quad + H\,O$ T. 350.

§ For details see T. *Org. Bodies*, 350.

|| *Acetone.* C_3H_3O. This name is given to what was termed *pyro-acetic spirit*, and which is obtained by heating several acetates. It is a transparent, volatile and inflammable liquid, entering into combination with water, alcohol, ether and some volatile oils. Acetone.

Mesite is a product of the distillation of wood named from μεσιτης a *mediator*.

¶ For a more particular description of the various colouring matters, and of the processes followed for their extraction and fixation, constituting the art of dyeing, the student must be referred to Thomson's *Organic Chemistry*, 367. Ure's *Dict. of Arts and Manuf.* Berthollet on *Dyeing*, and Thomson on *Calico-printing* in *Records of General Science*, Vols. i. ii. iii.

** First called *Cuthbert* from Dr. Cuthbert Gordon who first made it.

†† To prepare test papers, rub some good litmus with hot water in a mortar, pour the mixture into an evaporating basin, and add pure water until the proportion is about half a pint for each ounce of litmus. Cover it up and keep warm for an hour, then Preparation of test papers.

Chap. VIII. Turmeric. 2035. *Turmeric* is the root of the *curcuma longa*, a plant growing in the East Indies. It is yellow and its colouring matter has been called *curcumin;* it is imparted to boiling alcohol and separated by ether from which it is obtained by distillation. It is changed to brown by alkalies and some neutral salts.

2036. Many colouring matters have a great attraction for metallic oxides, combining with them when they are separated from solutions in which both the colouring matter and the oxides have been previously dissolved; thus when potassa is added to a solution containing hydrochlorate of tin and litmus, the potassa unites with the hydrochloric acid, litmus and oxide of tin falling down in combination. Lakes. The precipitates thus obtained are called *lakes.*

2037. On this property are founded many of the processes in Dyeing. dyeing and calico-printing. The art of the dyer consists in giving a uniform and permanent colour to cloth. This is sometimes effected merely by immersing the cloth in the coloured solution; whereas in other instances the affinity between the colour and the fibre of the cloth is so slight, that it only receives a stain which is removed by washing with water. In this case some third substance is requisite, which has an affinity both for the cloth and colouring matter, and which, by combining at the same time with each, may cause the dye to be permanent. A substance of this kind was formerly Mordants. called a *mordant;* but the term *basis*, introduced by Henry is now more generally employed. The most important bases, and indeed the only ones in common use, are alumina, oxide of iron, and oxide of tin. The two former are exhibited in combination either with the sulphuric or acetic acid, and the latter most commonly as the chloride.

Substantive colours, 2038. *Substantive colouring* matters include those which have so strong an attraction for cloth, that they can attach themselves to it permanently, and without the action of any other substance, as indigo.

Adjective. Those which require a mordant are termed *adjective* colouring matters.

Bleaching. 2039. Colouring matters are bleached by chlorine, which is usually employed in union with lime (901); sulphurous and some other acids are also used to remove colour.

Red dyes, 2040. For *red dyes*, Brazil wood, lac, archil, madder and cochineal, are the principal colouring matters in common use. The cochineal, is procured from an insect, which is believed to derive its colouring matter from a particular vegetable principle upon which it feeds.

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decant the clear liquor, and pour fresh hot water upon the residue. Cover up and keep warm as before, evaporate. These operations are to be repeated until all the colour is removed. The first solution is to be kept apart from the second and third, which may be mixed and reduced by evaporation until a piece of filtering paper dipped in and dried is of a blue colour. Paper is then to be dipped into the solution; it should be bibulous and not sized. The solution should be poured into a dish and the paper be drawn through it piece by piece, be drained, and dried where no acid fumes or those of burning charcoal can have access to it. As soon as dry the paper should be placed in a well closed tin box. The tint ought to be a pure blue, and can be judged of by applying a drop of very weak acid which should produce a vivid red. Turmeric paper is prepared in a similar manner. See Faraday's *Chem. Manip.* 272.

Yellow,

2041. *Yellow dyes* are procured principally from saffron, hiccory, quercitron bark, turmeric, fustic and annatto.

Black,

2042. *Black dyes* are made with the same materials as writing ink, logwood and madder are also employed with oxide of iron.

Blue,

2043. *Blue dyes* are commonly prepared with Prussian blue or indigo. Three different colouring principles have been detected in indigo, *indigo blue*, *indigo red* and *indigo brown*. It is obtained from an American and Asiatic plant the *Indigofera*, and the *Nerium tinctorium*; an inferior sort is prepared from the *Isatis tinctoria* or *wood*, a native of Europe.

Indigo.

2044. Indigo $C_{16}H_5NO_2$ as it occurs in commerce, is far from being pure, more than half its weight consisting of matter destitute of a blue colour and incapable of being used as a dye stuff. Part of these impurities may be dissolved by water, part by alcohol, and part by dilute acids and by alkaline leys.

Obtained pure.

2045. The best way of obtaining pure indigo, is from the calico-printers' vat, in which the indigo has been deprived of its blue colour by sulphate of iron and is held in solution by means of lime water. The colour of this solution is yellow. If a quantity of it be put into an open vessel it absorbs oxygen from the atmosphere and the indigo precipitates of a blue colour. If the precipitate be digested in hydro-chloric acid, washed and dried, it is pure indigo.

Sublimed indigo.

2046. Indigo sublimes in long flat needles at about 550°, its vapour is transparent and reddish violet. It melts and is decomposed at nearly the same temperature. The sp. gr. of sublimed indigo is 1.35.

Solubility, &c.

2047. It is insoluble in water, but soluble in sulphuric acid, the indigo being changed into what has been termed *cerulin*.[*] It is decomposed by nitric acid, with the formation of *indigotic* and *carbazotic acids*.

Action of deoxidizing substances.

2048. When treated with something capable of abstracting oxygen, it assumes a white or yellowish-white colour, and becomes soluble in the different bases. This white substance has been called by Liebig *indigogen*, it does not alter by exposure to dry air, but when placed under water assumes a deep-blue colour and acquires a coppery tint when dried. It dissolves in alkalies, but does not neutralize them. It is soluble in alcohol, but insoluble in acids and water.

Indigogen.

Exp.

Fill one leg of a syphon with a solution of indigogen in lime water, and the other leg with hydrochloric acid, the indigogen will separate in white flocks. Substitute nitric acid for hydrochloric, the precipitate will become blue and gradually disappear.

Exp.

Make a solution of indigogen in lime water, pass oxygen gas into it, it will be absorbed and indigo be reproduced and precipitated.

Cerulin.

2049. Cerulin is precipitated from the solution in sulphuric acid by any salt of potassa forming *ceruleo-sulphate of potassa*, of so deep a blue colour that when moist it appears black. Water in a wine glass containing $\frac{1}{500.000}$th of its weight of it is distinctly blue.[†]

Phenicin.

2050. According to Crum if the action of sulphuric acid on indigo be stopped at a certain point a new substance is formed possess-

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[*] *Saxon blue.*

[†] According to Berzelius when indigo is dissolved in sulphuric acid, two new acids are formed *hypo-sulpho-indigotic* and *sulpho-indigotic.*

ing rather singular properties. It is formed at the instant indigo changes from yellow to blue; Crum has called this *phenicin*.[*]

Uses of indigo.

2051. Indigo is used for dyeing woollen, silk, linen and cotton blue. To enable it to combine with the cloth, it must be in a state of solution and this state is induced in two ways. 1. The indigo is deprived of its oxygen, and reduced to the state of indigogen; this combines with alkalies and forms a compound soluble in water. 2. The indigo is dissolved in sulphuric acid, as in dyeing Saxon blue.[†] T.

Different tints produced.

2052. By combining red, yellow, blue or black colouring matters, all other tints may be produced, and by varying the strength of the colouring matter, or the strength of the mordant, different shades of the same colour may be had.[‡]

Anotta.

2053. *Anotta* or *Rocou* is a name given to the pulp of the seeds of the *bixa orellena* a South American shrub. It dissolves in small quantity in water, better in alcohol, and the solution is orange yellow. It is often adulterated with powder of bricks, &c.; the fraud is detected by exposing anotta, previously dried at 212°, to a red heat till it is quite burnt. If the anotta be pure the residual matter will not exceed 13 per cent.; all over that is adulteration.[§]

Saffron.

2054. *Saffron* consists of the dried stigmas of the *crocus sativus*. The colouring matter is termed *polychroite* on account of the numerous colours which it is capable of assuming. It is obtained from the watery infusion of saffron by evaporation, digestion of the residuum in alcohol and evaporation.

Chlorophyllite.

2055. *Chlorophyllite*, or *Chromulite* is the term applied to the green colouring matter of vegetables; in the autumn it is reddened by the production of acid.

Chromule.

2056. *Chromule* is the name given to the various coloured principles obtained from the leaves and flowers of plants.

CHAPTER IX.

Section I. *Oleaginous Substances.*

Oils, their characters,

2057. Oils are characterized by a peculiar unctuous feel, by inflammability and by insolubility in water. They have been divided into fixed and volatile oils, the former being comparatively fixed in the fire and giving a permanent greasy stain to paper, while the latter, owing to their volatility produce a stain which disappears by gentle heat.

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[*] *Ann. Philos.* 2d series, v. 95. Berzelius calls it the *purple of indigo*. *Traité de Chim.* vi. 98.

[†] For details see T. *Org. Bodies*, 381.

[‡] **Zanthin.** *Zanthin* is obtained from madder and is yellow; the other colouring principle of this root is *alizarin* and is red.

Carthamin. *Carthamin* is the red colouring matter of safflower. From this *rouge* is prepared, the carthamin being ground with talc.

Hæmatin. *Hæmatin* is the colouring matter of logwood; *Brezilin* of *Brazil wood*; *Santalin* of *Red sanders*.

[§] *Jour. de Pharm.* xxii. 101.

2058. There seems little reason to doubt that the fixed oils constitute, in reality, salts, or rather each oil is a mixture of two or more salts, if the term salt can be applied to the compounds of the oily acids with *glycerin*, which acts the part of a base. T. 427.

Fixed, Obtained,

2059. The fixed oils are usually contained in the seeds of plants, as for example in the almond, linseed, rape-seed, and poppy-seed; but olive oil is extracted from the pulp which surrounds the stone. They are procured by bruising the seed, and subjecting the pulpy matter to pressure in hempen bags, a gentle heat being generally employed at the same time to render the oil more limpid.

Properties.

2060. Fixed oils are nearly inodorous, have little taste, and are lighter than water, their density in general varying from 0.9 to 0.96. Some, such as cocoa-nut and palm-oil, are fixed at 50° or 60; but most of them are fluid at common temperatures, and they all become limpid in becoming warm. They are commonly of a yellow colour, but may be rendered nearly or quite colourless by the action of animal charcoal. At or near 600° they begin to boil, but suffer partial decomposition at the same time, an inflammable vapour being disengaged even below 500°. When heated to redness in close vessels, a large quantity of the combustible compounds of carbon and hydrogen is formed, together with the other products of the destructive distillation of vegetable substances; and in the open air they burn with a clear white light, and formation of water and carbonic acid. They may hence be employed for the purposes of artificial illumination, as well in lamps, as for the manufacture of gas.

Effect of air.

2061. By exposure to the air they absorb oxygen, become rancid and sometimes assume a waxy consistence. Some few, such as linseed, and nut-oil, and the oils of the poppy and hemp-seed become covered with a pellicle, and when thinly spread upon a surface, instead of remaining greasy, become hard and resinous; these are termed *drying oils*, and their drying quality is much improved by boiling them upon a small quantity of litharge.[*]

Drying oils.

Spontaneous combustion.

2062. The absorption of oxygen by fixed, and especially by drying oils, is under some circumstances so abundant and rapid, and accompanied with so much heat, that light porous combustible materials, such as lampblack, hemp, or cotton-wool, may be kindled by it. Substances of this kind, moistened with linseed-oil, have been known to take fire during the space of 24 hours, a circumstance which has repeatedly been the cause of extensive fires in warehouses and in cotton manufactories.

Action of nitric acid.

2063. Nitric acid acts with great energy on the fixed oils. In a small proportion, its chief effect is to render them thicker. Red and smoking nitric acid, when suddenly mixed with a fixed oil, especially with the addition of a little sulphuric acid, occasions a violent com-

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Printers' ink.

[*] The drying oils, and especially nut-oil, form the basis of *printer's ink*, the history of which will be found in Lewis's *Phil. Commerce of the Arts*. The oil is heated and set fire to, and after having been suffered to burn for half an hour is extinguished, and boiled till it acquires a due consistency; in this state it is called *Varnish*, and is viscid, tenacious, and easily miscible with fresh oil, or with oil of turpentine, by which it is properly thinned, and afterwards mixed with rosin, soap, and lamp-black. See also Ure's *Dict. Arts and Manuf.* 1031.

bustion. Chlorine gas, passed through them, thickens them, and renders them tenacious like wax.

Effect of alkalies, &c. 2064. Fixed oils are converted into a peculiar kind of acids* and glycerin when heated with the fixed alkalies and water. The acids uniting with the alkali constitute soap, the glycerin remains in solution. The acids are the margaric, stearic and oleic.

Stearine and Oleine. 2065. The researches of Chevreul on the nature of oils and fats have shown that these bodies are compounds of at least two other compounds, one of which is solid at common temperatures, while the other is fluid. To the former he applied the name of *stearine*, from *στεαρ suet*, and to the latter *elaine* or *oleine*, from *ελαιον oil*. Oleine is the fluid principle of oils, and gives fluidity to those oils in which it predominates. It requires a cold of 20° for congelation, and is prepared from oils by exposing them to a cold of about 25°, and pressing the congealed mass between folds of bibulous paper; when the oleine is absorbed, and may be separated by pressing the paper under water. Oleine is well adapted for lubricating the wheels of watches or other delicate machinery, since it does not thicken or become rancid by exposure to the air.†

Croton oil. 2066. *Croton oil*, is obtained from the seeds of the *croton tiglium*, a tree growing in the East Indies. It is yellow, of an acrid taste, soluble in alcohol and ether. Its purgative qualities are owing to a portion of crotonic acid dissolved in the oil. A single drop generally acts as a purgative.

Olive oil. 2067. *Olive oil* is expressed from the pericarpium of the fruit of the *olea europea*, or common olive. Its sp. gr. at 77° is .9109, it congeals at 36° depositing little spheres of stearin.

Action of hyponitrous acid. 2068. By the action of hyponitrous acid on olive oil a solid is formed which has been called *elaidin;* it is saponified by potassa or soda, glycerin being evolved and a fatty acid which combines with the alkali and forms soap. The acid has been called the *elaidic acid*.

Palm oil. 2069. *Palm oil* is one of the solid oils and is extracted from the *cocos butyracea;* it is yellow and has the consistence of lard. It is said to be composed of stearine 31, elaine 69. It is used in the manufacture of yellow soap.

Cocoa oil. 2070. *Cocoa nut oil* is white and hard, and contains both elaine and stearin. It is used as a substitute for tallow. The stearin is used as a substitute for wax in the manufacture of candles.

Wax. 2071. *Wax* differs from the solid vegetable oils in its consistence and in the way in which it combines with alkalies; but it resembles them so much that an accurate line of separation cannot be drawn.

Beeswax. 2072. *Bee's wax*, though an animal production, agrees so closely with wax from plants, that it would be improper to separate them. It is an exudation from the rings in the abdomen of bees.

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* See *Oily Acids*.

† The watchmakers purify olive oil, by placing it in a phial along with a plate of lead; after being corked it is exposed in a window to the direct rays of the sun. A cheesy matter separates, the oil loses its colour and becomes limpid. The clear oil is poured off and kept for use.

2073. Yellow wax is purified by fusion in water and casting into thin ribbons which are exposed to light and moisture by which it is bleached. When pure it has no taste or smell, unbleached wax fuses at 142°, if bleached, at 155°; the sp. gr. of the former is about .9600, of the latter .8203. It is insoluble in water, but soluble in boiling alcohol. Purified.

2074. Bee's wax has been stated to contain two distinct kinds of wax, called *cerin* and *myricin*.* Cerin is soluble in fixed and volatile oils, insoluble in water, cold alcohol and ether, and of the consistence of wax. It unites with caustic alkalies and forms a soap. It fuses at 143½°. Cerin and myricin.

2075. *Myricin* fuses at 149°, at common temperatures is insoluble in alcohol. It cannot be converted into soap by caustic potassa. According to Hess 100 parts of wax are composed of

Hydrogen,	12.95
Carbon	79.77
Oxygen	7.33*

3076. *Myrtle wax* is obtained from the *myrica cerifera*, a shrub that is common in the United States. The wax is separated from the berries by means of hot water.‡ Myrtle wax.

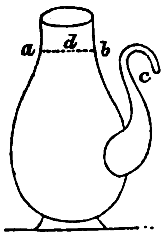
2077. *Galactin*, or *cow-tree wax* exists in the milk of the cow tree *Galactoderdron utile*, a large tree resembling the fig, which grows in South America.

SECTION II. *Volatile Oils*.

2078. The volatile oils may be divided into three sets; 1. Those that contain only carbon and hydrogen; they are lighter than water, and seem to have the property of combining in definite proportions with acids. Hence they are probably bases or analogous to bases. 2. Those that contain carbon, hydrogen and oxygen. They are probably as heavy, or heavier than water, and seem to have the property of combining in definite proportions with bases, and are, therefore, analogous to acids. 3. Vesicating oils. They contain sulphur, and probably also nitrogen. Volatile oils.

2079. These oils are generally obtained by distilling the plants which afford them with water in common stills; the water and oil pass over together, and are collected in the *Italian recipient* shown in Fig. 196, in which the water having reached the level *a b*, runs off by the pipe *c*, and the oil being generally lighter than water, floats upon its surface in the space *d*. The whole contents of the recipient are then poured into a funnel, the tube of which is closed with the finger, and when the oil has collected upon the surface, the water is suffered to run from it, and the oil transferred into a bottle. The distilled water being saturated with the oil, should be retained for a repetition of the distillation. The produce of oil is sometimes increased, by adding salt to the water in the still, so as to elevate its boiling point a few degrees. How obtained.

Fig. 196.



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* According to late experiments of Hess bee's wax when pure, is always of the same constitution, but by oxidation is converted into an acid.

† According to Ettling's analysis, cerin, myricin and cerain are isomeric bodies, and composed of $C_{18}H_{19}O$.

‡ See Dana's analysis, *Amer. Jour.* 1. 294.

Some of the volatile oils are obtained by expression, such as those of *lemon*, *orange*, and *bergamot*, which are contained in distinct vesicles in the rind of those fruits.

2080. The volatile oils vary considerably in specific gravity, as will be seen by referring to the *Tables*.

Properties. The volatile oils have a penetrating odour and taste, and are generally of a yellowish colour; they are for the most part very soluble in alcohol, and very sparingly soluble in water; these solutions constitute *perfumed essences* and *distilled waters*. The latter are principally employed in pharmacy, and the former as perfumes.

When pure they pass into vapour at a temperature somewhat below that of 212°, when distilled with water, they pass over at its boiling point. They are inflammable, and water and carbonic acid are the results of their perfect combustion. Adulteration. As many of these oils bear a very high price, they are not unfrequently adulterated with alcohol and fixed oils. The former addition is rendered evident by the action of water; the latter by the greasy spot which they leave on paper, and which does not evaporate when gently heated.

2081. Nitric and sulphuric acids rapidly decompose the volatile oils.

Exp. A mixture of four parts of nitric, and one of sulphuric acid, poured into a small quantity of oil of turpentine, produces instant inflammation.

2082. The relative quantity of essential oils, furnished from different materials, is liable to much variation; the products of 1 cwt. of the different vegetable substances are given below.*

Oil of turpentine. 2083. *Oil of turpentine* is obtained from turpentine, a viscid, transparent, semifluid substance, which exudes from various species of the genus *pinus*. Common turpentine of the shops flows by incision from the *pinus abies* and *pinus sylvestris*. To obtain the volatile oil, called oil of turpentine, the turpentine is mixed with water and distilled. The oil comes over with the water, and the residue is common *rosin*.

Action of hydrochloric acid. 2084. Oil of turpentine absorbs a large quantity of hydrochloric acid, and forms a crystallizable substance resembling camphor. From the analysis of artificial camphor it is probable that pure oil of turpentine is $C_{20}H_{16}$.

Boiling point. 2085. Oil of turpentine begins to boil at 313°; if the ebullition is continued the temperature rises to 350°, or even higher, showing the presence of more than one volatile oil. The sp. gr. of its vapour at 313° is 4.83 air = 1.

	Ounces.
* Juniper berries (common) . . .	4 to 5
Ditto (fine Italian) . . .	7 to 8
Aniseed (common)	32 to 36
Ditto (finest)	36 to 38

		lbs.	oz.		lbs.	oz.
Caraways . . .	from	3	12	to	4	12
Dill-seed . . .	from	2		to	2	6
Cloves . . .	from	18		to	20	
Pimento . . .	from	2		to	3	4
Fennel-seed					2	
Leaves of the *Juniperus Sabina* . .						14

2086. It takes fire in chlorine, giving out much smoke. It dissolves iodine.*

Camphors.

2087. *Camphors.* The term camphor has been applied by apothecaries to various solid bodies, which occasionally appear in volatile oils. They are distinguished by their great volatility, a strong and peculiar smell, by melting when heated, and burning brilliantly when held to a lighted candle.

Common camphor.

2088. *Common Camphor.* $C_{12}H_9O_1$. In its ordinary state it is white, semi-transparent, and concrete. Its specific gravity .9887. It fuses at about 300°, in close vessels. It dissolves in the fixed and volatile oils and in alcohol. It is scarcely acted upon by the alkalies; some of the acids dissolve, others decompose it.

The camphor of commerce is obtained from the *Laurus Camphora*, and comes chiefly from Japan. It is originally separated by distillation, and subsequently purified in a subliming vessel somewhat of the shape of a turnip, from which the cakes of camphor derive their form. When slowly sublimed it crystallizes in octohedrons or in six-sided pyramids.

Composition.

2089. The analysis of camphor by Dumas gave carbon 78.02, hydrogen 10.39, oxygen 11.59.

Camphrone.

2090. *Camphrone* was discovered in 1835 by Fremy, by passing fragments of camphor into a porcelain tube, heated to redness, and containing lime. It is a slightly coloured liquid, having the odour of camphor. It boils at 167°.

Camphogene.

2091. Dumas distinguishes by the name *camphogene*, what he considers as the basis of camphor. It is a volatile oil composed of 10 atoms carbon and 8 atoms hydrogen. It may be extracted pure from artificial camphor. Camphor consists of an integrant particle of camphogene and an atom of oxygen.†

Resins,

2092. *Resins.* Resins are the inspissated juices of plants, and commonly occur either pure or in combination with an essential oil. They are solid at common temperatures, brittle, inodorous, and insipid. They are non-conductors of electricity, and when rubbed become negatively electric. They are generally of a yellow colour, and semi-transparent.

2093. Resins are fused by the application of heat, and by a still higher temperature are decomposed. In close vessels they yield empyreumatic oil, and a large quantity of carburetted hydrogen, a small residue of charcoal remaining. In the open air they burn with a yellow flame and much smoke, being resolved into carbonic acid and water.

Solvents of.

2094. Resins are dissolved by alcohol, ether, and the essential oils, and the alcoholic and ethereal solutions are precipitated by water, a fluid in which they are quite insoluble. Their best solvent is pure potassa and soda, and they are also soluble in the alkaline

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* The volatile oils are very numerous; many of them have been described by Thomson, but there are many not yet described. Raybaut of Paris has given a table of no fewer than 207 volatile oils prepared by himself, with the names of the plants from which they were obtained, and the quantity from a given weight of the plant, in the *Jour. de Pharm.* xx. 444. See T. *Organic Bodies*, 459.

† For description of camphors from oil of peppermint and other essential oils, see T. *Org. Bodies*, 493.

carbonates by the aid of heat. The product is in each case a soapy compound, which is decomposed by an acid.

Concentrated sulphuric acid dissolves resins; but the acid and the resin mutually decompose each other, with disengagement of sulphurous acid, and deposition of charcoal. Nitric acid acts upon them with violence.

Uses. 2095. The uses of resin are various. Melted with wax and oil, resins constitute ointments and plasters. Combined with oil or alcohol, they form different kinds of oil and spirit varnish. Sealing wax is composed of lac, Venice turpentine, and common resin. The composition is coloured black by means of lampblack, or red by cinnabar or red lead. Lampblack is the soot of imperfectly burned resin.

Of the different resins the most important are common rosin, copal, lac, sandarach, mastich, elemi, and dragon's blood.

Tar and pitch. 2096. When turpentine is extracted from the wood of the fir-tree by heat, partial decomposition ensues, and a dark substance, consisting of resin, empyreumatic oil, and acetic acid is the product. This constitutes *tar;* and when inspissated by boiling, it forms *pitch.* Common resin fuses at 276°, is completely liquid at 306°, and at about 316°, bubbles of gaseous matter escape, giving rise to the appearance of ebullition. By distillation it yields empyreumatic oils: in the first part of the process a limpid oil passes over, which rises in vapour at 300°, and boils at 360°; but subsequently the product becomes less and less limpid, till towards the close it is very thick. This matter becomes limpid when heat is applied, and boils at about 500° F. At a red heat resin is entirely decomposed, yielding a large quantity of combustible gas, which has been employed for the purpose of artificial illumination.*

Balsams. 2097. *Balsams.* These are semi-fluid resins containing a volatile oil, which may, in general, be separated by distillation, leaving the solid resin. In this division Thomson includes turpentine in which the oil is united with two resins, which Unverdoben has distinguished by the names *pinic* and *silvic acids*, and Berzelius by the terms *resin alpha* and *resin beta.* The oil varies from 5 to 25 per cent., as do the resins also.

Venice turpentine. 2098. *Venice turpentine* is extracted from the *pinus larix*, or *common larch.* It is limpid, of a light yellow colour, and of the consistence of honey. It contains from 18 to 25 per cent. of oil of turpentine, what remains after distillation is *colophan* or common *rosin.* It dissolves in alcohol.†

Copaiva. 2099. *Copaiva* is obtained from the *copaifera officinalis* and *coriacea;* it exudes from incisions made in the trunk of the tree. It is transparent, yellow, of an agreeable smell and pungent taste. Its sp. gr. is 0.950. It yields a volatile oil by distillation.

Properties. 2100. It is insoluble in water, but imparts to it its peculiar taste

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* In the arrangement of the apparatus for this purpose, the rosin liquefied by heat is allowed to pass into the retort containing coal or coke. It has not been found economical in England. See Ure's *Dict. Arts and Manuf.* 1076.

† *Strasburg turpentine* is extracted from the *pinus picea.*

Canada balsam is obtained from the *pinus canadensis* and *balsamea* and the *turpentine of Cyprus and Chio* from the *pistacea terebinthus.*

and smell. It dissolves in all proportions in absolute alcohol; alcohol of sp. gr. 0.848 dissolves only the 9th or 10th of its weight. It dissolves in ether and fixed and volatile oils.[*] It combines with salifiable bases. It has a remarkable affinity for magnesia, 1 part of magnesia dissolving in 30 of balsam into a transparent liquid.

Adulteration detected.

2101. It is sometimes adulterated with fixed oils; which can be detected by alcohol dissolving the balsam but leaving the oil. Castor oil is however soluble in alcohol, but it may be detected by agitation with ammonia, sp. gr. .965, in a glass tube; the solution is transparent if the balsam be pure, but milky if it contains castor oil.

Balsam of Peru.

2102. *Balsam of Peru* is obtained from the *myroxylon peruiferum* of South America. Two varieties occur in commerce, one obtained by incisions in the tree, having a slight tint of yellow; the other by boiling the branches and bark of the tree in water.

According to the analysis of Stoltze balsam of Peru is composed of

Volatile oil	69.
Resin very soluble in alcohol	20.7
Do. little	2.4
Benzoic acid	6.4
Extractive matter	0.6
Moisture	0.9
	——100.

The oil is much less volatile than the other volatile oils, and cannot be separated by distillation.[†]

Solid resins.

2103. The principal *solid resins* are, rosin or colophan, mastich,[‡] sandarach, elemi, guaiacum,[§] storax, dragon's blood,[||] benzoin, and anime.

Copal,

2104. *Copal* is the most important of this class, it flows from the *rhus copalinum* and *elæocarpus copaliferus;* the first a native tree of America, the second of the East Indies. It is white with a tint of brown, sometimes opaque, at others nearly transparent. It differs from other resins in not being soluble in alcohol nor in oil of turpentine without peculiar management. Its sp. gr. varies from 1.045 to 1.069.

Uses.

2105. Its solution is much employed as a varnish, in the formation of which several processes are followed.[¶] The following method is recommended by Lenormand:

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[*] Stoltze in *Berlin Juhrb.* xxvii. 2, 179.

[†] *Balsam of Tolu* is obtained from the *tulifera balsamum*, it is reddish brown, becomes brittle by exposure to the air, and has a fragrant odour. It dissolves in ether, alcohol, and the volatile oils. For other balsams see T. *Org. Bodies*, 520.

[‡] From late investigation of resins it appears that mastich consists of two resins; the one soluble and acid, the other insoluble and not acid. Johnson, in *Phil. Trans.* April 1839.

Adulteration of guaiacum.

[§] Guaiacum is rendered blue by various animal and vegetable substances; it becomes blue when rubbed with the gluten of wheat, or the farina. It is often adulterated with common rosin. To discover this fraud, dissolve the guaiacum in caustic potassa; if pure the solution is limpid, but muddy if rosin be present, as long as there is excess of alkali.

[||] Lump Dragon's blood is the natural and pure resin, while the strained and red varieties, being manufactured articles, are more or less decomposed: it contains alcohol and ether with considerable tenacity, but they may be expelled by long exposure to a temperature not higher than 200°. Johnson, *Phil. Trans.* April 1839.

[¶] Nicholson's *Jour.* ix. 157; T. *Org. Bodies*, 544; Neil in *Trans. Soc. of Arts*, xlix. Ample details for making a great variety of varnishes are given in Ure's *Dict. Arts and Manuf.* 1264.

Solution of copal. Drop upon the pieces of copal pure essential oil of rosemary. Those pieces that are softened by the oil are fit for the purpose, the others are not. Reduce them to a fine powder; put this powder into a glass vessel not thicker than a finger breadth; pour oil of rosemary over it, and stir it about with a glass rod. In a short time the whole is converted into a thick liquid. Pour alcohol on this liquid by little at a time, incorporating it, by gently agitating the vessel, till it is of the requisite thinness for use.*

Lac. 2106. *Lac* is an important resin deposited in different trees in the East Indies, viz. *ficus indica*, *f. religiosa*, and *rhamnus jujuba*. It flows out in the state of a milky liquid, in consequence of the puncture of a small insect, the *coccus ficus*, on the branches of these trees, made by the insect in order to deposit its ova. The various kinds of lac distinguished in commerce, are *stick-lac*, which is the substance in its natural state, investing the small twigs of the tree; *seed-lac*, which is the same broken off; and which, when melted, is called *shell-lac*. These substances have been examined by Hatchett. Their component parts are exhibited below.†

Solvents. 2107. Water dissolves the colouring matter of lac, and alcohol the resin which constitutes the chief ingredient of lac. A solution of borax in water dissolves lac; the best proportions are 20 grs. of borax, 100 grs. of lac, and 4 ounces of water. This solution mixed with lampblack, constitutes Indian ink. Lac contains a peculiar body called *laccin*.

Amber. 2108. *Amber* is a substance which, in some of its properties, resembles resin; it is however, very sparingly soluble in alcohol, and difficultly soluble in the alkalies. When submitted to distillation, it furnishes an acid sublimate, which has received the name of *succinic acid*. (Succinic acid.) It is found in beds of wood coal.

Section III. *Gum Resins.*

Gum resins. 2109. The term *gum resin* is applied to a number of concrete vegetable juices which contain various proportions of resin, gum, and other vegetable principles. They are opaque, solid, brittle, or sometimes with a fatty appearance. They are less combustible than the resins; they do not melt like resins but are softened by heat, and swell. They burn with flame. They are partially soluble in water and alcohol. The aqueous solution is milky, the alcoholic transparent, but becomes milky on dilution. Their best solvent is dilute alcohol.

Fœtid gum resins. 2110. Those gum resins which have a fetid or alliaceous odour, are ammoniac, galbanum, assafœtida, opoponax, and sagapenum. The stimulating gum resins‡ are olibanum, myrrh, euphorbium, and bdellium; the first is the frankincense of the ancients.

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[*] *Jour. de Chim.* iii. 218.

[†]

	Stick-Lac.	*Seed-Lac.*	*Shell-Lac.*
Resins	68	88.5	90.9
Colouring matter	10	2.5	0.5
Wax	6	4.5	4.0
Gluten	5.5	2.0	2.8
Foreign bodies	6.5	—	—
Loss	4.0	2.5	1.8
	100	100	100

Phil. Trans. 1804.

[‡] Of Thomson.

2111. The cathartic gum resins are aloes, scammony, and gamboge. The sedative gum resins are opium, lactucarium[*] and upas.

Opium. 2112. Of the sedative gum resins opium is the most important; it is the milky juice of the *papaver somniferum*, inspissated into a dark coloured solid by exposure to the atmosphere. Its best solvent is common spirits. Its principal constituents have been already described. It differs much in its qualities.

SECTION IV. *Neutral Vegetable Principles.*

Neutral principles. 2113. Neutral vegetable principles are those bodies which neither possess the properties of acids nor bases, and which so far as is known, do not combine in definite proportions with other substances. They have been arranged by Thomson in thirteen divisions.

Division 1st. Amides. 2114. *Amides*, or *Amidets*. The term amide signifies an anhydrous ammoniacal salt deprived (if an expression apparently contradictory may be allowed) of an atom of water. (1562)

Oxamide, Obtained, 2115. *Oxamide*. $C_2O_2+NH_2 = 44$. (T.) This was discovered by Dumas in 1830.[†] When oxalate of ammonia is heated in a glass retort, it loses in the first place its water of crystallization, and the crystals become opaque. The salt then melts and boils, but only in those parts which receive immediately the impression of the heat. Those portions which melt undergo decomposition and disappear rapidly,[‡] When the distillation is at an end some trace of charcoal merely remains in the retort; all the rest has been volatilized. In the receiver is found water impregnated with carbonate of ammonia, This water holds in suspension a flocky matter of a dirty white colour.[§] The white flocks and deposit on the beak of the retort constitute the substance called *oxamide*. To purify it, it is washed out upon a filter and thoroughly edulcorated with cold water. Being nearly insoluble, it remains on the filter.

Gases evolved. 2116. The gases disengaged during the distillation change their nature as it proceeds; they are ammonia, then carbonic acid and oxide, and cyanogen; water and carbonate of ammonia are also formed.[||]

Properties. 2117. Oxamide is obtained in crystallized plates, or as a granular powder. When pounded and well washed it is a dirty-white powder, resembling uric acid, without taste or smell, or any action on vegetable colours. It is volatile, and crystallizes when cautiously heated in an open tube. It is not sensibly soluble in cold water; but dissolves in boiling water.

Action of $\dddot{S}$. 2118. Heated in sulphuric acid it dissolves, and gas is given out in abundance, consisting of equal vols. of carbonic acid and carbonic oxide. At the same time a quantity of ammonia is formed, which

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[*] *Lactucarium* is obtained from the juice of the *Lactuca sativa* or common garden lettuce. [†] *Ann. de Chim. et de Phys.* xliv. 129.

[‡] But the mass in general retains its appearance, and a careful examination is necessary to be able to perceive the thin layer of the salt which is in a state of fusion.

[§] The neck of the retort exhibits usually crystals of carbonate of ammonia, and a thick layer of the same white matter.

[||] Liebig has shewn that when caustic ammonia is added to oxalic ether, alcohol is evolved, and a copious deposit of oxamide is produced. This is by far the most economical method of preparing oxamide. See *Ann. de Pharm.* ix. 129. T. 591.

and of potassa. combines with the acid. Boiled in a concentrated solution of potassa it gives out ammonia in abundance, with the formation of oxalic acid which combines with the potassa.

Analysis. 2119. According to the analysis of Dumas[*] its constituents appear to be $C_2O_2+H_2N = 44.0$. If we add HO (an atom of water), the oxamide becomes $C_2O_3+H_3N$, or oxalate of ammonia.[†] T. 592.

Ether oxamide. 2120. *Etheroxamide* is obtained when a current of dry ammoniacal gas is passed over a given quantity of pure oxalic ether. *Succinamide* is formed when the same gas is made to act upon anhydrous succinic acid. *Benzamide* is obtained when the gas is absorbed by pure chloride of benzoul. *Sulphamide* is formed when dry ammoniacal gas is combined with anhydrous sulphuric acid.

Division 2d. 2121. This division comprises *benzoyl* and its compounds.[‡]

Benzoyl. 2122. The base of benzoic acid has been termed by Liebig and Wöhler *benzoyl*, and was obtained by Laurent by passing a current of chlorine gas through benzoin kept in fusion while the gas was passing; hydrochloric acid was formed and benzoyl disengaged. It was purified by solution in alcohol and crystallization.

2123. The volatile oil of bitter almonds is a hydret of benzoyl, and this oil has the property of absorbing oxygen and of being converted into benzoic acid. The change may be thus explained:

The oil is . . .	$C_{14}H_6O_2$
Benzoic acid . . .	$C_{14}H_5O_3$

Explanation. So that the oil contains 1 atom more of hydrogen, and 1 atom less of oxygen, than the acid; 2 atoms of oxygen are absorbed, the one unites with 1 atom of hydrogen and forms water, while the other combines with $(C_{14}H_5O_2)$ and converts it into benzoic acid. $C_{14}H_5O_2$ must be the base of benzoic acid, and the oil must be this base combined with an atom of hydrogen, or a hydret of ~~benzoyl.~~ T. benzoyl

Properties. 2124. Benzoyl is slightly yellow, without taste or smell; insoluble in water, very soluble in alcohol and ether, crystallizing in six-sided prisms. Its lustre is vitreous. It may be volatilized without decomposition; becomes solid at about 196°; burns on platinum with a red flame. T. 603.

Analysis. The analysis afforded

Carbon . .	14 atoms	per cent.	80.
Hydrogen . .	5 "	" "	4.76
Oxygen . .	2 "	" "	15.24
			100.

Compounds of Benzoyl. 2125. The compounds of benzoyl and their composition are the following:

Benzoyl - - -	$C_{14}H_5O_2$
Hydret of " or oil of bitter almonds	$C_{14}H_5O_2 + H$
Benzoin - - - - - -	$C_{14}H_5O_2 + H$
Benzoic acid - - - - -	$C_{14}H_5O_2 + O$
Chloride " - - - - -	$C_{14}H_5O_2 + Cl$
Bromide " - - - -	$C_{14}H_5O_2 + Br$
Iodide " - - - - -	$C_{14}H_5O_2 + I$
Sulphuret " - - - -	$C_{14}H_5O_2 + S$
Cyanide " - - - - -	$C_{14}H_5O_2 + C_2N$

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[*] *Ann. de. Chim. et de Phys.* xliv. 129, and *Jour. de Pharm.* xvii. 177.

[†] $NH_2+C_2O_2$, eq. 44.39. L. 752.

[‡] *Benzule.* T and L.

Benzone[*]	$C_{14}H_5O$
Benzine[†]	C_6H_3. Now, $2(C_6H_3)+2(CO_2)=C_{14}H_5O_2+O_2$
Benzamide	$C_{14}H_5O_2+H_2N$
Benzimide	$C_{14}H_5O_2+H_{\frac{1}{2}}N_{\frac{1}{2}}$?
Nitrobenzide[‡]	$2(C_6H_3)+NO_4$
Sulphobenzide	$2(C_6H_3)+SO_3$
Azotobenzide[§]	$2(C_6H_3)+N$

Division 3d.

2126. *Spiroil and its compounds.* Spiroil is the supposed base of the volatile oil extracted from the flowers of the *spiræa ulmaria.* It is a compound of $C_{12}H_5O_4$ with an atom of hydrogen. It has not been obtained in a separate state, but it has been combined with oxygen, chlorine, bromine, iodine and hydrogen, and shown to form definite compounds with each.

Division 4th.

2127. *Sugar.* $C_{12}H_{10}O_{10} = 162.24$. The term sugar has been applied to various substances characterized by a sweet taste.

Sugars. Preparation of.

2128. Sugar may be extracted from the juice of a number of vegetables, and is contained in all those having a sweet taste; that which is commonly employed is the produce of the *arundo saccharifera*, or *sugar-cane,* a plant which thrives in hot climates. Its juice is expressed and evaporated with the addition of a small quantity of lime, until it acquires a thick consistency; it is then transferred into wooden coolers, where a portion concretes into a crystalline mass, which is drained and exported under the name of *muscovado,* or *raw sugar.* The remaining liquid portion is *molasses,* or *treacle.* A gallon of juice yields on an average about a pound of raw sugar. Molasses.

Varieties of sugar.

2129. The juice, which flows spontaneously from incisions made in the American maple-tree, affords a quantity of sugar sufficient to render it a process worth following. The juice of the carrot, the melon,[||] and still more remarkably of the beet (*beta vulgaris,* L.) yields a considerable proportion of sugar. To obtain it from the latter vegetable, the roots, softened in water, are to be sliced, and the juice expressed. It is then to be boiled down, with the addition of a little lime, till about two thirds remain, and afterwards strained. These boilings and strainings are repeated alternately, till the liquid attains the consistence of syrup, when it is left to cool. The sugar thus extracted, retains somewhat of the taste of the root; but it may be purified by the operation used for the refining of West India sugar, and it then loses its peculiar flavour. The quantity obtained varies considerably; but in general it may be stated at between four and five pounds from 100 lbs of the root, besides a proportion of uncrystallizable syrup. In Germany the expense has been calculated at about three pence per pound.[¶] Beet sugar.

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[*] This term was applied from the analogy between *benzone* and *acetone,* the name given by Dumas and Liebig to the liquid formerly called *pyroacetic spirit.*

[†] The benzine of Mitscherlich is the same with the *bicarburet of hydrogen* of Faraday.

[‡] Formed when nitric acid is made to act upon his benzin.

[§] A substance obtained by distilling a mixture of nitrobenzide and lime. For details respecting these compounds, see Thomson's *Org. Bodies*, 604.

[||] *Quart. Jour.* N. S. 1. 239.

[¶] See Chaptal *On the manufacture of Sugar in France, Phil. Mag.* xlvii. 331. For details respecting the manufacture and refining of sugar, see Ure's *Dict. Arts and Manuf.* 1191.

Action of sulphuric acid,

2130. Sugar is altered by the action of the strong acids. Concentrated sulphuric acid poured upon sugar blackens it, and causes it to deposit a charry matter when we dilute the acid with water. When long boiled with this acid it is converted into *sugar of grapes*, or that species of sugar into which starch is converted by the same process.

Of nitric acid,

2131. By nitric acid it is converted into oxalhydric and oxalic acids: 480 grs. of sugar, treated with 6 ounces of nitric acid, diluted with its own weight of water, and cautiously heated, separating the crystals as they are formed, yielded 280 grs. of oxalic acid. So that 100 parts of sugar yield by this treatment 58 parts of oxalic acid.* Hydrochloric acid acts upon sugar like the sulphuric. When chlorine is passed through a solution of sugar, it transforms it into oxalhydric acid, while the chlorine is converted into hydrochloric acid.

Of acids in general.

2132. Malagutti and Bouchardt† have lately ascertained that acids, in general, even when very dilute, act upon sugar in the same manner when assisted by heat. They first convert it into uncrystallizable sugar, then into sugar of grapes, then into uncrystallizable sugar, then into ulmic acid; and finally, if atmospheric air be present, into ulmic and formic acids.

Absorbs ammonia.

2133. Sugar combines with the acidifiable bases. When introduced into ammonia, over mercury, it absorbs the gas, diminishes in bulk, becomes coherent, compact, and soft, so that it can be cut with a knife, and gives out an ammoniacal smell.

Solvents.

2134. Sugar is soluble in alcohol, but not in so large a proportion as in water. When the solution is set aside it deposits crystals. It unites with oils, and renders them miscible with water. A moderate quantity of it retards the coagulation of milk; but a large quantity promotes it.

Effect of heat.

2135. When heated sugar melts, swells, becomes brownish black, and exhales a peculiar smell known in French by the name *caramel*. At a red heat it bursts into flame. See Appendix.

Product of its distillation.

2136. When distilled in a retort sugar yields water, pyromucic acid, empyreumatic oil, and a bulky charcoal. When a solution of sugar is used carbonic acid and carburetted hydrogen are obtained. It is therefore decomposed by heat.‡

Liquid sugar.

2137. *Liquid sugar* exists in a variety of fruits and vegetable juices. It is distinguished by being uncrystallizable. It may be obtained from the stalks of the *zea mays*, or Indian corn and constitues a considerable portion of the molasses of common sugar.

Sugar of grapes.

2138. *Sugar of grapes.* $C_{12}H_{12}O_{12}$. Verjuice, or the liquid obtained from unripe grapes, contains tartar, sulphate of potassa, sulphate of lime, much citric acid, a little malic acid, extractive, and water, but neither gum nor sugar. As the grapes advance to maturity, the citric acid disappears, and gum and sugar appear in its place. The ripe grape juice yields from a third to a fifth of solid matter.

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* Cruickshanks, Rollo *on Diabetes*, 460. † *Jour. de Pharm.* xxi. 440, and 627.

‡ For the result of Prout's analysis of sugar, see *Phil. Trans.* 1827.

Fremy obtained an oily looking matter from 1 part sugar and 8 parts lime, which yielded *acetone* C_3H_3O and *metacetone* C_6H_5O. Two atoms of sugar may be resolved into 3 atoms metacetone, 6 atoms carbonic acid and 7 atoms water; and 1 atom of sugar into 3 atoms of acetone, 3 atoms of carbonic acid and 2 atoms water (T. 636). Starch and gum distilled with lime afford the same products.

The sugar may be extracted with the aid of potassa and heat. It is less sweet than that from sugar cane.

Conversion of starch into sugar.

2139. Starch may be converted into a sugar possessing the properties of sugar of grapes, by mixing it with about 4 times its weight of water, and about $\frac{1}{10}$ part of its weight of sulphuric acid, boiling for 36 hours, supplying water as it evaporates, saturating the acid with lime, separating the sulphate of lime and concentrating.

Honey.

2140. *Honey* is also a variety of sugar containing a crystallizable and an uncrystallizable portion; the predominance of one or other of which gives to it its peculiar character; they may be partially separated by mixing the honey with alcohol, and pressing it in a linen bag; the liquid sugar being the most soluble, passes through, leaving a granular mass, which forms crystals when its solution in boiling alcohol is set aside. Honey also frequently contains wax, and a little acid matter.

Manna.

2141. *Manna* is an exudation from the *Fraxinus ornus*, a species of ash, growing in Sicily and Calabria. It exists in the leaves of celery and several other plants. To obtain pure manna, dissolve the manna of the shops in boiling alcohol and allow it to cool; the manna crystallizes. It has a sweet and somewhat nauseous taste, and is used in medicine as a mild aperient. The sweetness of manna is owing, not to sugar, but to a distinct principle called *mannite*. Its solution in water does not appear susceptible of vinous fermentation.

Liquorice sugar.

2142. *Liquorice sugar* is the inspissated juice of the *glycyrrhiza glabra* a native of Spain. It combines with bases and with salts. It precipitates the greater number of metallic solutions.

Glycerin.

2143. *Glycerin.* $C_6H7O_5 = 83$. (T.) This substance was called by Scheele *sweet principle of oils.*

Process.

To obtain it an oil may be digested with an alkaline ley till converted into soap. The soap being separated, the alkaline liquid is saturated with sulphuric acid, and any excess of acid removed by carbonate of baryta. Filter and evaporate to the consistence of a syrup: dissolve the syrup in alcohol and filter; evaporate the alcoholic solution; the glycerin remains.

Properties.

2144. It is a colourless syrup, uncrystallizable, of a sweet taste and without smell. From the analysis of Liebig and Pelouze 1 atom of glycerin is combined in stearin with 2 atoms of stearic acid.

Division 5th. Amylaceous substances.

2145. *Amylaceous substances.* When wheat flour is formed into a paste with water, and then held under a small stream of water, kneading continually till the water runs off colourless, the flour is divided into two constituents *gluten* and *starch.* The *starch* is removed by the water and subsides on standing.

Process for obtaining starch.

2146. The common process for obtaining the starch of wheat consists in steeping the grain in water till it becomes soft; it is then put into coarse linen bags, which are pressed in vats of water; a milky juice exudes, and the starch falls to the bottom of the vat. The supernatant liquor undergoes a slight fermentation, and a portion of alcohol and a little vinegar is formed, which dissolves some impurities in the deposited starch; it is then collected, washed, and dried in a moderate heat, during which it splits into the columnar fragments which we meet with in commerce, and which are generally rendered slightly blue by a little smalt.

2147. Starch or *Fecula,* may be separated from a variety of substances; and many roots. By diffusing the powdered grain or the rasped root in cold water, the grosser parts may be separated by a strainer and the liquor which passes deposits the starch, which is to be washed in cold water and dried in a gentle heat.

Arrow root. Sago.

2148. *Arrow root* consists entirely of very pure starch. It is extracted from the potato, and the roots of the *jatropha manihot* afford the variety known as *cassava* and *tapioca*. *Sago*, another variety, is extracted from the pith of a species of palm the *sagus raphia* which grows in the East India Islands.* *Salop* comes from Persia and is supposed to be the prepared roots of different species of *orchis*. Of rice, starch constitutes, according to Braconnot, from 83 to 85 per cent.

Properties of starch. Insoluble in alcohol, &c.

2149. Pure starch is a white substance, insoluble in cold water, but readily soluble at a temperature between 160° and 180°. Its solution is gelatinous, becomes mouldy and sour by exposure to air, and by careful evaporation yields a substance resembling gum in appearance, which is a compound of starch and water. Starch is insoluble in alcohol and in ether; its most characteristic property is that of forming a blue compound with iodine.

Composition of starch.

2150. Starch consists essentially of two distinct substances. 1. The liquid portion which fills each little vesicle composing it, and this liquid consists of water holding in solution a peculiar substance which is called *amidin*.† 2. The vesicular portion of the grain, insoluble in water, and called *amylin*.‡ According to Guerin—Vary, potato starch is composed of

Exterior tegumentary amylin, - - - -	2.12
Amidin - - - - - - - - -	38.13
Amylin - - - - - - - - -	59.75
	———100§

Amidin.

2151. *Amidin* or the soluble part of starch has neither taste nor smell. Cold water dissolves it, but it is more soluble in boiling water: it is insoluble in alcohol and ether. Its aqueous solution soon becomes acid. Digested in nitric acid it forms oxalhydric acid, and then oxalic acid. 100 parts of amidin and 250 of sulphuric acid at the temperature of 150° furnish 95.8 parts of anhydrous sugar.

Amylin.

2152. *Amylin* is insoluble in water, it does not dissolve in boiling water, nor in alcohol or ether; but it swells in water and becomes white. When 100 parts are digested with 800 of nitric acid, 25.46 parts of anhydrous oxalic acid are formed. When digested in sulphuric acid and water it is converted into sugar: 100 parts of amylin give 110.57 of hydrous sugar.

Analysis.

From pure amylin Prout obtained

Carbon - - - - - - - - -	43.31
Hydrogen - - - - - - - -	6.49
Oxygen - - - - - - - - -	50.20
	———100

Numbers which lead to the conclusion that it is composed of 12 atoms carbon, 10 hydrogen and 10 oxygen. (T.)

It is probable that the *dextrine* of Biot and Person consists chiefly of amidin. T. 656.

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* See an account of its preparation in Forest's *Voyage*, p. 39.

† Vary in *Ann. de Chim. et de Phys.* lvi. 231.

‡ From the Greek word *αμυλον starch*.

§ *Jour. de Pharm*, xxii. 210.

Hordein.

2153. *Hordein* may be obtained from barley-meal made into a paste with water and washed by a current of water dropping on it. The starch and hordein are washed away. By boiling in acidulous water, the starch is taken up, and the hordein remains unaltered. It amounts to from 54 to 56 per cent. of the meal.

Properties.

2154. It is a yellow powder, resembling sawdust; insoluble in water and alcohol, does not yield ammonia; but yields oxalic and acetic acids. During the malting of barley, the hordein is converted into starch.

Lichenin.

2155. *Lichenin* is the name given to what was once called the starch of the *cetraria islandica* or Iceland moss, which when good yields about 44½ per cent. In cool water it swells up but does not dissolve. It is coloured blue by iodine, and is precipitated by alcohol. It appears to be isomeric with amidin. According to Herberger it is poisonous.[*]

Inulin.

2156. *Inulin* is obtained from the roots of the *inula helenium, colchicum autumnale,* and more abundantly from the *dahlia purpurea.* It is a fine, white, tasteles powder. It is precipitated from its aqueous infusion by infusion of nut-galls.

Lignin.

2157. *Lignin* or *woody fibre* constitutes the fibrous structure of vegetable substances, and is the most abundant principle in plants. The different kinds of wood contain about 96 per cent. of lignin. It is prepared by digesting the sawings of any kind of wood successively in alcohol, water, and dilute hydrochloric acid, until all the substances soluble in these menstrua are removed.

Properties.

2158. Lignin has neither taste nor odour, undergoes no change by keeping, and is insoluble in alcohol, water, and the dilute acids. By digestion in a concentrated solution of pure potassa, it is converted according to Braconnot into a substance similar to ulmin. Mixed with strong sulphuric acid it suffers decomposition, and is changed into a matter resembling gum; and on boiling the liquid for some time the mucilage disappears, and a saccharine principle like the sugar of grapes is generated. Braconnot finds that several other substances which consist chiefly of woody fibre, such as straw, bark, or linen, yield sugar by a similar treatment.[†]

Xyloidin.

2159. *Xyloidin* is a substance obtained by the action of concentrated nitric acid on starch, lignin and some other substances. When the acid of density 1.5 is added to starch, a solution is obtained, which if treated immediately with water, deposits the xyloidin.

Xyloidin is a compound of nitric acid and starch, an atom of water in common starch being replaced by an atom of nitric acid.[‡] It is very combustible.[§]

Division 6th. Gums.

2160. The exudations from various trees and plants which have been called *gums,* may be arranged under three genera, viz. *arabin, bassorin* and *cerasin.*

Arabin.

2161. The term Arabin was applied by Chevreul to gum arabic,

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[*] *Jour. de Pharm.* xvii. 229.

[†] *Ann de Chim. et de Phys.* xii. For other principles of this division see T. *Org. Bodies.*

[‡] *Pelouze.*

[§] See *Jour. of the Frank. Instit.* xxiv. 119.

which consists almost entirely of arabin. Gum arabic comes from the Levant but its use has been in a great measure superseded in G. Britain by gum senegal. It is in small rounded drops or tears. sp. gr. is 1.355. It is composed of

Arabin - - - - - - - -	79.4
Ashes - - - - - - - -	3.0
Water - - - - - - - -	17.6
	——100

Properties. 2162. Arabin is colourless, tasteless, inodorous, and transparent, friable when dry, tough when moist. It softens at a temperature between 282° and 392° and may be drawn out into threads. It is insoluble in alcohol. With water it forms *mucilage.*

Uses. It is viscid and glutinous, and is used by calico-printers to thicken their colours and mordants to prevent their spreading on the cloth. It may be kept for years without much change, but finally becomes acid.

Action of sulphuric acid. 2163. Boiled with sulphuric acid it is converted into sugar, but which differs from starch sugar in not fermenting with yeast. With nitric acid it yields mucic and oxalic acids. Its atomic composition is the same as that of sugar in crystals.

2164. The principal varieties of gum consisting altogether or chiefly of arabin, are gum arabic, gum senegal and mucilage of lintseed.

Bassorin. 2165. *Bassorin* was first noticed by Vauquelin in a gum from Bassora. When this gum is treated with water, the bassorin remains in a gelatinous form. It has since been found in gum tragacanth and cherry-tree gum. It is solid, colourless, insipid and inodorous; insoluble in water, but swells up and becomes a jelly. It is insoluble in alcohol. By the action of nitric acid mucic and oxalic acids are formed. With sulphuric acid it forms a crystallizable sugar.

Cerasin. 2166. *Cerasin* is the name given to a substance in cherry-tree gum which remains undissolved when that gum is treated with cold water. It is isomeric with arabin. It is solid, insipid and inodorous; insoluble in alcohol, swells in cold water, but does not dissolve. When boiled in water it is converted into arabin.*

Division 7th. Glutinous substances. 2167. *Gluten* may be obtained from wheat-flour, by forming it into a paste and washing it under a small stream of water. The starch is thus washed away, and a tough elastic substance remains, which is gluten.

Properties. Its colour is gray, and, when dried, it becomes brown and brittle. It is nearly insoluble in water and in ether. When allowed to putrefy it exhales an offensive odour, and when submitted to destructive distillation, it furnishes ammonia, a circumstance in which it resembles animal products. Most of the acids and the alkalies dissolve it.

Gluten has been resolved by modern chemists into four distinct principles, viz. *albumen*, *emulsin*, *mucin*, and *glutin.*

Albumen. 2168. *Albumen.* When fresh gluten is digested in hot alcohol till every thing soluble is taken up, a bulky substance of a grayish

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* *Calendulin* is obtained from the flower of the *calendula officinalis*, or Marygold. *Saponin* was discovered in the root of the *saponaria officinalis.*

colour remains, which constitutes what has been called *vegetable albumen.* It is soluble in water; but coagulates when heated. It is insoluble in alcohol and ether. When dry it is opaque. It is precipitated from acid solutions, by carbonate of ammonia.

Emulsin.

2169. *Emulsin* is the name given to a peculiar substance which exists in almonds, and which has the property of decomposing amygdalin, and of forming hydrocyanic acid and volatile oil of bitter almonds.

Mucin.

2170. *Mucin* is obtained when alcohol is boiled upon the gluten of wheat. It dries into transparent grains, burns like animal matter; is more soluble in water than gluten, and constitutes about 4 per cent. of the gluten of wheat flour. 100 parts of hot water dissolve 4 parts of mucin, and the solution soon putrefies.

2171. The aqueous solution of mucin is precipitated by infusion of nutgalls, slightly by alcohol. When made into a paste with starch and kept for 10 hours at 145° it converts the starch into sugar and dextrine.

Glutin obtained.

2172. *Glutin* may be obtained by boiling alcohol upon the gluten of wheat and freeing the solution from mucin by repeated precipitations. On evaporating the alcohol the glutin is left as a yellowish translucent matter.

Characters.

2173. Glutin is almost insoluble in water, but soluble in alcohol, ether, dilute acids and caustic alkaline leys. It is precipitated by infusion of nutgalls.*

Division 8th. Caoutchouc.

2174. Caoutchouc, elastic gum or Indian rubber, is the concrete juice of the *Hævea caoutchouc* and *Iatropa elastica*, natives of South America, and of the *Ficus Indica* and *Artocarpus integrifolia*, which grow in the East Indies. It is a soft yielding solid, of a whitish colour when not blackened by smoke, possesses considerable tenacity, and is particularly remarkable for its elasticity.† It is inflammable, and burns with a bright flame. It is insoluble in water and alcohol; but it dissolves, though with some difficulty, in pure ether. It is very sparingly dissolved by the alkalies, but its elasticity is destroyed by their action. By the sulphuric and nitric acids it is decomposed, the former causing deposition of charcoal, and the latter formation of oxalic acid.

2175. Caoutchouc is soluble in the essential oils, spirits of turpentine, ether, naphtha, cajeput oil, and in the volatile liquid obtained by distilling caoutchouc; and from all these solvents, except the essential oils, it is left on evaporation without loss of its elasticity.

Zein. * *Zein* is the name given by Gorham (*Jour. of Scien.* xi. 205.) to the gluten of *zea mais* or *Indian corn.* According to Gorham it contains no nitrogen and yields no ammonia when distilled; but Bizio affirms that he obtained ammonia from it.

Viscin. *Viscin* is obtained from bird-lime; which is prepared from the middle bark of the holly boiled in water and deposited in pits till it becomes viscous.

Pollenin. *Pollenin* is a peculiar substance found in the pollen of the *pinus abies*, *lycopodium clavatum*, &c.

Legumin. *Legumin* is contained in the cotyledons of the seeds of papilionaceous plants.

Amygdalin. *Amygdalin* exists in the bitter almond.

Glairin. *Glairin* is the name applied to a substance observed in the sulphureous waters of some springs. It gelatinizes by concentration. Decomposed it yields ammonia. It is probably of vegetable origin.

† For some curious experiments on the connection between the temperature of caoutchouc and its elasticity see T. *Org. Bodies*, 696, and *Manchester Memoirs*, ii. 2d series.

Before actually dissolving, the caoutchouc swells up remarkably, and acquires a soft gelatinous aspect and consistency; in this state it is used for rendering cloth and leather impervious to water, and, as suggested by Mitchell, may be cut with a wet knife into thin sheets or bottles, and be extended to a great size.*

Preparation of caoutchouc. In preparing caoutchouc for the action of spirits of turpentine, ammonia is now used with advantage. The caoutchouc is cut into shreds, covered with caustic ammonia, and left in this state several months; it becomes soft, swells, but is still elastic. It is then treated with spirits of turpentine, and by agitation converted into an emulsion; in a short time it swims on the surface, and may be removed. A much smaller quantity of turpentine is required when the caoutchouc has been thus softened.

Effect of heat. 2176. When caoutchouc is cautiously heated, it fuses without decomposition; but at a higher temperature it is resolved into a volatile liquid of a brown colour, which amounts to $\frac{8}{10}$ths of the original caoutchouc. When carefully rectified, a very volatile liquid of sp. gr. 0.64 is obtained, which is very combustible and burns with a bright flame, mingles with alcohol, and dissolves copal and other resins. It is very useful as a solvent for caoutchouc and for the preparation of varnishes.

Uses. 2177. Caoutchouc in thin sheets is exceeding useful in the laboratory, for joining glass tubes, &c. so as to make an air tight joint and at the same time preserve flexibility.

2178. The milky juice carried from South America was found by Faraday to be composed of

Water,	56.37
Caoutchouc	31.70
Albumen	1.90†
Wax, a trace	——
An azotic body	7.13
Gummy body	2.90
	——100

His analysis of caoutchouc gave

Carbon,	87.2
Hydrogen,	12.8

Thomson thinks it composed of an equal number of atoms of carbon and hydrogen.

Products of distillation. 2179. By distillation at a low temperature and exposing the products to a freezing mixture, several different liquids have been obtained from caoutchouc.‡ These are *Eupion*§ a limpid liquid that boils at 124°; *Caoutchene* an oily substance; *Heëvene* which remains

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* Soak the common bags in sulphuric ether, sp. gr. 0.753, at a temperature not less than 50° Fahr. for a period of time not less than one week, (the longer the better.) Empty the bag, wipe it dry, put into it some dry powder, such as starch, insert a tube into the neck, and fasten it by a broad soft band slightly applied, and then commence by mouth or bellows the inflation. If the bag be unequal in thickness, restrain by the hand the bulging of the thinner parts, until the thicker have been made to give way a little. When the bag has become by such means nearly uniform, inflate a little more, shake up the included starch, and let the bag collapse. Repeatthe inflations until the bag is sufficiently distended.

† From recent experiments Ure infers that albumen is not a necessary constituent of the juice. See his new experiments in *Philos. Mag.* July 1839.

‡ Bouchardt, *Jour. de Pharm.* xxiii. 454.

§ From the Greek ευ well and πιων fatty.

after the volatile oils are distilled off; it is an acid liquid boiling at 600° and burning like the volatile oils; and *carburet of hydrogen.*

Division 9th. Extractive.

2180. *Extractive.* Most plants yield to water a substance differing from any proximate principles of vegetables, which constitutes a part of what is called an *extract* in pharmacy, and which has been expressed by the term *extractive.* It is always mixed with other principles and there is no proof that it is identical in different plants. Berzelius distinguishes it by the name of *apotheme* (deposite).

Division 10th. Bitter principles.

2181. Many vegetable substances have an intensely bitter taste, and on that account are employed in medicine, by brewers, &c. There appears to be a great variety of bitter principles, many of which have received distinct names derived from the name of the vegetable, as *quassite* from Quassia, *gentianite* from gentian, *colocynthite* from colocynth, &c.

Division 11th. Products of destructive distillation.

2182. *Products of the destructive distillation of vegetable substances.* Some of these are found in matters existing on the earth; but it is probable that they have been formed originally by the destructive distillation of vegetables or trees, in some great processes of nature.

Naphtha,

2183. *Naphtha.* This liquid exudes from the earth in Persia and some other countries; and is obtained by distilling petroleum and asphaltum, and by rectifying coal tar. Naphtha is limpid, and colourless, like water; it has a bituminous odour, a sp. gr. of 0.817 and burns with much flame and smoke.

Properties.

2184. It is insoluble in water, but soluble in alcohol. It softens caoutchouc which swells in it to more than 30 times its original bulk and becomes gelatinous and transparent: by long boiling a solution is effected.

Petroleum. Asphaltum.

2185. *Petroleum* is less limpid than naphtha, and unctuous to the touch. *Asphaltum* is a solid, brittle bitumen of a black colour, and vitreous lustre. It is soluble in about 5 times its weight of naphtha, and the solution forms a good varnish. It is found on the surface and on the banks of the Dead Sea, and in large quantities in Barbadoes and Trinidad.

Tar from coal.

2186. Among the products of the destructive distillation of vegetable and animal substances is a black inflammable liquid called *tar.* A large quantity is formed during the distillation of wood and the preparation of coal gas. This tar has been found to contain several new principles *paraffin, eupion, creosote, picamar, capnomor* and *pittacal.*

Paraffin.

2187. *Paraffin* is obtained most abundantly from the tar of the beech tree. It is a transparent and crystalline substance, of a white colour, and destitute of taste and smell. It melts at 110° into a colourless oil: at a higher temperature it boils and may be distilled. Its sp. gr. is 0.870.

2188. It has very little tendency to combine with other bodies; hence its name paraffin (*parum affinis.*) Ether is its best solvent.

Eupion.

2189. *Eupion* is obtained by distilling the tar which is procured by decomposing animal matter in the dry way. It may also be obtained from vegetable and coal tar; or much purer from rapeseed oil. The oil is distilled in an iron retort with a moderate fire, so that the oil may not pass over.*

Properties. 2190. It is a colourless liquid, which does not become solid though cooled down to —4°. It is tasteless but smells like blossoms. It boils at 116½°. Its sp. gr. is 0.655. Absolute alcohol dissolves it. Naphthaline, camphor, tallow, and many other substances dissolve in eupion; caoutchouc swells enormously in it, and on boiling is dissolved.

Creosote. 2191. *Creosote* was discovered by Reichenbach in 1832. It exists in impure pyroligneous acid, but is best prepared from those portions of the oil distilled from wood-tar which are heavier than water. The oil is first freed from adhering acetic acid by carbonate of potassa, and, after separation from the acetate, is distilled. A little phosphoric acid is mixed with the product to neutralize ammonia, and another distillation resorted to. It is next mixed with a strong solution of potassa, which combines with creosote, allows any eupion which may be present to collect on its surface, and by digestion decomposes other organic matter: the alkaline solution is then neutralized by sulphuric acid, and the oil which separates is collected and distilled. For the complete purification of the creosote, this treatment with potassa, followed by neutralization and distillation, requires to be frequently repeated.

Properties. 2192. Creosote is a colourless transparent liquid of an oily consistence, which retains its fluidity at —17°, has a sp. gr. of 1.037 at 68°, boils at 397°, is a non-conductor of electricity, and refracts light powerfully. It has a burning taste followed by sweetness, and its odour is like that of wood-smoke or rather of smoked meat. It is highly antiseptic to meat: the antiseptic virtue of tar, smoke, and crude pyroligneous acid seems owing to the presence of creosote. Its name, from ϰϱεὰς *flesh*, and σωζω *I save*, was suggested by this property.

Solubility, &c. 2193. Creosote requires about 80 parts of water for solution, and is soluble in every proportion in alcohol, ether, sulphuret of carbon, eupion, and naphtha. It has neither an acid nor alkaline reaction with test paper, but combines both with acids and alkalies. With potassa, soda, lime, and baryta it forms compounds soluble in water; but the creosote is separated even by feeble acids. Of the acids, it unites most readily with the acetic, dissolving in every proportion: by strong nitric and sulphuric acid it is decomposed. Creosote unites also with chlorine, iodine, bromine, sulphur, and phosphorus.

Coagulates albumen. 2194. Creosote acts powerfully in coagulating albumen, this effect being produced by a solution of one drop in a large quantity of water. It acts with energy on living beings. Insects and fish thrown into the aqueous solution of creosote are killed, and plants die when watered with it. It appears useful in medicine; it is said to be very efficacious as a topical application in tooth ache, ulcers, and cutaneous diseases; and it probably admits of many other applications.

Creosote is a compound of carbon, hydrogen, and oxygen; the ratio of its elements is $C_6H_{3\frac{1}{2}}O$.† T.

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* For details of the process see T. *Org. Bodies*, 726.

Ampelin. †*Ampelin* was prepared by Laurent from the oil of bituminous slate, which boils at 392° and 536.° (*Ann. de Chim. et de Phys.* xiv. 326.) It is an oily looking liquid soluble in water.

Picamar.

2195. *Picamar.* This substance is the bitter principle of tar, whence it derives its name (*in pice amarum.*) It is present in the heaviest portions of the rectified oil of tar, and when these are treated by potassa, a crystalline compound of the alkali and picamar is formed: this compound, when purified by repeated solution in water and crystallization, is decomposed by phosphoric acid, and the picamar separated by distillation.

Properties.

2196. Picamar is an oily colourless liquid, of a peculiar odour and very bitter taste. Its sp. gr. is 1.100, and it boils at 545°, being considerably less volatile than creosote. It is insoluble in eupion and sparingly soluble in water; but it dissolves without limit in alcohol and ether. It has no action on test paper; but it unites with potassa as above mentioned, and strong sulphuric acid dissolves it without decomposition. From its permanence in the air, its fixity when heated, and its oily nature, it is well adapted for greasing machinery and protecting it from rust.

Pittacal.

2197. *Pittacal.* When the heavy oil of tar is digested with a solution of baryta, a fine blue colour appears, which is due to pittacal, from *πιττα pitch*, and *καλλος ornament*. It is a solid of a beautiful blue colour, which admits of being fixed as a dye. It is very permanent, contains nitrogen as one of its elements, and appears to belong to the same class of bodies as indigo.

Capnomor.

2198. *Capnomor.* This substance occurs along with creosote, picamar, and pittacal in the heavy oil of tar. On digesting that oil with solution of potassa, the three latter principles are dissolved, and the capnomor collects on the surface, combined with a little eupion. The capnomor is then dissolved by sulphuric acid, in which eupion is insoluble; and from the solution, on being neutralized with carbonate of potassa, capnomor separates, and is purified by distillation. Its name is derived from *καπνος smoke*, and *μοῖρα part*, because it is one of the ingredients of smoke.

Properties.

2199. Capnomor is a colourless transparent liquid, of a pungent taste and rather pleasant odour, has a sp. gr. of 0.975, and refracts light almost as powerfully as creosote. It boils at 365°. It is insoluble in water and solution of potassa, and is soluble in alcohol, ether, and eupion. It has the property of dissolving caoutchouc, especially when heated, and is the only ingredient of tar which does so: its presence in coal naphtha is the cause of the solvent action of that liquid on caoutchouc. The composition of capnomor has not been ascertained, though doubtless carbon and hydrogen are its principal ingredients. T. 6. From its being decomposed by nitric acid Thomson is inclined to suspect that it contains oxygen.

Cedriret.

2200. *Cedriret* has been still more recently obtained by Reichenbach from the rectified oil of the tar of beech wood. It strikes a red colour with persulphate of iron, and all substances that easily part with oxygen; even the oxygen of the air renders the liquid red. It forms red crystals which lie upon the filter, entangled in each other like a net, hence the name from *cedrium* an old name for the sour water of *tar burners*, and *rete* a net.

Naphthaline.

2201. *Naphthaline.* $C_{10}H_4 = 64$ eq. This substance was discovered in 1819 in one of the condensing vessels erected in London for the distillation of coal tar.[*] It was named from its connexion with coal naphtha.

Obtained. 2202. When coal is heated in iron retorts, for the preparation of coal gas, much brown semi-fluid matter is obtained called *coal tar*. It is from this tar that coal naphtha and naphthaline are procured. To obtain the latter the tar is distilled.

The first fourth that comes over is partly naphtha, with water holding ammonia and naphthaline in solution. The next fourth part is a dense oil mixed with naphthaline, the latter increases in quantity as the distillation proceeds. From the last portions distilled the naphthaline crystallizes and may be freed from the oil by pressure between folds of blotting paper and then subliming at a gentle heat.[†]

Properties. 2203. Naphthaline is white and of a pearly lustre. Its smell is aromatic, its taste pungent. It evaporates spontaneously. It melts at 174° and boils at 410°.[‡] With sulphuric acid it forms *sulphonaphthalic acid.*

Action of chlorine. 2204. Chlorine and bromine act with violence on naphthaline, heat is disengaged and hydrochloric and hydrobromic acids are formed. It is composed of 10 atoms carbon and 4 hydrogen = 65.2.

2205. When nitric acid and naphthaline are left in contact at common temperatures no action takes place. But if the acid is boiled, red vapours are emitted and an oily layer collects on the surface, which affords two products: one solid, which is *nitronaphthalese*, the other a liquid separable by bibulous paper.

Nitronaphthalese.

Another substance obtained from coal tar is *paranaphthaline*, so named by Dumas from its composition being the same as that of naphthaline.[§]

In oil and coal gases. 2206. In the coal and oil gases prepared for ordinary combustion, small portions of several of the foregoing substances are believed to be present, communicating their peculiar properties and improving the brilliancy of the light.

Coal gas obtained. The distillation of coal is conducted in oblong cast-iron cylinders, or retorts, which are ranged in furnaces to keep them at a red heat, and all the volatile products are conveyed by a common tube into a *condensing vessel*, kept cold by immersion in water; and in which the water, tar, ammoniacal, and other condensable vapours, are retained; the gaseous products consist principally of carburetted hydrogen, hydrosulphuric acid gas, carbonic oxide and acid; these are passed through a mixture of quicklime and water in vessels called *purifiers*, by which the hydrosulphuric acid and carbonic gases are absorbed, and the carburetted hydrogen and hydrogen gases, transmitted sufficiently pure for use in to *gasoemters*, whence the pipes issue for the supply of streets, houses, &c. The coke remaining in the retorts is of a very good quality.[‖]

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[*] *Ann. Philos.* xv. 74, vi. N. S. 135, and *Phil. Trans.* 1821, 209.

[†] Reichenbach has endeavoured to prove that naphthaline does not exist ready formed in coal-tar, but that it is formed when the oil existing in this tar is exposed to a high temperature, but this was not confirmed by the experiments of Laurent, for which see T. *Org. Bodies*, 738.

[‡] 413½°, Dumas.

Naphthalic acid. [§] *Naphthalic Acid.* $C_{10}H_2O_4$. This acid has great resemblance to benzoic; it is white, when pure, and crystallizes in long feathery crystals. It melts at 212° and may be volatilized without decomposition. Its fumes readily take fire. It has no smell, and a weak taste. While dry it does not affect litmus paper, but reddens it if moistened. It combines with bases and forms *naphthalates*. The greater number of these when heated elongate to a great extent under the form of a black glass, attended with the disengagement of a peculiar crystallizable matter.

This acid belongs to the *volatile acids* of Thomson (*Org. Bodies*, 27) to whose description the reader is referred for details and for an account of its compounds.

[‖] For a full account of the process, see Ure's *Dict. Arts and Manuf.* 546.

2207. The best kind of coal for distillation is that which contains most bitumen and least sulphur; 112 pounds of good coal are capable of yielding from 450 to 500 cubic feet of gas of such quality, that half a cubic foot per hour is equivalent to a mould candle of six to the pound, burning the same space of time. H. The sp. gr. of the gas varies, the mean as given by Ure is 0.529 and that of oil gas 0.96.*

Oil gas.

2208. The apparatus for the conversion of oil into gas consists of a furnace with a contorted iron tube containing fragments of bricks or coke, passing through it, into which, when red-hot, the oil is suffered to drop; it is decomposed, and converted almost entirely into charcoal, which is deposited in the tube, and into a mixture of carburetted hydrogen, and hydrogen gases, of which one volume may be regarded as equivalent to two of coal-gas, for the production of light.†

The commonest whale oil, quite unfit for burning in the usual way, affords abundance of excellent gas, requiring no other purification than passing through a refrigerator to free it from a quantity of empyreumatic vapour. A gallon of whale-oil affords about 100 cubical feet of gas.

Lamp black.

2209. *Lamp-black* is prepared from the refuse of resin collected in the distillation of oil of turpentine. It is a fine black powder, exceedingly light. The *soot* which collects in chimneys where coal or wood is burnt differs from lamp-black. When boiled with water a matter is deposited of the appearance of pitch; alcohol and ether remove a portion of an exceedingly acrid and bitter taste, which Braconnot has called *asbolin*, from *ασβολη soot;* it is fluid and not volatile.

Animal charcoal.

2210. *Animal charcoal*, though derived from the animal kingdom, is supposed to owe its most important properties to the charcoal which it contains. It is known as *ivory black* and is prepared from

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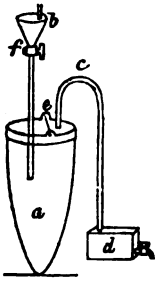
Illuminating power of candles and lamps.

* The illuminating power of different gases burned in the same circumstances, is proportional, generally speaking, to their sp. gr. as this is to the quantity of carbon they contain. A mould tallow candle of 6 in the pound, burning for an hour, is equivalent to half a cubic foot of ordinary coal gas, and to four tenths of a foot of good gas. The flame of the best Argand lamp of Carcel, in which a steady supply of oil is maintained by pump-work, consuming 649 grains in an hour, and equal to 9.38 such candles, is equivalent to 3.75 cubic feet of coal gas per hour. A common Argand lamp, equal to 4 candles, consumes 463 grains per hour, and is represented by 1.6 cubic feet of gas. Ure.

Oil gas apparatus.

† The cut (Fig. 197) represents an apparatus contrived by me, and which is very convenient for obtaining oil gas, in sufficient quantity for the exhibition of its properties; *a* is a vessel of cast iron about 16 inches in depth, and 6 in diameter at its upper part; having a cast iron cover, with two openings, to the smallest of which, a copper pipe leading from a funnel-shaped oil vessel *b*, is secured by brazing; into the larger opening a gun-barrel *c* is screwed which enters a small copper condensing vessel *d* furnished with a cock for drawing off any oil, or condensable vapours that may pass over. From the upper part of the condenser a copper or lead pipe issues, which conveys the gas to the gasometer. When oil gas is to be obtained, the vessel *b* is filled with oil, and the pieces of bricks are put into the retort *a*, the cover is then secured by a rod of iron passing through the ears *ee*, and the joint is made tight by a mixture of about 2 parts of sal ammoniac, 1 of sulphur and 30 of cast iron filings or borings, made into a paste with water.* This retort may be placed in any convenient furnace, and when heated to redness the cock *f* is turned so as to allow the oil to pass drop by drop. W.

Fig. 197.



* This cement should be allowed to become hard before the apparatus is used.

the bones of animals which are heated in close vessels, so as to drive off all the volatile matter. The earth of bones remains mixed with charcoal. Being reduced to powder it is fit for use.

Uses.

2211. It is a much more powerful discolourizing principle than vegetable charcoal. It is much employed in refining sugar. When used to remove the colour of liquids, it acts much better if the liquid be slightly acid or neutral, and at a boiling temperature. It appears to act chemically upon the colouring matter.*

SECTION V. *Of the Parts of Plants.*

Sap of plants.

2212. It is the general opinion that plants receive a considerable part of their nourishment by the root; that it enters them in a liquid state, and passes up in proper vessels towards the leaves. This liquid is distinguished by the name of *sap*. In nearly all vegetables it is as liquid as water. It always contains an acid, sometimes free, but more commonly combined with lime and potassa. Various vegetable principles are also present; of these sugar is the most remarkable, and mucilage. Sometimes albumen and gluten, and tannin can be detected. When left to itself, sap soon effervesces and becomes sour; or even vinous, when the proportion of sugar is considerable.

Changes of,

2213. In its passage to the leaves the sap is altered by a process similar to that of digestion in animals, and formed into all the liquid substances required for the purposes of the plant. These liquids flow from the leaves towards the root in appropriate vessels, and have received the name of the *peculiar juices* of vegetables. They differ in different plants. They always contain much more vegetable matter than the sap. Sometimes they exude spontaneously and may always be procured by incisions through the bark.

Peculiar juices.

Gum resin.

2214. The milky juices concrete into a solid matter which has been called *gum resin*. Several of the gum resins are employed in medicine; the most important of which is the juice of the poppy affording opium.

Air in plants.

2215. In many plants the stem is hollow and filled with air; in some, as the onion, it is contained in the leaves; it is lodged in the pod of the pea, and in the leaves of some species of fuci. In some plants the proportion of oxygen in this air is greater than in common air,† and others contain more nitrogen; but generally so far as experiments have been made it is common air unaltered.

Bark.

2216. The *bark* is composed of three distinct portions; the outermost or epidermis, the parenchyma, and that next the wood the *cortical layers*. The latter consist of several thin membranes, composed of fibres forming a kind of net-work.

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* See Bussy's experiments, T. *Org. Bodies*, 756, and *Jour. de Pharm.* viii. 257.

Neutral compounds containing nitrogen.

There are several substances obtained from plants by processes similar to those employed for obtaining the vegetable alkalies, which have been arranged together by Thomson. They are *caffein* from coffee, *piperin* from pepper, *daphnin* from *daphne alpina* and *mezerium*, *jalappin* from jalap, *sinapin* from mustard, *hesperidin* from the unripe orange and lemon, *populin* and *plumbagin*. For details see T. *Org. Bod.* 757.

† Priestley, iii. 279.

Cork. 2217. The substance known as *cork* is the epidermis of the *quercus suber*, which contains a peculiar principle called *suberin*. Three different kinds of cinchona bark were early distinguished, the pale, red and yellow. The first is the bark of the *cinchona lancifolia*, the second of the *c. oblongifolia*, and the last of the *c. cordifolia*.*

Roots. 2218. The *roots* of a great variety of plants are employed in medicine and the arts. The substances found in them are various; and indeed, as the peculiar juices of the roots are always included in such examinations, it is clear that almost all the vegetable principles will be found in them. T.

Bulbs. 2219. *Bulbs* are composed of concentric coats like the onion, or are imbricated. Several of them are used as nutritive articles of food, and some constitute active medicines.

Squill. *Squill*, the bulbous root of the *scilla maritima*, owes its peculiar properties to a species of bitter principle which has been called *scilitin*.

Potatoes. *Potatoes* are the bulbs of the *solanum tuberosum*, an American plant, said to grow wild in Peru and Chili. According to Einhof potatoes afford

Starch	15†	
Fibrous matter	7	
Albumen	1.4	
Mucilage	4	
		27.4

They afforded also a mixture of tartaric and phosphoric acids.

Action of frost upon. When potatoes are exposed to the action of frost, they acquire a sweet taste, followed by an acid taste, owing to the rapid evolution of acetic acid, and the root soon putrefies. The sugar is formed at the expense of the mucilage. Potatoes differ from wheat and barley by containing no gluten.

Woods. 2220. *Woods.* The mere woody fibres of all plants are probably nearly the same, and the differences are owing to the various proportions of liquids and empty spaces with which the woody fibres are intermixed.‡ The *vegetable fibres* in herbaceous plants correspond to the wood of trees. In some it is flexible and tough, as in hemp, nettles, &c.§

Cotton. 2221. *Cotton* is a soft down which envelopes the seeds of various species of *gossypium*. It has a strong affinity for some of the earths, especially alumina; hence this substance is used to fix colours on cotton; the cloth is steeped in a solution of alum or acetate of alumina, and afterwards dyed. Several of the metallic oxides also combine with it readily, of which oxide of iron is one of the most remarkable. Oxide of tin also combines with it and is used as a mordant.

2222. Cotton combines readily with tannin and forms a yellow or brown compound. Hence infusion of galls, and of other astringent substances is often used as a mordant for cotton.

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* The bark from which quinia is extracted in France, is called *quinquina calisaya*; but the species of cinchona to which it belongs does not seem yet accurately known. T.

† For table of the quantity of starch from different kinds of potatoes, see T. *Org. Bodies*, 841.

‡ For a table of the results of the analysis of various woods see T. *Org. Bodies*, 849.

§ Perhaps the fibres ought to be considered rather as the *liber* or inner bark.

Quantity of oxygen required for combustion of woods.

2223. The quantity of oxygen required for burning 100 parts of various kinds of wood has been made the subject of experiments which are important, as this oxygen is proportionable to the quantity of heat evolved by each.

100 parts of Tilia Europea, *lime* require	. .	140.523
Ulmus suberosa, *elm* "	. .	139.408
Pinus abies, *fir* "	. .	138.377
" larix, *larch* "	. .	138.082
Acer campestris, *maple* "	. .	136.960
Pinus picea, *pitch-pine* "	. .	136.886
Juglans regia, *walnut* "	. .	135.690
Quercus robur, *oak* "	. .	133.472
Betula alba, *birch* "	. .	133.229*

Senna.

2224. *Leaves.* *Senna.* According to Lagrange the leaves of the *Cassia senna* are characterized by containing a peculiar extractive principle, *cathartina*, which, by long boiling, passes into a resinous substance, in consequence of absorbing oxygen; they also contain a resin which resists the action of water, and is soluble in alcohol; the whole of the soluble matter amounts to about one third the weight of the senna.†

Night-shade.

2225. *Nightshade.* The leaves of the *Atropa Belladonna* contain, according to Vauquelin,

1. Vegetable albumen, or gluten.
2. A bitter narcotic principle.
3. Nitrate, muriate, sulphate, binoxalate, and acetate of potassa.

Brandes announced the existence of a new vegetable alkali in this plant, which he calls *atropia.* It forms brilliant acicular crystals, tasteless, and difficultly soluble tn water and alcohol.

Hemlock.

2226. *Hemlock, conium maculatum.* This plant was formerly called *cicuta;* it contains a peculiar principle *conicina*, and its juice in chemical composition has a striking similarity to that of the cabbage.

Flowers.

2227. *Flowers.* The colouring matter of most flowers is extremely fugitive, and is generally much changed by mere exsiccation. They usually communicate their colour to water; the infusion of blue flowers is generally reddened by acids, and changed to green or yellow by alkalies; that of yellow flowers is made paler by acids, and alkalies render it brown; the red infusion of many flowers is exalted in tint by acids, and changed to purple, and in some instances, to green, by alkalies.

It is probable that one and the same principle gives colour to several of the blue and red flowers, but that the presence of acid in the latter produces the red; the petals of the red rose, triturated with a little carbonate of lime and water, give a blue liquor; alkalies render it green, and acids restore the red.

Colouring matter.

2228. A colouring matter analogous to that of the violet, exists in the petals of red clover, in the red tips of those of the common daisy, of the blue hyacinth, the holly-hock, lavender, in the inner leaves of the artichoke, and in numerous other flowers; reddened by an acid, it colours the skin of several plums, and the petals of the scarlet ge-

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* *Ann. de Pharm.* xvii. 144.

† In the *Lond. Med. Repos.* vol. xv. 169, the effects of the various re-agents on infusion of senna are detailed by Batley.

ranium and pomegranate. Some flowers which are red, become blue by merely bruising them; this is also the case with the colouring matter of red cabbage leaves, and of the rind of the long radish. Smithson has suggested that the reddening acid is in these cases the carbonic, which escapes on the rupture of the vessels which inclose it.

2229. The petals of the common *corn-poppy*, rubbed upon paper, give a purple stain, little altered by ammonia, or carbonate of soda, but made green by caustic potassa. The infusion of poppy-petals in very dilute hydrochloric acid, is florid red; chalk added, renders it of the colour of port wine; carbonate of soda in excess gives the same colour, but excess of potassa changes it to green and yellow. The expressed juice of the black mulberry possesses nearly the same properties.*

Seeds. 2230. *Seeds.* Starch is an essential component of the greater number of seeds, and it is generally united in them with a variable portion of gluten, and often of fixed and of volatile oil.

Davy examined a number of seeds with a view to determine their relative nutritive powers: for the results of his experiments see *Agricultural Chemistry*, 4to. 131.

Almonds. 2231. *Almonds*, the seeds of the *amygdalus communis*, consist of an albuminous substance and oil; the latter may be obtained by expression, five pounds yielding about one pound of cold drawn oil, and about a pound and a half when aided by heat. The bitter almond affords by pressure an oil analogous to that from the former; but if the expressed cake be distilled with water, a portion of volatile oil eminently poisonous, and smelling strongly of the almond, is obtained; this oil is used as a flavouring material by confectioners, and by the manufacturers of noyeau.†

Colocynth. 2232. *Colocynth.* The pulp of the fruit of the *cucumis colocynthis* or bitter cucumber is much used in medicine under the name *coloquintida.* It contains a peculiar bitter principle *colocynthin.*

Elaterium. 2233. *Elaterium* is deposited from an infusion of the fruit of the *momordica elaterium* or wild cucumber. The active principle has been obtained by Paris and Faraday and named *elatin.*‡

Coffee. 2234. *Coffee*, the seed of the *Coffea Arabica* has been examined both in its raw and roasted state.

Hermann has given the following comparative analysis of coffee from the Levant and from Martinique,§ the results of which differ much from those of Cadet:

	Levant.	Martinique.
Resin	74	68
Extractive	320	310
Gum	130	144
Fibrous matter	1335	1386
Loss	61	12
	1920	1920

When coffee is roasted it undergoes a peculiar change of compo-

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* Smithson, *Phil. Trans.* 1818, 110.

† In the *Phil. Trans.* for 1811, Brodie has detailed a variety of experiments illustrative of its action as a poison.

‡ Paris' *Pharmacol.* 4th edit. 373.

§ Crell's *Annales*, ii.

sition attended by the formation of tannin, and a volatile, fragrant, and aromatic principle; but in this state it has not been examined with any precision. It is developed also by roasting barley, beans and various vegetables, which are on that account occasionally employed as substitutes for coffee. Robiquet discovered in coffee the principle called *caffein.*

Mustard. 2235. *Mustard.* The seed of the *sinapis nigra* derives its acrimony from volatile oil; it also contains a tasteless fixed oil, albumen, gum, and traces of sulphur and earthy salts.

Lupulin. 2236. *Lupulin* was discovered by Ives[*] and Payen and Chevalier, about the same time, in the leaves of the *Humulus lupulus* or common hop. It is extremely bitter, of a yellow colour, and has an aromatic odour. It is the principle on which the characteristic properties of the hop depend.

Citisin. 2237. *Citisin* was discovered by Payen and Chevalier in the seeds of the *Cytisus Laburnum.* Its colour is yellow, and it has a disagreeable taste; it is soluble in water, alcohol and ether. It is easily decomposed by heat, and the strong acids produce the same effect.

Fruits contain acid, 2238. *Fruits.* The acid matter contained in fruits is either the tartaric, oxalic, citric, or malic; or a mixture of two or more of them; but the nature and proportion of the acid varies at different periods of their growth; gluten and starch are found in some fruits, and a gelatinizing substance, which has sometimes been regarded as identical with animal jelly, but which is probably a compound of gum and one or more vegetable acids.

And sugar. 2239. Most of our common fruits also contain sugar, and it exists in all those the juice of which is susceptible of vinous fermentation. In some fruits the quantity of sugar is increased by mashing and exposure to air; this is remarkably the case with some of the rough-flavoured apples used for cider, the pulp of which becomes brown, and at the same time sweet by a few hours' exposure.

Colouring matter. 2240. The colouring matter of fruits seems in most cases to bear a strong resemblance to that of flowers. The red juice of the mulberry was found to exhibit the same characters as the colouring principle of the wild poppy; carbonated alkalies render it blue, but caustic potassa changes it to green and yellow: the juice of red currants, cherries, elder-berries, and privet-berries, and the skin of the buckthorn berry, appear to contain a similar colouring principle.

Sap green. 2241. The unripe berries of the buckthorn furnish a juice, which, when inspissated, is known under the name of *sap green.* It is soluble in water, and rendered yellow by carbonate of soda and caustic potassa; the acids redden it, and carbonate of lime restores it to green, which is therefore probably the proper colour of the substance.[†]

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[*] *Amer. Jour.* ii.

[†] Smithson, *Phil. Trans.* 1818, p. 116.

SECTION VI. *Phenomena and Products of Fermentation.*

Sect. VI.

Fermentation. Vinous and acetous.

2242. The term *fermentation* is employed to signify the spontaneous changes, which certain vegetable solutions undergo, placed under certain circumstances, and which terminate either in the production of an intoxicating liquor, or of vinegar; the former termination constituting *vinous*, the latter acetous fermentation.

The principal substance concerned in vinous fermentation is sugar; and no vegetable juice can be made to undergo the process, which does not contain it in a very sensible quantity. In the production of beer, the sugar is derived from the malt; in that of wine, from the juice of the grape.

Malt.

2243. *Malt* is barley which has been made to germinate to a certain extent, after which the process is stopped by heat. The barley is steeped in cold water, and is then made into a heap or *couch*, upon the maltfloor; here it absorbs oxygen and evolves carbonic acid; its temperature augments, and then it is occasionally turned to prevent its becoming too warm. In this process the radicle lengthens, and the plume called by the maltsters the *acrospire*, elongates; and when it has nearly reached the opposite extremity of the seed, its further growth is arrested by drying at a temperature slowly elevated to 150° or more. The malt is then cleansed of the rootlets.

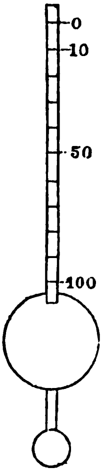
Beer. Wort.

2244. In the manufacture of *beer*, the malt is ground and infused in the *mash-tun*, in rather more than its bulk of water, of the temperature of 160° or 180°. Here the mixture is stirred for a few hours; the liquor is then run off, and more water added, until the malt is exhausted. These infusions are called *wort*, and its principal contents are *saccharine matter*, *starch*, *mucilage*, and a small quantity of *gluten*. The strength of the wort is adjusted by its specific gravity, which is usually found by an instrument, not quite correctly called a *saccharometer*, since it is influenced by all the contents of the wort, and not by the sugar only.*

The wort is next boiled with hops, amounting upon the average, to $\frac{1}{20}$ the weight of the malt, their use being to cover the sweetness of the liquor by their aromatic bitter, and to diminish its tendency to acidify. The liquor is then thrown into large, but very shallow, vessels, or *coolers*, where it is cooled to about 50°, as quickly as possible; it is then suffered to run into the *fermenting vat*, having been mixed with a proper quantity of *yeast*. (See *Addenda*)

2245. In the fermenting vessel, the different substances held in solution in the liquor begin to act upon each other; an intestine motion ensues, the temperature of the liquor increases, carbonic acid escapes in large quantities; at length this evolution of gas ceases, the liquor becomes quiet and clear, and it has now lost much of its sweetness, has diminished in specific gravity, acquired a new flavour, and become intoxicating.†

Fig. 198.



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* It is a brass instrument, of the shape shown in fig. 198, so adjusted in weight as to sink to the point marked 0°, in distilled water, at the temperature of 70°, and when immersed in a liquor of the same temperature, and of the specific gravity of 1.100, it is buoyed up to the mark 100, just above the bulb. The intermediate space is divided into 100 equal parts, and consequently will indicate intermediate degrees of sp. gr. This is the most useful form of the instrument, though not that in common use. The specific gravity of the wort for ale is usually about 1.090 to 1.100 and for table beer from 1.020 to 1.030.

Wash.

† The distillers prepare a liquor, called *wash*, for the express purpose of producing from it ardent spirits; instead of brewing this from pure malt, they chiefly employ raw grain, mixed with a small quantity only of malted grain; the water employed in the mash-tun is of a lower

Chap IX.

Wine.

2246. *Wine* is principally procured from the juice of the grape, and some other saccharine and mucilaginous juices of fruits. This sweet juice is termed *must*. The principal substances held in solution in grape juice are *sugar*, *gum*, *gluten*, and *tartrate of potassa*. It easily ferments spontaneously at temperatures between 60° and 80°, and the phenomena it gives rise to closely resemble those of the wort with yeast. After the operation, its sp. gr. is much diminished, its flavour changed, and it has acquired intoxicating powers.

Vinous fermentation.

2247. As the fermentation of *must* takes place without adding any *ferment*, it is obvious that the requisite substance is present in the juice. This was separated by Fabroni and found to be analogous to the gluten of plants; and gluten being substituted for it, the fermentation succeeded. He has shown that the saccharine part of must resides in the cells of grapes, while the glutinous matter, or ferment, is lodged on the membranes that separate the cells. It is only after the juice is squeezed out that these two substances are mixed. All other juices that undergo spontaneous fermentation have been shown by Thenard and Seguin to contain a similar substance.

Air necessary.

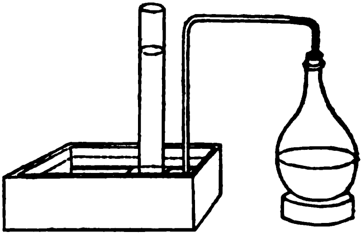
2248. Gay Lussac has shown that the juice of fruits will not ferment, if completely excluded from the air. But if a little oxygen gas be let up to it, this gas is absorbed and fermentation goes on, the carbonic acid evolved being 100 times as great as that of the oxygen absorbed.*

2249. It seems probable that the tartaric acid is partly decomposed and a portion of malic acid formed during the process, which is analogous to combustion, being attended by the evolution of caloric and the formation of carbonic acid.

Exp.

2250. If a mixture of 1 part sugar, 4 or 5 of water, and a little yeast, be placed in a due temperature, it also soon begins to ferment, and gives rise to the same products as wort or grape-juice; and the results may easily be examined by suffering the process to go on in the apparatus fig. 199, consisting of a matrice containing the fermenting mixture, with a bent tube issuing from it, and passing into an inverted jar standing in water.

Fig. 199.



Products of distillation.

2251. When any of the above-mentioned fermented liquors are distilled, they afford a *spirituous liquor;* that from wine is termed *brandy;* from the fermented juice of the sugar-cane we obtain *rum;* and from wash, *malt spirit;* and these spirituous liquors, by re-distillation, furnish *spirit of wine*, *ardent spirit*, or *alcohol*.†

Odour of wines.

2252. The peculiar odour of wine is owing to the presence of a small quantity of a substance analogous in properties to a volatile

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temperature than that requisite in brewing, and the mashing longer continued; by which it would appear that a part of the starch of the barley is rendered into a kind of saccharine matter. The wort is afterwards fermented with yeast.

[*] *Ann. de Chim.* xvi. 245.

[†] For the proportions of alcohol furnished by different fermented liquors see p. 445. The experiments of Brande (*Phil. Trans.* 1811—13) show that it is a real educt. See also Henderson's *Table* in Brewster's *Jour.* i. 166.

oil. It amounts, at an average, to about $\frac{1}{40.000}$th part of the wine. It may be obtained by distilling the lees of wine. It has been called *œnanthic* ether.*

Œnanthic ether.

Acetous fermentation.

2253. *Acetous fermentation.* When any of the vinous liquors are exposed to the free access of atmospheric air at a temperature of 80° or 85° they undergo a second fermentation, terminating in the production of a sour liquid, called *vinegar*. Vinegar is usually obtained from malt liquor or cider, while wine is employed as its source in those countries where the grape is abundantly cultivated.

Vinegar.

Properties.

2254. The colour of vinegar varies according to the materials from which it has been obtained; that manufactured in England is generally artificially coloured with burnt sugar: its taste and smell are agreeably acid. Its specific gravity is liable to much variation; it seldom exceeds 1.0250. When exposed to the air it becomes mouldy and putrid, chiefly in consequence of the mucilage which it contains, and from which it may be in some measure purified by careful distillation.

Alcohol does not undergo the change.

2255. Neither pure alcohol, nor alcohol diluted with water, is susceptible of this change. The weaker the wine or the beer the more readily it is converted into vinegar, yet strong wines yield a better vinegar, so that alcohol contributes to the formation of the acetic acid.

Wine entirely deprived of glutinous matter does not undergo the acetous fermentation, until some mucilaginous matter is restored to it.

Thomson's theory of formation of acetic acid.

2256. Wine which is completely deprived of all access to atmospheric air never becomes sour. In order to understand what takes place during the conversion of alcohol into acetic acid, we have only to attend to the constitution of these two bodies. Alcohol is C_4H_5O+HO while acetic acid is $C_4H_3O_3+HO$. In the first place 2 atoms of oxygen are absorbed from the atmosphere for every integrant part of alcohol present. These combine with two atoms of hydrogen and form water, leaving the alcohol in the state of C_4H_3O+HO, this is aldehyde. The aldehyde has a strong affinity for oxygen and absorbs 2 atoms of it from the atmosphere, and is converted into $C_4H_3O_3+HO$ or acetic acid. Thus during the conversion of alcohol into acetic acid, every atom of alcohol absorbs 4 atoms of oxygen from the atmosphere Here unless the air be renewed the process ceases to go on. Even when the process is properly conducted about $\frac{1}{15}$th of the whole acetic acid formed is lost. But when the air is not supplied to enable the aldehyde to absorb oxygen as fast as it is formed, a great deal is volatilized, and the consequent loss of acetic acid may be very great.†

Malic acid and alcohol disappears.

2257. When the acetous fermentation is over the whole of the malic acid of the wine has disappeared as well as the alcohol. We must conclude that they have been both converted into acetic acid. Part of the glutinous matter undergoes the same change, part is deposited in the state of flakes, and part remains in solution, disposing the vinegar to decomposition.

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* *Ann. de Chim. et de Phys.* lxiii. 113.

† This shows the necessity on the part of manufacturers of perpetually renewing the air of their chambers.

Sugar essential.

2258. Sugar appears to be the essential constituent in liquors to be converted into vinegar and the quantity of vinegar formed is proportional to the sugar.[*] T. 1032.

Panary fermentation.

2259. *Panary fermentation.* The change which dough undergoes, attended with the disengagement of carbonic acid gas, has been called the panary fermentation. The adhesive gluten of the flour enables it to be distended by the carbonic acid gas, and the mass rises. The mean heat of a baker's oven is 448°, this stops the fermentation, and the detained gas is expanded, giving to the loaf its vesicular structure. Carbonate of ammonia is sometimes employed to render the bread porous.

Putrefaction.

2260. *Putrefaction.* Vegetable substances are decomposed spontaneously if moist, provided the air has access to them and the temperature be not much under 45°, nor so high as to drive off the moisture. Plants do not putrefy in vacuo, or at least very slowly. If placed in bottles, well closed, and exposed to the temperature of boiling water a partial vacuum is formed within and they may be kept fresh for a considerable length of time.[†]

Offensive products.

2261. When vegetables contain nitrogen the gases given off during putrefaction are peculiarly offensive; this is the case with the cruciform plants, and when sulphur and phosphorus, it is much more so. When these substances putrefy on the surface of the ground, they leave *humus* or vegetable soil, which consists chiefly of the extractive matter called by Berzelius apotheme.

CHAPTER X.

ANIMAL SUBSTANCES.

Section I. *Ultimate Principles of Animal Matter, and Products of its Destructive Distillation.*

Proximate principles.

2262. The proximate principles of the animal creation consist, like those of vegetables, of a few elementary substances, which by combination in various proportions, give rise to their numerous varieties. Carbon, hydrogen, oxygen, and nitrogen, are the principal ultimate elements of animal matter; and phosphorus and sulphur are also often contained in it. The presence of nitrogen constitutes the most striking peculiarity of animal, compared with vegetable bodies; but as some vegetables contain nitrogen, so there are also certain animal principles, into the composition of which it does not enter.

Nitrogen.

Ammonia.

2263. The presence of nitrogen stamps a peculiarity upon the products obtained by the destructive distillation of animal matter, and which are characterized by the presence of ammonia, formed by the union of the hydrogen with the nitrogen. It is sometimes so abun-

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[*] Seven water, one sugar, and some yeast ferment in a proper temperature and form an excellent vinegar. *Ann. de Chim.* lxii. 248. For a full account of the processes see Ure's *Dict. A. and M.* 1.

[†] On this is founded the method of preserving vegetables, fruits, &c. See Ure's *Dict. A. and M.* 1045.

dantly generated as to be the leading product; thus, when horn, hoofs, or bones, are distilled *per se*, a quantity of solid carbonate of ammonia, and of the same substance combined with empyreumatic oil, and dissolved in water, are obtained; hence the pharmaceutical preparations called *spirit* and *salt of hartshorn*, and Dippel's *animal oil*. Occasionally the acetic, benzoic, and some other acids are formed by the operation of heat on animal bodies, and these are found united to the ammonia; cyanogen and hydrocyanic acid also frequently occur.

Carburetted hydrogen.

2264. If the gas evolved during the decomposition of animal bodies be examined, it is generally inflammable, and consists of carburetted hydrogen, often with a little sulphuretted and phosphuretted hydrogen; carbonic oxide, carbonic acid, and nitrogen are also sometimes detected in it.

The coal remaining in the retort is commonly very difficult of incineration, a circumstance depending upon the common salt and phosphate of lime, which it usually contains, forming a glaze upon its surface which defends the carbon from the action of the air. Animal charcoal is also found to be more effectual in destroying colour and smell, than that obtained from vegetables.

Putrefaction.

2265. By the term *putrefaction* we mean the changes which dead animal matter undergoes, and by which it is slowly resolved into new products. These changes require a due temperature, and the presence of moisture; for below the freezing point of water, or when perfectly dry, it undergoes no alteration.

During putrefaction the parts become soft and flabby, they change in colour, exhale a nauseous and disgusting odour, diminish considerably in weight, and afford several new products, some of which escape in a gaseous form, others run off in a liquid state, and others are contained in the fatty, or earthy residuum.

Antiseptics.

The presence of air, though not necessary to putrefaction, materially accelerates it, and those gases which contain no oxygen, are very efficient in checking or altogether preventing the process. Carbonic acid also remarkably retards putrefaction; and if boiled meat be carefully confined in vessels containing that gas, it remains for a very long time unchanged, as seen in Appert's method of preserving meat.*

Method of preserving meats, &c.

* This method is now successfully practised in England, upon the great commercial scale, for keeping beef, salmon, soups, &c. perfectly fresh and sweet for exportation. The process is as follows; Let the substance to be preserved be first parboiled, or rather, somewhat more, the bones of the meat being previously removed. Put the meat into a tin cylinder, fill up the vessel with seasoned rich soup, and then solder on the lid, pierced with a small hole. When this has been done, let the tin vessel thus prepared be placed in brine and heated to the boiling point, to complete the cooking of the meat. The hole of the lid is now to be closed by soldering, whilst the air is rarefied. The vessel is then allowed to cool, and from the diminution of volume, in consequence of the reduction of temperature, both ends of the cylinder are pressed inwards and become concave. The tin cases, thus hermetically sealed, are exposed in a test-chamber, for at least a month, to a temperature above what they are ever likely to encounter; from 90° to 110° F. If the process has failed, putrefaction takes place, and gas is evolved, which will cause the ends of the case to bulge, so as to render them convex, instead of concave. But the contents of those cases which stand the test will infallibly keep perfectly sweet and good in any climate, and for any number of years. If there be any taint about the meat when put up, it inevitably ferments, and is detected in the proving process.

For a variety of details and methods of preserving animal and vegetable substances see Ure's *Dict. Arts and Manuf.* 1045.

There are several substances which, by forming new combinations with animal matter, retard or prevent putrefaction, such as chlorine and many of the saline and metallic compounds; sugar, alcohol, volatile oils, acetic acid, and many other vegetable substances also stand in the list of anti-putrefactives, though their mode of operating is by no means understood.

Effect of the effluvia. 2266. The effluvia which arise from putrescent substances, and more especially those generated in certain putrid disorders, have a tendency to create peculiar diseases, or to give the living body a tendency to produce poisons analogous to themselves. An atmosphere thus tainted by infectious matter, may be rendered harmless by fumigation with the volatile acids, more especially the nitrous and the hydrochloric; chlorine is also very effectual: the vapour of vinegar, though sometimes useful in covering a bad smell, is not to be relied on. It appears evident that the acid and chlorine act chemically upon the pernicious matter, and resolve it into innocuous principles.

Fumigation.

Adipocere. 2267. When muscular flesh is immersed in a stream of running water, it is partially converted into a substance having many of the properties of fat combined with a portion of ammonia. The same changes have been observed where large masses of putrefying animal matter have been heaped together, or where water has had occasional access to it. Nitrate of ammonia is also sometimes formed under the same circumstances.

Section II. *Fibrin, &c.*

Fibrin. 2268. *Fibrin* is the principal part of muscular fibre, and is found also in the blood of animals. It is solid, tasteless, inodorous; has a whitish appearance; some elasticity, and is rendered hard and brittle by drying. Soluble in strong acetic acid, swelling at first, and forming a concentrated jelly.

Properties.

Action of acids. 2269. It is decomposed by strong and by diluted nitric acid, pure nitrogen being evolved from it when the acid is diluted; a yellow powder, called *yellow acid*, is formed during the reaction of the nitric acid. Berzelius has affirmed that it is a compound of nitric acid and fibrin after it has been affected by the acid. With sulphuric acid, a solution is procured, containing a peculiar white matter called *leucine;* the sulphuric acid is separated from it by chalk, the solution of the leucine being then filtered and evaporated. Diluted hydrochloric acid has little action on fibrin, and by the strong acid it is decomposed. Fibrine is also dissolved by concentrated solutions of potassa, soda, and ammonia, being at the same time decomposed. It is insoluble in water; alcohol converts it into a fatty matter.

2270. It is procured from muscular fibre by macerating it in water, or by stirring newly drawn blood with a stick, when it collects in considerable quantity upon it.

The analysis of fibrin affords carbon 53, hydrogen 7, nitrogen 19, oxygen 19.

Albumen. 2271. *Albumen*, 50 carb., 7 hyd., 15 nit., 26 oxy., is found abundantly in the solid form, and in solution in water, constituting in the latter case liquid albumen.

Solid Albumen.

2272. *Solid albumen* is found in the cellular membrane, and in a great number of other animal solids. *Liquid albumen* forms the white of the egg, and almost the whole of the serum of the blood. It is a thick fluid, distinctly alkaline from the presence of soda, combines with cold water, and is coagulated at 160° by heat; it is also coagulated by alcohol, by sulphuric, nitric, hydrochloric, metaphosphoric, and many other acids; by ferrocyanate of potassa after the addition of acetic acid; by bichloride of mercury, hydrochlorates of tin and iron, acetate of lead, and by the infusion of galls. Phosphoric and pyrophosphoric acids do not precipitate it. The coagulated albumen generally carries along with it a portion of the precipitating agent.

Properties.

2273. With bichloride of mercury, a precipitate of chloride of mercury and albumen is formed; or of the oxide of mercury, according to more recent investigation. Bichloride of mercury detects albumen in 2000 parts of water.* An excess of albumen dissolves those precipitates which are compounds of albumen and an oxide. It is also instantly coagulated by Voltaic electricity; and if two platinum wires connected with a small battery be immersed into diluted albumen, a very rapid coagulation will take place at the negative pole, and scarcely any effect at the positive pole.

Coagulated by Voltaic electricity.

2274. Albumen coagulated by heat, or by drying successive layers in the open air, resembles fibrine much, and can scarcely be distinguished from it by the action of tests. Berzelius states that it has no action on binoxide of nitrogen, but that fibrine produces a disengagement of oxygen.

Gelatine.

2275. *Gelatine*, 47 carb., 7 hyd., 16 nit., 27 oxy., is not found, like the preceding substances, in any animal fluids. It is obtained principally from skin, bones, membranes, ligaments, and tendons. *Isinglass* is a purer variety, which is prepared from the sounds of the sturgeon and other fish. It is solid, soluble in water, hot or cold; not coagulated by heat or acids; forms a solution which gelatinizes when cold, even when 100 parts of water are used with only 1 of gelatine. Tannin precipitates it copiously; the compound is called tanno-gelatine, and is of the same nature with leather, which is usually prepared by the action of tannin (derived from oak-bark) with the skins of animals. Glue consists of impure gelatine. Gelatine is insoluble in water; converted into a peculiar saccharine matter by sulphuric acid; not precipitated by bichloride of mercury or subacetate of lead.

Osmazome.

2276. *Osmazome* is found associated with muscular fibre and other animal matters; it is particularly distinguished by its solubility in water and alcohol at any temperature, and by not forming a gelatinous solid when its solution is evaporated. Osmazome is regarded as the matter which gives to broth its peculiar flavour.

SECTION III. *Bone, Muscle, &c.*

Bones.

2277. Bones contain about 33 per cent. of animal matter, and 67 of earthy substances. The animal matter is composed principally of gelatine and marrow or fatty matter. The following are the compo-

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* Bostock, in Nicholson's *Jour.*, xiv.

nent parts of the earthy matter in 100 parts of bones, omitting fractions :—

Analysis of bones.

Phosphate of lime, about	51 parts.
Carbonate of lime, ...	11 "
Fluoride of calcium, ...	2 "
Phosphate of magnesia, ...	1 "

Soda, chloride of sodium, and water in smaller proportion.
Silica and alumina, with
Oxides of iron and manganese, have also been detected.

Effect of heat.

2278. Exposed to heat in the open air, the animal matter is consumed, and the earthy substances alone left. Exposed to heat without access of air, ammonia, inflammable gases, oily matter, water, and other substances, are evolved, much of the carbon of the decomposed animal matter remaining with the earthy substances of the bone. In this condition it is termed *ivory black*, which is much employed as a decolourizing agent, charcoal from animal substances (2210) being very powerful in this respect. If the charcoal be required perfectly free from earthy matter, hydrochloric acid may be employed to dissolve it; and when it has been removed by solution, the remaining charcoal should be well washed, and heated to redness, before it is used to destroy animal or vegetable colouring matter.

2279. If bones be kept for some time in diluted hydrochloric acid, all earthy matter is removed, and the animal matter which remains retains the original form of the bone.

2280. Teeth are composed of the same materials as bones, but contain less animal matter.

Horns, &c.

2281. *Horns*, *hoofs*, *nails*, *tendons*, the *cuticle*, and the *true skin*, are composed principally of gelatine; horns contain also coagulated albumen, and a portion of earthy matter.

Hair.

2282. The *muscles* are composed principally of fibrine, with albumen, gelatine, osmazome, fatty, and saline matter.

Brain.

2283. *Hair*, *wool*, and *feathers*, are considered to contain a peculiar animal matter. Silica, sulphur, iron, manganese, and other substances, more particularly salts of lime, have also been detected in them.

2284. In *brain* and the matter of the nerves, 80 per cent. of water are found. Albumen, fatty matter, and osmazome, constitute the other principal ingredients. A variable proportion of phosphorus has also been detected, along with minute quantities of salts and sulphur.

SECTION IV. *Blood, Respiration, Animal Heat.*

Blood.

2285. The blood is a fluid slightly saline, unctuous, and has a peculiar odour. Sp. gr. 105, and temperature above 97° when newly drawn, or while circulating in the bloodvessels; it appears to be homogeneous, but by the microscope it is found to consist of a fluid almost without colour, in which numerous red particles are suspended.

2286. When removed from the bloodvessels, a halitus or vapour arises from the surface, composed of water and a little animal matter, and after a few minutes the whole mass gradually assumes a solid consistence. Shortly afterwards a few drops of yellowish fluid gather on the top, and, finally, the blood spontaneously separates into two parts, the clot or crassamentum, which is thick and solid, and the serum or fluid portion. From 2 to 3 parts of crassamentum are usually procured, with 1 of serum.

Coagulation of blood,

2287. The conversion of the fluid mass into the solid form is called the coagulation of the blood, and it commences within two or three minutes after its removal from the bloodvessels; the clot or coagulum, however, often continues to contract slightly for two or three days; it then assumes the form of a cup, and floats amidst the serum. The cause of the coagulation is not known; it has been attributed to a vital action, the blood being considered to have the property of vitality as well as the living solids. It indeed contains organized solids floating in a transparent medium.

Accelerated,

2288. The coagulation is accelerated by exposing the blood to a temperature of 120°, or drawing it from a small orifice into a shallow vessel.

2289. It coagulates quickly if the air be rapidly exhausted from the vessel in which it is received; and it has been observed to coagulate speedily in proportion to the depression of the vital energies, as, for instance, in hœmorrhage. Hence the blood last removed generally coagulates first. Alum, and the sulphates of zinc and copper, promote this change. The tint of coagulum is much affected by the colour of the vessel in which the blood is received.

Prevented.

2290. Saturated solutions of hydrochlorate of soda, hydrochlorate of ammonia, nitrate of potassa, and potassa, death arising from violent mental emotions, or preceded by severe exercise, prevent the process of coagulation. Low temperatures produce a similar effect, or retard it much; thus, blood which coagulates in five minutes at 60°, requires fully an hour at 40°.

2291. It has been stated that the blood does not coagulate in cases of death induced by lightning, but this has lately been contradicted. In animals killed by a powerful galvanic battery the blood has been found coagulated.

2292. Besides a particular exhalation from the blood, heat is evolved during coagulation. Carbonic acid gas was supposed to be disengaged; but it is not now considered that any of this gas is evolved.

Composition.

2293. The blood according to M. Le Canu, consists of the following substances in 1000 parts:

Water,	785.590
Fibrin,	3.565
Albumen,	69.415
Colouring matter,	119.626
Crystalline fatty matter, termed Seroline, (Cholesterine ?)	4.300
Oily matter,	2.270
Extractive soluble both in alcohol and water,	1.920
Albumen combined with soda,	2.010
Chlorides of sodium and potassium, with phosphates, sulphates, carbonates, of potassa and soda,	7.304
Carbonates of lime and magnesia; phosphates of lime, magnesia, and iron; peroxide of iron,	1.414
Loss,	2.586*

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* According to Gmelin and Tiedeman blood does not contain free carbonic acid. See their Researches on Blood in *Rec. of Gen. Sci.* 1. 56.

2294. Small portions of alumina, silica, and manganese, have been found in the blood, and even a minute trace of copper, by Sarzeau and O'Shaughnessy.

Peculiar volatile matter.

2295. Baruel maintains that the blood contains, in addition to the preceding principles, a volatile matter peculiar in each species, which is disengaged when the blood is mixed with strong sulphuric acid.

2296. The proportion of the different substances in blood varies at different periods of life, in different individuals, and in disease. The proportion also of the serum to the clot varies much from the shape of the vessel in which the fluid is received. The fatty matter has been regarded as Cholesterine.

Effect of bleedings.

2297. From experiments made on the changes produced in the composition of the blood by repeated bleedings, it appears that the albumen and salts decrease at each bleeding; the diminution is, however, very variable, and even after the fourth time does not amount to one and a half per cent. In the globules the same diminution takes place, but to such a degree that they are at least reduced to less than one-half their original quantity.

2298. The proportion of solid matter of the serum, and solid matter of the clot, is variously estimated, but Prevost and Dumas give the following relative quantities, in 1000 parts of human blood:—

Water, - - - - - -	784
Solid matter of crassamentum, - -	129
——————serum, - - -	87

Crassamentum.

2299. In the *Crassamentum* the principal solids are the fibrine and colouring matter of the blood, mixed with albumen derived from the serum. By washing in a cloth with water, all the colouring matter may be removed, the fibrine being left. The fibrine is found not only in the red globules, but also in solution in the serum, as it circulates in the living system.

Colouring matter.

2300. *Colouring matter of the blood.* Regarded formerly as depending essentially upon iron for its tint, which is attributed now to a peculiar animal matter resembling albumen, and called *Hematosine.* It differs from albumen in its colour, and is black when pure; it has a reddish colour when reduced to powder. It is more easily coagulated by heat than albumen, and is not precipitated by the acetate or subacetate of lead. It contains carbon, oxygen, hydrogen, and nitrogen, with a minute quantity of iron. It acts with other agents in the same manner as albumen.

Action of chlorine.

2301. When chlorine is transmitted through a solution of the colouring matter, a white flocculent matter is precipitated, and a transparent fluid is obtained, in which the iron may be detected by all the usual tests. Iron cannot be detected by the usual reagents, when dissolved in a solution containing organic matter.

Obtained.

2302. It is obtained by diluting a solution of colouring matter in albumen with 10 parts of water, and heating the liquid, when the colouring matter is separated by coagulation at the temperature of 149°, while albumen remains in solution till heated to 160°. It is also precipitated by several metallic oxides. A solution of the colouring matter in excess may be procured by stirring the clot in water, having drained it previously on bibulous paper, after cutting it in thin slices. The solution of colouring matter in albumen is procured by stirring newly drawn blood, so as to remove the fibrine.

Erithrogen.

2303. *Erithrogen* (from ερυθρος, ruber) is a term applied by Bizio to a peculiar animal principle obtained by him in a diseased gall-bladder, and which he considered as the base of the colouring matter of the blood. It is turned red by nitrogen.

Serum.

2304. The *serum* constitutes the fluid portion of the blood; it is of a pale yellow colour, with a slight tinge of green, and sometimes presents a milky appearance. Sp. gr. 1.030. It contains free alkali (soda.)

Effect of heat, &c.

2305. It is coagulated by heat, acids, alcohol, and by galvanism. On cutting and pressing the coagulum when produced by heat, a small quantity of colourless limpid fluid exudes, called the *serosity*, containing a considerable portion of the saline matter of the blood, and also a portion of animal matter.

Analysis.

2306. According to Marcet, 1000 parts of the serum consist of—

Water,	900.
Albumen,	86.8
Hydrochlorate of potassa and soda,	6.6
Muco-extractive matter,	4.
Carbonate of soda,	1.65
Sulphate of potassa,	0.35
Earthy phosphates,	0.60*

Respiration.

2307. Respiration consists in the inspiration and expiration of air, during which the air received into the lungs meets with the blood, when it changes from the dark purple colour of venous blood to the bright and brilliant red colour which it presents in the arteries. No difficulty is now entertained with respect to the air penetrating through the thin membrane of the cells of the lungs, as numerous experiments, particularly those of Mitchell† and Faust, have shewn that air can pass through membranous matter, and affect chemically the contents within.

Exp.

2308. The experiments on the diffusion of gases illustrate the passage of air through apertures impervious to water; while the movements that take place in different fluids separated by a membranous partition, also clearly prove the facility with which an interchange of principles can ensue with great force where it was not previously suspected. Dutrochet, who made many interesting experiments on this subject, found that a bladder filled with a sirupy fluid and placed in water, soon absorbed so much of the water that it burst, a portion of the viscid fluid also escaping through the pores.

Endosmose and exosmose.

Endosmose is the term applied to this peculiar action as it is observed in liquids, and *exosmose* to the passage of a portion of fluid from the interior to the other portion of liquid with which it may be surrounded; this exosmic movement always accompanies the endosmic action. The extensive surface on which the fluid is spread in the

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* A valuable paper on Blood and Chyle by Muller will be found in *Rec. of Gen. Sci.* i. 424.

†*Amer. Jour. Med. Sci. Philad.*

cells of the lungs, must be peculiarly favourable for the absorption of oxygen from the air by the blood, and the evolution of carbonic acid.

Effect of air, &c.

2309. Blood agitated with air or oxygen becomes of a florid red in the same manner as in the lungs; but with nitrogen and with carbonic acid the colour is darkened. The quantity of air affected appears to correspond with the amount of colouring matter in the blood. The presence of saline matter, as in the serum of the blood, is essential to the change of colour; it does not take place without it, however freely the air or oxygen may be supplied, as Stevens proved. The experiments of Gregory and Irvine have shewn that oxygen is necessary to induce the red tint in the globules diffused through serum, or any similarly diluted solution of saline matter, though the change may be produced in a strong saline solution without any oxygen. *Arterialization* is the term applied to the changes that are produced in the fluid derived from the food, as it is converted into blood.

Arterialization.

Oxygen removed,

2310. During respiration, the quantity of oxygen in the air is diminished, and in man it is replaced by an equal bulk of carbonic acid gas; in other animals, the quantity of this gas given out is occasionally observed to be greater, and sometimes less than the oxygen consumed. Every minute, it has been calculated by Allen and Pepys, 26 cub. inches of carbonic acid are produced, an estimate considered rather high by many chemists; the air given out from the lungs contains, according to other estimates, 3.6 per cent. of carbonic acid; according to them, from 6 to 8 per cent. of this gas.

And carbonic acid formed,

2311. The quantity of carbonic acid according to Coathupe is but 6.4 per cent. According to his recent experiments 460.800 cubic inches, or 266.66 cubic feet of air pass through the lungs of a healthy adult in 24 hours, of which 10.666 cubic feet will be converted into carbonic acid gas $=2386.27$ grs. or 5.45 ounces avoirdupois of carbon. This gives 99.6 grains of carbon per hour, produced by the respiration of one adult or 124.328 pounds annually.*

Its quantity.

2312. The experiments of Thomson, Prout, and Fyfe, shew that the quantity of carbonic acid evolved at different temperatures varies much under different circumstances, and even at different periods of the day.

2313. By a forced expiration, about 200 cub. inches of air may, on an average, be expelled from the lungs.

2314. The nitrogen of the air is little affected, apparently, by respiration; occasionally its quantity appears to be increased, and sometimes it is diminished, the effect varying with the seasons and other circumstances.

Animal heat.

2315. *Animal heat.* The discovery of carbonic acid in the air disengaged from the lungs during respiration, was made by Black. He considered respiration analogous to combustion, and that the carbonic acid is formed in the lungs. Crawford, adopting his views, believed that the capacity of the blood for caloric is increased at the moment the carbonic acid is produced, and hence the reason why no burning heat is perceived in the lungs; but the capacity of the

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* See Coathupe's experiments in *Lond. and Edin. Philos. Mag.* June, 1839.

Theories.

blood, he supposed, is diminished as it passes from arterial to venous blood in the extreme capillaries, when the heat that had originally been produced (though not rendered sensible in the lungs) is evolved, diffusing an equal degree of warmth over the whole body. His experiments, however, as to the relative capacities of oxygen, carbonic acid, venous, and arterial blood, on which the theory rests, have not been supported by other chemists.

2316. Ellis considered that carbon is separated from the blood as an excreted product, and then acts on the air inspired.

2317. Hassenfratz and Le Grange proposed another view of the manner in which the carbonic acid is produced, and it is most generally received at present. They considered that the oxygen of the air is absorbed by the blood, and a corresponding quantity of carbonic acid evolved, produced during the course of the circulation by the oxygen which had been previously absorbed. Carbonic acid gas has been detected in venous blood, being evolved when it is transferred directly from the living body into an atmosphere of hydrogen gas.

2318. The skin affects the air much in the same manner as the lungs, carbonic acid being produced and oxygen consumed.

2319. In some animals, respiration is carried on entirely by the skin, and a considerable quantity of carbonic acid evolved.

Black's theory.

2320. The production of animal heat was considered by Black to depend upon the formation of carbonic acid by the oxygen of the air combining with the carbon of the blood. Numerous experiments have now proved, that the greater the heat produced in the body, the greater the consumption of oxygen in the lungs; it is also supposed that this operation is not the only source of animal heat, but that it may be developed in part by other operations going on at the same time.

Effect of disease.

2321. By disease, blood is much altered in its properties. In cases of cholera it is very much affected; its colour becomes dark, sometimes it acquires the consistence of tar, and is less readily affected by the oxygen of the air. It loses much water, and most of its saline matter, the proportion of albumen and colouring matter being increased. Its density is greater, and it does not coagulate.

2322. Blood occasionally presents a white appearance, owing to the presence of fatty matter in considerable quantity, which is detected by ether dissolving it, and giving a solution, from which it may be procured by evaporation.

Buffy coat.

2323. In cases of inflammatory action, the crassamentum is covered with a coat of pure fibrin, usually called the buffy coat. This arises from the blood being so altered in its qualities, that the fibrin it contains in solution coagulates more slowly than the rest of the blood, and part of it is deposited above the red clot. The red globules of the blood, are considered heavier than pure fibrin, consisting of a small portion of colourless fibrin in the centre, which is surrounded by the colouring matter of the blood. When the blood is removed from the body, and the colouring matter escapes from the globule, the fibrin from the centre adheres firmly together.

Effects of disease on blood.

2324. The blood is affected to a great extent in a number of other diseases, though this may not in general be so easily recognised as in the preceding cases, chemical analysis being required to point out the change. Occasionally, however, the change is sufficiently evident, as in jaundice, when the blood acquires a greenish-yellow tint in consequence of the absorption of bile. The black vomit observed in yellow fever is regarded as a compound of blood and hydrochloric acid. Urea is frequently observed in the blood, more especially in those cases when the secretion of urine is suppressed.

SECTION V. *Salivary, and Gastric Juices, Bile.*

Saliva.

2325. The *Saliva* contains a small quantity of solids in *solution*, scarcely amounting to 1 per cent. The solid matter is composed of a peculiar animal matter and saline substances, among which free soda and sulphocyanate of potassa have been detected. It varies, however, in its composition, and has been frequently observed acid, neutral, and alkaline.

Pancreatic juice,

2326. *Pancreatic juice.* Regarded formerly as being of the same nature with saliva, though now considered very different, containing a little albumen, curdy matter, osmazome, a free acid (acetic?), but no sulphocyanic acid is present.

Gastric juice,

2327. *Gastric juice.* This fluid is secreted in its proper form only from the stimulus of food, when hydrochloric acid may be distinctly traced in it, to which the great solving powers which it possesses are attributed; acetic acid is also associated with it. The hydrochloric acid is probably derived from common salt, and to the soda produced, as the hydrochloric acid is removed, the alkaline reaction of the blood may perhaps be attributed. The stomach itself is supposed to be defended from the action of the corrosive acid by assuming a peculiar electric condition. In cases of sudden death, the stomach is often found corroded in consequence of the action of the acid on its fibres. Gastric juice acts powerfully in coagulating milk.

Its action on food.

2328. The gastric juice acting on the food produces a pulpy mass, termed chyme, from which, in the intestines, a milky fluid, the chyle is absorbed; this contains the nutritious matter derived from the food, and is conveyed to the heart, and thence to the lungs, where it acts with the air, and is converted into arterial blood.

Bile.

2329. *Bile* is a greenish-yellow coloured fluid, generally rather viscid, having a sweetish bitter taste and nauseous odour. Heavier than water, alkaline; coagulated by acids.

Thenard regards the bile of the ox as a compound of about 7 parts of water and 1 of animal and saline matter, composed of—

- Picromel.
- Resin.
- Yellow matter.
- Soda.
- Phosphate of soda.
- Hydrochlorate of soda.
- Hydrochlorate of potassa.
- Sulphate of soda.
- Phosphate of lime.
- Magnesia and oxide of iron.

The saline matter constitutes a small proportion of the ingredients.

Cholesterine, an odoriferous animal matter, and another peculiar animal matter, osmazome, gluten, cholic acid, and some fatty sub-

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* See experiments of Tiedemann and Gmelin in *Ann. de Chim.* lix. 348.

stances, have also been found in bile. In human bile, similar ingredients have been detected.

Picromel.

2330. *Picromel.* Solid, crystalline, soluble in alcohol and water; taste sweet. Prepared from bile by precipitating sulphuric acid and some other substances by acetate of lead, then adding subacetate of lead, the oxide falling down with the picromel and resin. By hydrosulphuric acid acting on the precipitate suspended in water, sulphuret of lead is formed, being left undissolved along with the resin; the picromel remains in solution.

Cholic acid.

2331. *Cholic Acid* is solid, crystalline, reddens litmus, and has a sweet taste. *Biliary Calculi* are composed principally of cholesterine, and the colouring matter of the bile. Sometimes they contain no cholesterine.

Cholesterine.

2332. *Cholesterine* is white, crystalline, with a pearly lustre. Melts at 278°; does not form a soap with potassa. Insoluble in water; dissolved abundantly by boiling alcohol; sparingly soluble in cold alcohol. By the action of nitric acid, cholesteric acid is produced.

Section VI. *Milk and Chyle.*

Milk.

2333. *Milk* contains the following substances, of which the first, water, constitutes nearly 929 parts in 1000:—

Water.
Butter.
Caseous matter.
Sugar of milk.
Lactic acid.
Hydrochlorate of potassa.
Acetate of potassa.
Phosphate of potassa.
Phosphate of lime.
Traces of iron.

Cream.

2334. *Cream* contains rather more than 3 per cent. of caseous matter, and 4 of butter, the rest being whey.

Whey.

2335. *Whey* consists principally of water, with small portions of animal matter, and a large quantity of a peculiar saccharine matter, called sugar of milk, which may be procured by evaporation.

Butyrine.

2336. *Butyrine* is the name given to oily matters which constitute butter.

Caseous matter.

2337. *Caseous Matter* is the curdy substance obtained from milk coagulated by rennet, the infusion made by the action of water upon a portion of the stomach of the calf, which is powerful in coagulating milk. It always contains in this condition some foreign matter associated with it, being soluble in water when pure, and forming a mucilaginous solution. Sulphuric, nitric, hydrochloric, and other acids; alcohol, the infusion of galls, and a variety of other substances, coagulate milk by combining with the caseous matter.

2338. Caseous matter is maintained by some chemists to contain two distinct principles, *caseic acid*, and *caseous oxide of aposepidine.* Others again regard it as approaching very nearly to coagulated albumen in its leading characters.

Chyle.

2339. *Chyle* is the milky looking fluid taken up from the chyme. It approaches in its characters to blood, but has only a slight pink tint, and contains less solid matter. It forms a less firm crassamentum during coagulation, and from its serum a flocculent precipitate is obtained by heat, termed by Prout incipient albumen. The chyle of two dogs analyzed by him contained from 89 to 94 of water, the rest being fibrin, incipient albumen, albumen with a slight pink tint, and minute quantities of sugar, and oily and saline matters.

SECTION VII. *Oleaginous and Fatty Substances.*

2340. These resemble much in all their leading characters the fixed oils of vegetables. *Stearine* is found in most of them associated with variable proportions of oleine. Berard prepared a substance very similar to fat, by passing through a red-hot tube a mixture of carbonic acid, carburetted hydrogen, and hydrogen. Dobereiner succeeded in producing an analogous compound with coal gas and watery vapour.

Stearine. 2341. *Stearine* is obtained with facility in brilliant crystals when deposited from a hot ethereal solution. It is very soluble in hot ether, sparingly soluble in cold ether. It is also soluble in boiling alcohol. Melts at 129°. Prepared by boiling mutton suet in ether, after melting it to separate any membranous matter, and removing the adhering solution from the crystals by bibulous paper; this process is repeated with the crystals several times. Similar processes may be adopted in preparing stearine from other fatty matters.

2342. When boiled with a solution of potassa or soda, it is resolved into stearic acid and glycerine. The stearic acid may be separated by neutralizing the alkali with sulphuric acid (1690).

Margarone. 2343. *Margarone* is the name given to another fatty matter very similar to stearine, but more soluble in ether, and melting at 117°. It is procured by allowing the matter separated from the stearine (1693) to evaporate and crystallize spontaneously.

Olein. 2344. Olein is obtained by pressing lard in bibulous paper, to which it adheres. It is similar to that procured from vegetable substances.*

Ambergris. 2345. Ambergris is considered to be a concretion produced in the stomach of the spermaceti whale. It is found floating on the sea coast of India and Africa. It consists principally of a peculiar fatty matter, called ambreine, which resembles cholesterine.†

Dippel's oil. 2346. *Dippel's Oil* is the name given to a thin limpid oil, the product of the destructive distillation of animal substances.

Fat, hogs-lard, and suet. 2347. *Fat, Hogs'-lard* and *Suet*, are compounds of stearine and oleine in various proportions; they melt at various temperatures between 59° and 102°. The stearine and oleine differ often in the fat obtained from different animals.

Hircine. 2348. *Hircine* is procured from the fat of the goat and sheep.

Spermaceti. 2349. *Spermaceti* is prepared from the fatty matter found in the head of the spermaceti whale. Solid, white, crystalline, insoluble in water, soluble in ether and alcohol. Melts at a temperature below 212°. It is usually mixed with a little fluid oil, and is termed *cetine* when purified by solution in boiling alcohol and crystallization. *Ethal* is a solid fatty matter which remains after the separation of margaric and oleic acids; boiling cetine with potassa or soda, so as to produce soap.

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* *Adipocire*. See 2267.

† *Cholesterine*. See Bile.

2350. *Spermaceti Oil* is the fluid expressed from the fatty matter from which the spermaceti is obtained.

Train oil.

2351. *Train oil* is procured by heating blubber to 212°. Its offensive odour arises from decomposed animal matters which are mixed with it.

SECTION VIII. *Mucus, Pus, &c.*

Mucus.

2352. *Mucus.* The existence of a distinct principle to which this name has been applied is doubtful. The mucus described by Bostock is soluble in hot and cold water, and does not gelatinize. Tannin and bichloride of mercury do not precipitate it. The mucus of the nose is rendered transparent by water, but not dissolved. It is dissolved by nitric acid, dilute sulphuric acid, and potassa.

Pus.

2353. *Pus* varies much in its qualities, according to the nature of the source from which it is produced. Healthy pus is a bland, thick fluid, apparently homogeneous, but composed of a thin transparent fluid, with opaque globules floating in it. Sp. gr. 1.030. Neutral, but becomes acid by the action of the air. Soluble in sulphuric, nitric, and hydrochloric acids, and in alkalies. Ammonia produces a gelatinous mass with it.

2354. The following are the principal tests which have been proposed for distinguishing pus from mucus :—

Tests of mucus and pus.

TESTS.	MUCUS.	PUS.
Mixed with an equal weight of water, and then with an equal weight of a saturated solution of carbonate of potassa,	does not gelatinize.	produces a jelly.
Diffused through water.	from a catarrh, it floats.	precipitated.
Dissolved in potassa, and water added,	not affected.	precipitated.
Dissolved in sulphuric acid, and water added.	remains suspended in the water.	precipitated.

Fluid of serous surfaces.

2355. *Fluid of Serous Surfaces.* Composed principally of water, with small portions of albumen, mucus, and saline matter. The lymph which lubricates the cellular membrane is considered of analogous composition. Small portions of lactic acid are also found in it.

Lactic acid.

2356. *Lactic acid* has been found in most animal fluids, and in a number of vegetables; it was first obtained from sour milk, from which its name is derived. Its concentrated solution is sirupy, very acid, and can displace acetic acid from its combinations. It is prepared by evaporating solutions containing it to a sirupy consistence, extracting the lactic acid by alcohol. By combination with oxide of zinc, separating it afterwards by baryta, and ultimately removing the baryta by sulphuric acid, it is obtained in a pure form.[*]

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[*] *Formic Acid* has been already described (1610).

SECTION IX. *Urea—Uric Acid.*

Urea.

2357. Urea has been already described (1742). According to Cass and Henry it does not exist in urine uncombined, but united with different acids in different beings; in man combined with hippuric acid, in serpents and birds with lithic acid, or at least with the peculiar acid, which, according to Liebig, is its radical.*

Uric or lithic acid prepared.

2358. *Uric* or *Lithic Acid* may be prepared from calculi of uric acid, or from the uric acid deposited from acidulated urine, by dissolving it in a solution of potassa, and adding an acid to precipitate it from the urate of potassa.†

Purpuric acid.

2359. *Purpuric Acid* is white when pure, and is particularly distinguished by the brilliant coloured purple compounds which it forms with several of the salifiable bases. Formed in combination with ammonia by the action of nitric and uric acids. The ammonia may be displaced by potassa, and the purpuric acid precipitated by adding sulphuric acid to combine with the potassa. The erythric acid of Brugnatelli, and the sediment often deposited from urine in fevers, and called at one time *rosacic acid*, are considered by Prout to be composed of purpurate of ammonia.

Cyanuric acid.

2360. *Cyanuric Acid*, called also *Pyrouric Acid*, is formed when uric acid is heated, or by the action of chlorine on different compounds containing cyanogen and water. Urea also may be made to produce this acid (1761).

2361. A peculiar colouring matter, not containing any purpuric acid, has also been discovered in the urine.

Urine.

2362. *Urine* is a transparent limpid fluid, of an amber colour; sp. gr. 1.0224,‡ when recently discharged it has an acid reaction, but after a short time it acquires decided alkaline properties. The following are the component parts of urine, according to Berzelius, in 1000 parts:—

Analysis.

Water,	933.00
Urea,	30.10
Uric acid,	1.00
Free lactic acid, and lactate of ammonia with animal matter,	17.14
Mucus of the bladder,	0.32
Sulphate of potassa,	3.71
" soda,	3.16
Phosphate of soda,	2.94
Phosphate of ammonia,	1.65
Hydrochlorate of soda	4.45
" ammonia,	1.50
Earthy matters with a trace of fluate of lime,	1.00
Siliceous earth,	0.03

Sulphur, phosphorus, and albumen, are also found, but in very small quantities. In children, and also in graminivorous animals, a considerable amount of benzoic acid may be detected. Its sp. gr. varies very much, both in health and disease.

Decomposed.

2363. Urine is quickly decomposed spontaneously; and as the

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[*] *Jour. de Pharm.* March, 1839, and *Edin. Philos. Mag.* Aug., 1839.

[†] See Thomson in *Rec. of Gen. Sci.* ii. 3.

[‡] 1.0128, Thomson.

urea is resolved into carbonate of ammonia, phosphate of lime and phosphate of ammonia and magnesia are deposited.

2364. From disease the urine is often much changed in its qualities; the following are the principal alterations.

Deposition of Calculi, &c.

2365. The urine often becomes so loaded with different materials, that much is deposited in the solid form before it is discharged, giving rise to the production of urinary sand or calculi, according to the cohesion of the precipitated matter.

Uric acid,

2366. *Uric Acid Calculi* are of a brownish-yellow colour, and generally consist of different layers of acid. They are decomposed by heat, soluble in potassa, produce purpurate of ammonia by nitric acid. In most calculi, small portions of uric acid may be detected. An excess of uric acid, or the decomposition of urate of ammonia by other acids, are considered the principal causes of the deposition of uric acid.

Urate of ammonia,

2367. *Urate of Ammonia Calculi* have a clay colour; evolve ammonia when heated with potassa. With the other agents mentioned in the preceding paragraph, the same phenomena are produced as with uric acid calculi.

Oxalate of lime,

2368. *Oxalate of Lime Calculi* are rough and tuberculated on the surface. Heated to dull redness they produce carbonate of lime. Heated to whiteness nothing is left but quicklime. With sulphuric acid, sulphate of lime is formed, and then the oxalic acid may be separated in solution by water.

Phosphate of lime,

2369. *Phosphate of Lime Calculi.* Not decomposed by heat; insoluble in potassa; soluble in diluted nitric or hydrochloric acid; give no ammonia when heated with potassa; not dissolved by cold acetic acid.

Phosphate of ammonia and magnesia,

2370. *Phosphate of Ammonia and Magnesia Calculi* evolve ammonia when heated alone, or with potassa. Not dissipated by heat, though the ammonia is expelled. Soluble in diluted nitric and hydrochloric acids; soluble also in cold acetic acid.

Fusible,

2371. The *Fusible Calculus* is a mixture of phosphate of lime with phosphate of ammonia and magnesia. It is melted by heat. Cold acetic acid dissolves the phosphate of ammonia and magnesia, but does not affect the phosphate of lime.

Carbonate of lime,

2372. The *Carbonate of Lime Calculus* is distinguished in the same manner as common carbonate of lime. A portion of animal matter is generally blended with it. A calculus composed of oxalate and carbonate of lime has lately been noticed. Both these varieties, however, are extremely rare.

Alternating,

2373. The *Alternating Calculus* consists of alternate layers of some of the preceding calculi. *Siliceous Gravel* has occasionally been noticed in some urinary complaints. It is not affected by heat, is insoluble in acids, fuses with alkalies added in excess, and produces silicated potassa.

Cystic oxide,

2374. *Cystic Oxide Calculi* contain a peculiar animal matter, cystic oxide, which is soluble in acids, alkalies, alkaline carbonates, and lime-water. *Xanthic Oxide Calculi* consist of another peculiar animal matter. With nitric acid it produces a lemon-yellow coloured compound.

Fibrinous calculi.

2375. *Fibrinous Calculi* are composed of fibrin. The last three

Addenda.

varieties of calculi are extremely rare, and are decomposed by heat, in the same manner as other animal substances.

2376. The uric acid and the phosphate of ammonia and magnesia calculi, are those most frequently observed.

Production of Sugar, Albumen, &c.

2377. Sugar is found in considerable quantity in the urine of individuals affected with diabetes; 6 per cent. of sugar may often be procured from it. Kane obtained a still larger quantity. Albumen is often found in large quantity in the urine of individuals affected with some varieties of dropsy, coagulating when exposed to heat like the serum of the blood. In some cases it has coagulated even within the bladder.

Urea detected.

2378. *Urea* is sometimes found in excess in urine. Prout states, that, when this is the case, nitric acid added in an equal bulk to a few drops of urine in a watch-glass, produces a crystalline precipitate of nitrated urea in half an hour. Healthy urine produces it more slowly. It is not absent in diabetic urine, as was at one time supposed.

2379. In some diseases of the liver, the urine becomes tinged with bile, and has a deeper yellowish tint than usual. Hydrochloric acid produces a green tint in urine charged with bile. R. 179.

ADDENDA.

Radiation of caloric.

Radiation of Caloric. The late experiments of Melloni have afforded results which do not confirm the deductions of Leslie (215) in regard to the influence of the state of surfaces upon radiation. A square vessel was made out of a block of marble, the sides of which were of uniform thickness, and the external surfaces were differently prepared. The first was smooth and brilliant; the second was equally smoth, but unpolished, and tarnished; the third was streaked in one direction; and the fourth in two, crossed at right angles. The vessel was then filled with hot water, and projected the same quantity of radiating caloric from each of the four sides. Experiments with metallic surfaces were attended with a much more abundant emission of caloric from streaked surfaces than from polished; this is attributed by Melloni to a change of hardness or density, in consequence of the mechanical compression. A surface of cast silver had nearly one third more radiating power than one of the same metal forged, and the radiating power of the latter was increased four fifths by roughening with emery, while that of the former was diminished nearly one fifth.*

Influence of colour on absorption of odours.

Influence of Colour on Absorption of Odours. Some important observations have been made by Stark† on the influence of colour on the absorption and disengagement of odorous matters. He found that white bodies are the least absorbent, and dark the most so; and has made several important applications of the results of his experi-

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* *Edin. Philos. Jour.* xxvi. 299.

† *Phil. Trans.* 1833.

ments in respect to clothing, white-washing, the retention of noxious effluvia by different coloured bodies, and the consequent communication of disease.

Compound blow-pipe.

Compound Blow-pipe. The notice of Hemming's safety tube was inserted (128) after the apparatus had been subjected to severe trials, the results of which fully warranted its recommendation as a valuable addition to the compound blow-pipe. Since then an explosion of the mixed gases has occurred in a strong copper globe to which the safety tube was attached. The tube being uninjured and still arresting explosion as perfectly as before, the cause of the occurrence cannot be attributed to its imperfection; while it furnishes additional caution not to mix the gases prior to their combustion. The student should also bear in mind that explosion may occur, even when the gases are contained in separate vessels, from unequal pressure; an accident which Dr Torrey informs me he has experienced, the jet becoming clogged at the outlet, and a portion of the gas under the greatest pressure being forced into the vessel containing that under less pressure. This, however, can never occur when the double concentric jet (Fig. 129), as contrived by me, is used, the two orifices of the conical extremity being in the *same plane*—in the jet where the two orifices open into *one* common outlet, (as in Fig. 128 *e*,) the accident may occur.*

Photographic drawing.

Photographic Drawing. Paper may be prepared with a solution of bichromate of potassa, instead of the silver salt (1247), which acquires a deep orange tint on exposure to the sun. The paper should be well soaked in the saturated solution of the salt, dried rapidly at a brisk fire, excluding it from day-light. Paper thus prepared is sufficiently sensitive for taking copies of prints, dried plants, &c. The portion covered by the object retains the original bright yellow tint, and the object is represented yellow upon an orange ground. To fix the drawing, it is to be carefully immersed in water, by which the portions of the salt that have not been acted upon by the light are dissolved out, while those which have been exposed to it are fixed in the paper. The object then appears white upon an orange ground.

A pleasing variety may be made by using sulphate of indigo with the bichromate of potassa, the colour of the object and of the paper being then of different shades of green.†

Daguerre's method.

A method of fixing images of objects upon metal has been recently made known by Daguerre. A plate of silvered copper, well cleaned with dilute nitric acid, is exposed to the vapour of iodine, and an extremely thin coating of iodide of silver is formed. Several precautions are required to render the coating uniform, the chief of which is the use of a rim of metal round the plate. The prepared plate is placed in a *camera obscura* and allowed to remain from eight to ten minutes. It is subsequently exposed, at an angle of 48°, to the vapour of mercury, and when it has been heated to 167° F. the images appear. The plate is then exposed to the action of hyposulphite of soda and finally washed in a large quantity of distilled water.‡

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* See an account of this explosion in *Amer. Jour.* xxxvii. 104.

† Ponton in *Trans. Soc. Arts, Scotland,* May, 1839.

‡ See *Jour. Franklin Inst.* xxiv. 207.

Addenda.

Detection of Iodine and Bromine.

Detection of Iodine and Bromine. Schweitzer has very recently described a method of ascertaining the proportion of iodine and bromine in water, by which he obtained from 100,000 grs. of the water of the Congress spring of Saratoga 0.12164 gr. of iodide of silver, representing in 1000 grs. of the water 0.00067 gr. of iodine. Schweitzer recommends an ammoniacal solution of chloride of silver, prepared by mixing one part of a saturated solution of recently precipitated chloride of silver in ammonia with one of liquid ammonia (sp. gr. 0.935) and two parts water. If to a concentrated solution of chloride of sodium containing one thirtieth part of a bromide, a few drops of this solution be added, the solution of chloride of sodium will remain clear, but if the most minute particle of an iodide be present, it will be rendered turbid. For the method of examination for bromine, and of analysing sea-water, see *Lond. and Edin. Phil. Mag.* July, 1839.

The quantity of iodine in sea-water is very minute, 174 pounds Troy not containing one grain.

The following is a comparative analysis of sea-water:

	*Sea-Water of the British Channel.** Grs.	*Of the Mediterranean.*† Grs.
Water	964.74372	959.26
Chloride of sodium	27.05948	27.22
" potassium	0.76552	0.01
" magnesium	3 66658	6.14
Bromide of magnesium	0.02929	——
Sulphate of magnesia	2.29578	7.02
" lime	1.40662	0.15
Carbonate of lime	0.03301	{Carbonate of lime and magnesia.} 0.20
	1000.00000	1000.00

Very beneficial results in scrofulous diseases are stated by Schweitzer to have followed from the internal and external use of the waters of several saline springs in Germany, concentrated by evaporation.

Oxide of Phosphorus.

Oxide of Phosphorus. M. Botger has found that sulphuret of carbon is the best solvent of phosphorus, dissolving 20 parts at mean temperature, while the oxide of phosphorus is not acted upon by it. To separate the oxide he directs to put the impure oxide, obtained by combustion, into a large bottle, pour sulphuret of carbon upon it with an equal measure of absolute alcohol; cork the bottle, and shake it well for about a minute, then allow the oxide to subside, and pour off the phosphorized liquor; repeat this operation with a fresh portion of the sulphuret and alcohol, and then put the oxide of phosphorus on a filter, and wash it first with alcohol, and then with water; after this dry it by exposure to the air, or, what is better, under a receiver with sulphuric acid.

The product resists combustion at a high temperature; with chlorate of potassa it produces a strongly detonating powder, violent explosion taking place even during mixture without much pressure. According to Pelouze, the oxide obtained by combustion and purified by distillation, is P_3+O, while that procured by the decomposition of the chloride (565 note) consists of P_4+O.‡

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* By Schweitzer. † By Laurens.

‡ *Jour. de Pharm.* Feb., 1839, and *Lond. and Edin. Phil. Mag.* July, 1839.

Detection of nitric acid.

Detection of Nitric Acid. Richemont has proposed a method of much delicacy of detecting nitric acid, depending on the fact that a mixture of a concentrated solution of protosulphate of iron and sulphuric acid becomes rose-red by the addition of deutoxide of nitrogen, or purple, if the latter is present in larger proportion; the quantity of the deutoxide required is so small, that an exceedingly minute portion may be detected by it. A small quantity of sulphuric acid is added to the solution to be examined, the latter being equal to three fourths of the bulk of the former. When the mixture has cooled, drop in a concentrated solution of protosulphate of iron, which, if any nitric acid is present, decomposes it, causing the evolution of nitric oxide, which produces the rose-red or purple tint. This mode of operating detects one part of nitric acid in 24.000 of water.*

Detection of nitrogen.

Detection of Nitrogen. Mix the gas under examination with from 3 to 6 times its volume of a mixture of oxygen and hydrogen (in equal vols.), and detonate the whole in a eudiometer by the electric spark. Mix the fluid that bedews the eudiometer after the explosion with sulphuric acid, to which a few drops of protosulphate of iron in solution have been added, the fluid will assume the rose-red tint if the minutest portion of nitrogen is present. It is of course necessary to avoid any source of fallacy arising from the presence of atmospheric air in the oxygen and hydrogen employed.†

Traill's indelible ink.

Indelible Ink. A solution of the gluten of wheat in pyroligneous acid, has been recommended by Traill, as an indelible ink. He directs the gluten to be separated from the starch as completely as possible, and when recent to be dissolved in the acid with the aid of heat. This forms a saponaceous fluid which is to be tempered with water until the acid has the usual strength of vinegar. Each ounce of the fluid is then to be ground with from 8 to 10 grains of the best lamp-black, and 1½ gr. of indigo.‡

Salts of baryta and strontia.

Salts of Baryta and Strontia. According to Smith these salts are distinguished by the action of chromate of potassa and acetic acid. It is only necessary to add to a solution of the salt, a solution of chromate of potassa, which, if baryta be present, will produce a light yellow precipitate insoluble in acetic acid. This reagent will also serve to distinguish baryta from lime.§

Ethyle.

Ethyle. When small pieces of potassium are placed in a glass tube 3 to 5 lines wide, containing chloride of ethyle, a powerful action ensues, and the metal becomes covered with a white crust, which should be broken up so as to cause a fresh metallic surface to be exposed to the action of the fluid. The mixture soon begins to boil, and chloride of ethyle distils over. A tube bent at right angles should be fixed in the mouth of the large one to connect it with a receiver kept cool by a freezing mixture. If sufficient chloride of ethyle is present, all the potassium is converted into the white crust, which is dissolved by water with the disengagement of hydrogen

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* *Lond. and Edin. Phil. Mag.* xiii. 393.

† Richemont, *Ibid.*

‡ *Edin. Philos. Jour.* xxv. 213.

§ J. L. Smith, in *Amer. Jour.* xxxvi. 183. See also a method by Rose, in *Lond. and Edin. Phil. Mag.* Jan., 1839.

gas. On agitating the watery solution with ether and decanting the ethereal solution, a volatile oily fluid is obtained by evaporating *in vacuo* at a low temperature. This fluid burns vividly, has a peculiar odour, and very acrid taste.

The white powder consists of C_4H_5. From these experiments Löwig concludes, that by the action of potassium on chloride of ethyle, chloride and *ethylide* of potassium are formed, the latter combination being decomposed by the action of water, setting free the ethyle, either pure or as a hydrate.*

Diastase. *Diastase*, is the name given to a substance extracted from malted barley, and which may be applied to important purposes in domestic economy. It is obtained by macerating the ground malt in cold water for some time. It is then pressed and the liquid filtered, and heated to 158°. The coagulated portion is separated and the liquid being again filtered is mixed with a sufficient quantity of alcohol to throw down the diastase, the diastase is again dissolved in water and thrown down by alcohol, and this is to be repeated several times.

Diastase is solid, white, insoluble in water, but soluble in dilute alcohol. Its solution separates amidin from all starchy substances containing it, hence its name.† It exists in the seeds of malted barley, oats and wheat. One part is sufficient to render soluble the interior portion of two thousand parts of starch, and to convert it into sugar.

To prepare it upon a large scale, 850 lbs. of water are heated to 86°, 10 parts of ground malt are then added and the heat raised to 140°; 220 lbs. of flour are then added and the whole well mixed. When the temperature has risen to 158° we should endeavour to keep it steady at that point, or at least not to allow it to cool below 150°, nor to rise above 167°. In twenty minutes the liquid becomes more transparent, and from being viscid and thready at first, it becomes almost as fluid as water. When this happens the temperature should be suddenly raised to 212°. The whole is then left at rest, the clear portion drawn off, filtered and evaporated by means of steam at 230°, the scum being removed. When sufficiently concentrated, it is poured into a receiver of tin plate or wood, and on cooling it coagulates into an opaque jelly.

While hot, if it be mixed with yeast and kneaded into the dough; it serves well for the preparation of bread.

If spread out in thin layers and dried in the air, or by a stove, we obtain *dextrine*, which being reduced to powder, may be introduced into all kinds of pastries, chocolate, bread, &c.‡

Dextrine. *Dextrine* dissolved in diluted alcohol has been lately recommended as a temporary varnish for oil paintings, preventing the imbibition of colours, even when employed a few days after the finishing of the picture. Applied with a soft brush, it gives a clearness like a light varnish, which can be removed by a moist sponge, when, after a few months, common varnish may be applied with its ordinary effect. The same solution serves as a perfect varnish for water colours, and

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* Poggendorff, *Ann.* 45, p. 347, and *Lond. and Edin. Phil. Mag.* July, 1839.

† From διιστημι, *to separate.*

‡ T. *Org. Bod.* 666.

for fixing pencil and crayon drawings. The solution of dextrine, in about an equal portion of warm water, furnishes a paste which remains liquid and possesses great energy. It may be advantageously used as a substitute for the greater number of common pastes.[*]

Nature of ferment, or yeast.

Nature of Ferment, or Yeast. The following results have been given by M. Cagnard-Latour.[†] Yeast is a mass of small globular bodies capable of self-reproduction, and of course oxygenized, and not an inert or purely chemical substance. These bodies appear to belong to the vegetable kingdon, and are generated in two different modes. They appear to act upon a solution of sugar as if they were alive, whence it may be inferred, that it is in all probability by some effect of their vegetation that they disengage carbonic acid from this solution and thus convert it into a spirituous liquor.

In a valuable memoir by T. A. Quevenne,[‡] the author arrives at the following conclusions:—1st. Yeast is a substance which constantly presents the appearance of little globules of nearly uniform figures. 2d. These globules appear to be always of the same nature, whatever their origin. 3d. It is the insoluble constituent part of these globules which is apt to produce fermentation, and not the extractive matters which accompany it. 4th. The globules of yeast can effect the decomposition of sugar not only at a temperature from 10° to 30° or 40° Cent. (50° to 86° or 104° F.), but even at the heat of boiling water; but, with this difference, that at a temperature inferior to 50° they transform the sugar into alcohol and carbonic acid, while above 50° (= 122° F.), alcohol appears not to be formed; the only gas obtained in either case is carbonic acid. 5th. Yeast, during the alcoholization of sugar, undergoes a thorough modification. It loses all its nitrogen, which goes to form ammonia, by which means its fermentative power is completely exhausted. 6th. The globular aspect of yeast, and its principal chemical properties, are sufficient to induce us to regard it as an organic substance of new formation; and hence fermentation ought not to be considered merely as a decomposition, but simply as a modification which gives birth at one and the same time to products both organic and inorganic. 7th. The circumstances under which fermentation takes place, and the phenomena which accompany it, and the influence which a great number of bodies have over the progress of the operation, are of a nature to induce the belief that it is actually owing to a sort of vegetation, but this proposition requires additional proof.[§]

Respiration of plants.

Respiration of Plants. Edwards and Colin have instituted experiments upon the respiration of plants from which they have drawn the following results:—1st, that water is decomposed; 2d, that the oxygen of the decomposed portion, unites with the carbon of the seed, and forms carbonic acid gas; 3d, that this carbonic acid disengages itself from the seed, in whole or in part; and 4th, the other portion of the decomposed water, the hydrogen, is absorbed by the seed, in whole or in part. They also infer from their experiments that respiration is not, as it has been hitherto considered, solely a function of excretion.[‖]

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[*] *Jour. Franklin Inst.* xxiv. 114.

[†] *Comptes rendus de l'Instit.*, 1837, 906.

[‡] *Jour. de Pharm.* Juilliet, 1838.

[§] See *Jour. Franklin Instit.* xxiii. 119.

[‖] *Ann. des. Sci. Nat.* Dec., 1838, and *Edin. Philos. Jour.* July, 1839.

Addenda.

New compound of bicyanide with binoxide of mercury.

New compound of Bicyanide with Binoxide of Mercury. dilute hydrocyanic acid is digested on red oxide of mercury cess, a white nearly insoluble compound is formed, which separated from any soluble bicyanide which may be presen supernatant liquid by collecting it on a filter. Boiling wa solves the new compound, and leaves the excess of oxide of m On cooling, the salt is, in a great measure, deposited on the si bottom of the vessel in minute, pure, white, transparent, pri needles. This salt is anhydrous, its solution has an alkalin tion, and it consists of equal atoms of the two mercurial comp or it is $(HyCy_2+HyO_2)$. When heated in a tube, it decon with a slight detonation, giving off carbonic acid, nitrogen, nogen, and metallic mercury, leaving a black residue (*para-* *gen.*) Neutralized by nitric acid, it gives a beautiful salt in delicate, quadrangular prisms, which are represented by Hy($(HyO_2+\frac{1}{2}NO_5)$, and are very soluble in water. It gives also acetic acid, a crystalline compound, in which the quantity of appears to exist in a still smaller proportion. With acid nitr silver, it gives Wöhler's salt $(HgCy_2+Ag\overset{\cdot\cdot\cdot\cdot\cdot}{N}+4\dot{H})$, nitrate of me ry remaining in solution. With neutral nitrate of silver and ous other salts, it gives crystalline compounds.*

Preservation of potassium.

Preservation of Potassium. Dr Gale has stated that the o copaiva contains oxygen, which renders it liable to convert potass into potassa, forming with it a peculiar species of soap; from e periments made upon several specimens of the balsam, the oil tained from them afforded similar results, and he is of opinion t no substance hitherto used will supply the place of naphtha.†

Emulsin.

Emulsin. The following process has been employed for obta ing *emulsin*, by Thomson and Richardson. Sweet almonds we triturated in a mortar and small portions of water gradually add until a milky fluid was obtained. This fluid was mixed with fo times its vol. of ether and frequently agitated so as to effect an timate mixture. A clear fluid gradually separated at the bottom the stoppered bottle in which the experiment was made, which the course of three weeks was drawn off by means of a syphon. T fluid was filtered, and to one half of the clear solution a large qu tity of alcohol was added; a copious precipitation of white flo ensued; these were *emulsin*. Washed with alcohol, and dried o sulphuric acid in the vacuum of an air pump, it was obtained in state of a white powder, without taste or smell, soluble in water, soluble in alcohol and ether. Its analysis gave the relation of carbon and nitrogen as $6CO_2 : 1N$ or $3C : 1N$. When boiled w baryta, ammonia was disengaged, and from the experiments it w inferred to be an amide, and the salt formed with baryta to be a co pound of baryta and *emulsic acid*. The authors are inclined to in that fibrin, gelatin, casein, &c. are all amides.‡

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* Johnston in Eighth *Report of British Association*, 69.

† *Amer. Jour.* xxi. 64.

‡ *Eighth Report of British Assoc.* 48.

APPENDIX.

Chemical Formulæ. Various changes have been made in chemical formulæ. Thus Berzelius now uses HO, KO, FeS, instead of H+O, K+O, Fe+S, for water, potassa, and sulphuret of iron.

The formula for apophyllite is now $8\ \dot{Ca}\,\ddot{Si} + \dot{K}\ddot{S}_2 + 16$ aq; the 8 denoting 8 eq. of $\dot{Ca}\dddot{Si}$, or silicate of lime, which are united with 1 eq. of bisilicate of potassa, and 16 of water.

The system of Liebig and Poggendorff is based upon the following principles. Numbers are placed *below* and to the right of the symbols which affect those to which they are attached. Numbers are placed *before* the symbols which affect all that follow as far as the next full stop or sign of addition. A figure placed before a parenthesis applies to all contained within it. The same compound may therefore be written in different ways. Thus the constitution of a crystal of alum is represented by $\dot{K}\ddot{S} + \underline{\ddot{A}}\,l\ddot{S}_3 + 24\dot{H}$, or $KO, SO_3 + Al_2O_3, 3SO_3 + 24$ aq.

To distinguish water in different states of combination Liebig and Poggendorff propose to express water of crystallization by aq. When the water is more powerfully retained and the compounds are more permanent, or in the state of *hydrates*, the water is denoted by an h attached to the symbol of the substance containing it. Thus $\overline{A}$ being the symbol of acetic acid, $\overline{A}_h$ is the symbol of the hydrate; $M_gO,\overline{M}_h + 4$ aq. denotes the malate of magnesia and 5 eq. of water, but distinguishes 4 of these as water of crystallization, while the fifth is united with the malic acid and forms with it a hydrate. The symbol HO is used in doubtful cases, and when changes effected by chemical action are explained. L. and T. 240.

Wollaston's Synoptic Scale of Chemical Equivalents.[*] The scale consists of a moveable slider with a series of numbers upon it, from 10 to 320, on each side of which and on the fixed part of the scale, are set down the names of various chemical substances.

The scale is founded on the constancy of composition in chemical compounds (106); the equivalent power of the quantities that enter into combination (108); and the properties of a logometric scale of numbers.

The numbers are so arranged, that at equal intervals they bear the same proportion to each other. The student will easily observe and understand this, by measuring a few distances upon the scale with a pair of compasses, or even a piece of paper. If his paper extend from 10 to 20, it will also extend from 20 to 40, or from 55 to 110, or from 160 to 320. Whatever number is at the upper edge of the paper will be doubled at the lower. If any other distance be taken, the same effect will be observed. If, for instance, the paper extends from 10 to 14, then any other two numbers found at its upper and lower edge will be in the same proportion as these two numbers 10 and 14. Thus make the upper number 100, and the lower number will be 140.

Now supposing that the paper were cut of such a width that, one of its edges being applied upon the scale to the number representing the equivalent of one body, the other should coincide with the number of the equivalent of a second body; then upon moving the paper, wherever it was placed over the numbers, those at its upper and lower edges would still represent the corresponding proportional quantities of the two bodies as accurately as at first, because the numbers at equal distances on the scale are proportional to each other. Thus suppose the upper edge were made to coincide with 40 and the lower

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[*] The paper, by its author, describing the scale is inserted in the *Philosophical Transactions* for 1814.

with 78, then the upper edge might be called sulphuric acid, and the lower baryta; and this width once ascertained, the paper wherever applied upon the scale, would shew at its lower edge the quantity of baryta necessary to combine with the quantity of sulphuric acid indicated by its upper edge.

It is evidently of no consequence whether the paper be moved up and down over the the scale, or the line of numbers be moved higher and lower, to bring its different parts to the edges of the paper. And supposing the piece of paper just described to be pasted upon the side of the scale, then by moving the latter any of the numbers might be made to coincide with the upper or lower edge at pleasure, and consequently the quantity of sulphuric acid necessary to combine with any quantity of baryta, and vice versa, ascertained by mere adjustment and inspection of the scale. Or if, instead of referring to the separate piece of paper, marks were to be made on the side of the scale at 40 and 78, and named sulphuric acid and baryta, the same object would be attained, and the same method of inquiry rendered available.

Other substances are to be put down upon the scale exactly in the same manner. Thus the scale being adjusted until the number 40 coincides with the sulphuric acid already marked, then sulphate of baryta is to be written at 118, and thus its place is ascertained; nitrate of baryta at 132; soda at 32; sulphate of soda at 72; and a similar process is to be adopted with every substance, the number of which has been ascertained by experiment. The instrument, which in this state merely represents the actual numbers supplied by experiment, will faithfully preserve the proportions thus set down, whatever the variation of the position of the slider may be. It is therefore competent to change all the numerical expressions to any degree required, the knowledge of one only being sufficient first by adjustment, and then by inspection to lead to the rest.

A few illustrations of the powers and uses of this scale will be sufficient to make the student perfect master of its nature and applications. Suppose that in analysing a mineral water, the sulphates in a pint of it have been decomposed by the addition of muriate of baryta, and the resulting sulphate of baryta washed, dried, and weighed: from its quantity may be deduced the exact quantity of sulphuric acid previously existing in the mineral water. Thus, if the sulphate of baryta amount to 43.4 grains, the slider is to be moved until that number is opposite to *sulphate of baryta*, and then at *sulphuric acid* will be found the quantity required, namely 14.7 grains. In the same manner the scale will give information of the quantity of any substance contained in a given weight of any of its compounds; these having previously been deduced from experiment, and accurately set down on the table in the manner just explained.

If it be desired to know how much of one substance must be used in an experiment to act upon another, it is evident that the equivalent must be taken, and this may be learned from the scale. Suppose that a pound of sulphate of baryta has been mixed with charcoal, and well heated, to convert it into a sulphuret, and that by the addition of nitric acid it is to be converted into nitrate of baryta. The quantity of acid which will probably be required may be learned by bringing 100 to sulphate of baryta, and then by looking for the number opposite nitric acid: it will be found to be 46. But this represents the quantity of dry acid; casting the eye therefore lower down, upon liquid nitric acid of a specific gravity of 1.50, it will be found that 61 lbs. or a little more, is the equivalent for 100 lbs. and consequently that 61 hundredth parts, or somewhat above six-tenths of a pound of such acid, will be sufficient for the pound of sulphate of baryta operated with.

If a certain weight of carbonate of baryta be required in that moist and finely divided state, in which it is obtained by precipitation, and in which it cannot be weighed, the accuracy of the quantity may be insured by taking the equivalent of dry muriate, or nitrate of baryta, precipitating it by an excess of carbonate of potassa, and then washing off the the salts which remain in solution. Suppose 100 grains of the carbonate were required; by bringing that number to carbonate of baryta, it will be found that the quantity of dry muriate necessary will be 105.8 parts, and the quantity of nitrate 133.4; and if the quantity of carbonate of potassa necessary for this purpose be also required, it will be found opposite the name of that substance on the scale, to be a little less than 70 parts, so that 5 or 10 parts more will ensure a satisfactory excess.

The second paragraph of Wollaston's description of this scale may be transcribed, as a further illustration of the powers of the instrument. "If, for instance, the salt under examination be the common blue vitriol, or crystallized sulphate of copper, the first obvious questions are—(1) How much sulphuric acid does it contain? (2) How much oxide of copper? (3) How much water? He [the analytic chemist] may not be satified with these first steps in the analysis, but may desire to know further the quantities (4) of sulphur, (5) of copper, (6) of oxygen, (7) of hydrogen. As means of gaining this information, he naturally considers the quantity of various reagents that may be employed for discovering the quantity of sulphuric acid (8), how much baryta, (9) carbonate of baryta, or (10) nitrate of baryta, would be requisite for this purpose? (11) How much lead is to be used in the form of (12) nitrate of lead; and when the precipitate of (13) sulphate of baryta, or (14) sulphate of lead are obtained, it will be necessary that he should also know the proportion which either of them contains of dry sulphuric acid. He may also endeavour to ascertain the same point by means of (15) the quantity of pure potassa, or (16) of carbonate of potassa requisite for the precipitation of the copper. He might also use (17) zinc, or (18) iron for the same purpose, and he may wish to know the quantities of (19) sulphate of zinc, or (20) sulphate of iron, that will then remain in the solution."

All these questions and points are answered by moving the slider until the number expressing the quantity operated with coincides with *sulphate of copper crystallized.* 5, *Water.* Let it for instance be 100: this being brought opposite crystallized sulphate of copper, the information relative to all the above points, except the sixth and seventh, is supplied by mere inspection. The sixth may be supplied by substracting (5) the quantity of copper from (2) the quantity of oxide of copper, or by halving the quantity at 2 oxygen, or taking the third of that at 3 oxygen. The seventh relates to the quantity of hydrogen in the 5 water present in the salt; this quantity of hydrogen does not come within the line of numbers, but may easily be obtained by doubling the quantity of water, or doubling the quantity of the salt used, which will then bring 10 hydrogen into the scale, and the half of this is to be taken as the quantity in 5 water, or in 100 grains of the salt. Putting therefore 200 to sulphate of copper, 10 hydrogen, is indicated as 17 parts nearly, when of course the half of this, or 8½ parts is the quantity in 100 grains of the crystallized salt of copper.

Whenever it thus happens that the number known or the number sought for is out of the scale, then some convenient multiplier of the numbers may be used. The most convenient method is to use the tens or the hundreds as units, or what is the same thing, to consider for the time that decimal points are inserted between the units and the tens, or between the tens and the hundreds of all the numbers on the scale. Thus if it were required to ascertain how much magnesia and sulphuric acid were contained in a pound of crystallized sulphate of magnesia, no 1 exists upon the scale, and of course no fractions or small parts of 1; but imagine decimal points between the tens and the hundreds, then 10 upon the scale becomes one-tenth, 22 twentytwo hundredths, 100 one, 220 two and two-tenths and so on. Bringing therefore 100 to crystallized sulphate of magnesia, it represents the 1 pound, and by inspection it will be found that it contains 16 hundredths of a pound of magnesia, and 32½ hundredths of a pound of sulphuric acid.

As another illustration; suppose that the quantity of magnesia in 50 lbs. of crystallized Epsom salt were required; upon bringing 50 opposite the name of the salt, the quantity of magnesia will be found smaller than any quantity expressed upon the scale: but all that is necessary to obtain the answer is, to double the quantity of the salt, and then to halve the quantity of magnesia indicated; in which way it will be found that the 50 lbs. contain about 8 lbs. of the oxide.

These *Synoptic scales* are generally constructed of paper or wood. It is almost impossible that they should be accurate, because of the extension and contraction of the paper, and the facility with which it yields to mechanical impressions, and may be stretched when in a moistened state. These scales should never be considered as accurate when they first come from the instrument-maker. They may be examined by a pair of compasses or a a piece of paper, as before described (p. 513), to ascertain how nearly, equal intervals on the scale of numbers, accord with equal proportions between the numbers at the extremities of those intervals and thus the degree of error in them, and the part where it exists to the greatest extent may be observed: but it will be useless to do so, with the view of finding one so accurate as to dispense with calculation in exact analytical experiments.

Those scales, which are laid down directly upon wood, though not liable to the same sources of error as the paper scales, are still seldom, if ever, so accurate as to compete with calculation.

The errors just referred to, relate to the accuracy of the scale of numbers, and its proportional value in every part. Others relate to the imperfect and inaccurate results of the experiments, by which the numbers representing the equivalent or combining quantities of bodies are obtained. If an inaccurate result be mistaken for a correct one, and the proportional number of a body be entered erroneously upon the scale, it is evident that all estimations of substances including that body, which are given by the scale, must involve this original inaccuracy. Whenever therefore a more accurate determination of the number of a body is obtained than was before possessed, its place on the scale should be corrected; and as the equivalent numbers of substances, previously undetermined, are satisfactorily ascertained, the substances themselves should be put upon the scale in their proper situations, as before described.

In consequence of the unavoidable errors in the scale of numbers, which, however small, still interfere in the investigation of complicated cases, and the determination of accurate conclusions, the instrument should only be used in those instances where accuracy within a certain degree is sufficient for the purpose. All nicer results should be obtained by calculation from a *table* of equivalents: if, for instance, the quantity of sulphuric acid in 64.7 grains of sulphate of baryta were required to two or three places of decimals, it would be better to take the equivalent numbers of sulphate of baryta and sulphuric acid from such a table, and to say, as the first number is to the second, so is 64.7 to the quantity of sulphuric acid it contains, than to work with the scale. The present determination of the sulphate of baryta is 118, and that of sulphuric acid 40, hydrogen being 1 or unity, and as 118 is to 40, so is 64.7 to 21.932 very nearly. It will be impossible to ascertain this last number accurately on an ordinary scale, or to observe how far it differs from 22.

There are numerous tables of equivalents published in different chemical works. Whichever may be adopted should be examined from time to time, and the numbers affixed to bodies on it corrected, whenever they are more accurately determined.

It has been shewn by Gay-Lussac and others that all gases and all volatile substances when in the state of vapour, combine or act chemically in volumes, which have very simple relations to each other. These volumes once ascertained, may be considered in the relation of equivalents, and their proportions are so simple, as to be remembered without the least difficulty: it is therefore highly advantageous in all tables of chemical equivalents, to place small diagrams by the sides of the substances and their numbers, which may represent the volumes of the equivalents when brought into the state of gas or vapour. For it requires no great power of discernment to perceive that, if bodies combine in definite weights, and also in simple ratios of volumes, these volumes so combining must contain the weights previously found to be definite: for whether two substances which combine to form a third, are observed by weight or volume, still they combine only in one proportion.

So arranged, the table will have an appearance of the following kind:

Hydrogen	1	□
Oxygen	8	▭
Chlorine	36	□
Iodine	125	□
Water	9	□
Muriatic acid	37	□□
Hydriodic acid,	126	□□
Ammonia	17	□□

and will be found very useful when referred to for gaseous or vaporous substances. The proportions of these volumes are much more easily remembered than the proportions of their equivalent numbers; which, added to the facility with which the bulk of gases or vapours are ascertained, may often properly induce the chemist to dispense with the determination of weights, and work with volumes only.*

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* Faraday's *Chemical Manipulation.*

TABLE I.

*The following are the results obtained by a commission appointed by the Parisian Academy of Sciences to examine the elastic force of vapour.** *They were obtained by experiment up to a pressure of* 25 *atmospheres, and at higher pressures by calculation.*

Elasticity of the vap. taking amospheric press. as unity.	Temperature according to Fahr.	Elasticity of the vap. taking atmospheric press. as unity.	Temperature according to Fahr.
1	212°	13	380.66°
1½	233.96	14	386.94
2	250.52	15	392.86
2½	263.84	16	398.48
3	275.18	17	403.82
3½	285.08	18	408.92
4	293.72	19	413.78
4½	300.28	20	418.46
5	307.5	21	422.96
5½	314.24	22	427.28
6	320.36	23	431.42
6½	326.26	24	435.56
7	331.70	25	439.34
7½	336.86	30	457.16
8	341.78	35	472.73
9	350.78	40	486.59
10	358.88	45	491.14
11	366.85	50	510.60
12	374.00		

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* Brande's *Jour.* N. S. viii; 191.

TABLE II.

Table *of the Elastic Force of Aqueous Vapour at different Temperatures, expressed in Inches of Mercury.*

TEMP. Fah.	Force of Vapour.		TEMP. Fah.	Force of Vapour.		TEMP. Fah.	Force of Vapour.	
	Dalton.	Ure.		Dalton.	Ure		Dalton.	Ure.
32°	0.200	0.200	79°	0.971		126°	3.89	
33	0.207		80	1.00	1.010	127	4.00	
34	0.214		81	1.04		128	4.11	
35	0.221		82	1.07		129	4.22	
36	0.229		83	1.10		130	4.34	4.366
37	0.237		84	1.14		131	4.47	
38	0.245		85	1.17	1.170	132	4.60	
39	0.254		86	1.21		133	4.73	
40	0.263	0.250	87	1.24		134	4.86	
41	0.273		88	1.28		135	5.00	5.070
42	0.283		89	1.32		136	5.14	
43	0.294		90	1.36	1.360	137	5.29	
44	0.305		91	1.40		138	5.44	
45	0.316		92	1.44		139	5.59	
46	0.328		93	1.48		140	5.74	5.770
47	0.339		94	1.53		141	5.90	
48	0.351		95	1.58	1.640	142	6.05	
49	0.363		96	1.63		143	6.21	
50	0.375	0.360	97	1.68		144	6.37	
51	0.388		98	1.74		145	6.53	6.600
52	0.401		99	1.80		146	6.70	
53	0.415		100	1.86	1.860	147	6.87	
54	0.429		101	1.92		148	7.05	
55	0.443	0.416	102	1.98		149	7.23	
56	0.458		103	2.04		150	7.42	7.530
57	0.474		104	2.11		151	7.61	
58	0.490		105	2.18	2.100	152	7.81	
59	0.507		106	2.25		153	8.01	
60	0.524	0.516	107	2.32		154	8.20	
61	0.542		108	2.39		155	8.40	8.500
62	0.560		109	2.46		156	8.60	
63	0.578		110	2.53	2.456	157	8.81	
64	0.597		111	2.60		158	9.02	
65	0.616	0.630	112	2.68		159	9.24	
66	0.635		113	2.76		160	9.46	9.600
67	0.655		114	2.84		161	9.68	
68	0.676		115	2.92	2.820	162	9.91	
69	0.698		116	3.00		163	10.15	
70	0.721	0.726	117	3.08		164	10.41	
71	0.745		118	3.16		165	10.68	10.800
72	0.770		119	3.25		166	10.96	
73	0.796		120	3.33	2.300	167	11.25	
74	0.823		121	3.42		168	11.54	
75	0.851	0.860	122	3.50		169	11.83	
76	0.880		123	3.59		170	12.13	12.050
77	0.910		124	3.69		171	12.43	
78	0.940		125	3.79	3.830	172	12.73	

TABLE II.—CONTINUED.

TEMP. Fah.	Force of Vapour.		TEMP. Fah.	Force of Vapour.		TEMP. Fah.	Force of Vapour.	
	Dalton.	Ure.		Dalton.	Ure.		Dalton.	Ure.
173°	13.02		224°	37.53		275°	83.13	93.480
174	13.32		225	38.20	39.110	276	84.35	
175	13.62	13.550	226	38.89	40.100	277	85.47	97.800
176	13.92		227	39.59		278	86.50	
177	14.22		228	40.30		279	87.63	101.600
178	14.52		229	41.02		280	88.75	101.900
179	14.83		230	41.75	43.100	281	89.87	104.400
180	15.15	15.160	231	42.49		282	90.99	
181	15.50		232	43.24		283	92.11	107.700
182	15.86		233	44.00		284	93.23	
183	16.23		234	44.78	46.800	285	94.35	112.200
184	16.61		235	45.58	47.220	286	95.48	
185	17.00	16.900	236	46.39		287	96.64	114.800
186	17.40		237	47.20		288	97.80	
187	17.80		238	48.02	50.300	289	98.96	118.200
188	18.20		239	48.84		290	100.12	120.150
189	18.60		240	49.67	51.700	291	101.28	
190	19.00	19.000	241	50.50		292	102.45	123.100
191	19.42		242	51.34	53.600	293	103.63	
192	19.86		243	52.18		294	104.80	126.700
193	20.32		244	53.03		295	105.97	129.000
194	20.77		245	53.88	56.340	296	107.14	
195	21.22	21.100	246	54.68		297	108.31	133.900
196	21.68		247	55.54		298	109.48	137.400
197	22.13		248	56.42	60.400	299	110.64	
198	22.69		249	57.31		300	111.81	139.700
199	23.16		250	58.21	61.900	301	112.98	
200	23.64	23.600	251	59.12	63.500	302	114.15	144.300
201	24.12		252	60.05		303	115.32	147.700
202	24.61		253	61.00		304	116.50	
203	25.10		254	61.92	66.700	305	117.68	150.560
204	25.61		255	62.85	67.25	306	118.86	154.400
205	26.13	25.900	256	63.76		307	120.03	
206	26.66		257	64.82	69.800	308	121.20	157.700
207	27.20		258	65.78		309	122.37	
208	27.74		259	66.75		310	123.53	161.300
209	28.29		260	67.73	72.300	311	124.69	164.800
210	28.84	28.880	261	68.72		312	125.85	167.000
211	29.41		262	69.72	75.900	313	127.00	
212	30.00	30.000	263	70.73		314	128.15	
213	30.60		264	71.74	77.900	315	129.29	
214	31.21		265	72.76	78.040	316	130.43	
215	31.83		266	73.77		317	131.57	
216	32.46	33.400	267	74.79	81.900	318	132.72	
217	33.09		268	75.80		319	133.86	
218	33.72		269	76.82	84.900	320	135.00	
219	34.35		270	77.85	86.300	321	136.14	
220	34.99	35.540	271	78.89	88.000	322	137.28	
221	35.63	36.700	272	79.94		323	138.42	
222	36.25		273	80.98	91.200	324	139.56	
223	36.88		274	82.01		325	140.70	

TABLE III.

Dr Ure's Table, *showing the Elastic Force of the Vapours of Alcohol and Ether at different Temperatures, expressed in Inches of Mercury.*

Ether.		Alcohol sp. gr. 0 813.		Alcohol sp. gr. 0.813.	
Temp.	Force of Vapour.	Temp.	Force of Vapour.	Temp.	Force of Vapour.
34°	6.20	32°	0.40	193.3	46.60
44	8.10	40	0.56	196.3	50.10
54	10.30	45	0.70	200	53.00
64	10.00	50	0.86	206	60.10
74	16.10	55	1.00	210	65.00
84	20.00	60	1.23	214	69.30
94	24.70	65	1.49	216	72.20
104	30.00	70	1.76	220	78.50
105	30.00	75	2.10	225	87.50
110	32.54	80	2.45	230	94.10
115	35.90	85	2.93	232	97.10
120	39.47	90	3.40	236	103.60
125	43.24	95	3.90	238	106.90
130	47.14	100	4.50	240	111.24
135	51.90	105	5.20	244	118.20
140	56.90	110	6.00	247	122.10
145	62.10	115	7.10	248	126.10
150	67.60	120	8.10	249.7	131.40
155	73.60	125	9.25	250	132.30
160	80.30	130	10.60	252	138.60
165	86.40	135	12.15	254.3	143.70
170	92.80	140	13.90	258.6	151.60
175	99.10	145	15.95	260	155.20
180	108.30	150	18.00	262	161.40
185	116.10	155	20.30	264	166.10
190	124.80	160	22.60		
195	133.70	165	25.40		
200	142.80	170	28.30		
205	151.30	173	30.00		
210	166.00	178.3	33.50		
		180	34.73		
		182.3	36.40		
		185.3	39.90		
		190	43.20		

TABLE IV.

Dr Ure's Table *of the Quantity of Oil of Vitriol, of sp. gr.* **1.8485**, *and of Anhydrous Acid, in* 100 *Parts of dilute Sulphuric Acid, at different Densities.*

Liquid.	Sp. Gr.	Dry.	Liquid.	Sp. Gr.	Dry.	Liquid.	Sp. Gr.	Dry.
100	1.8485	81.54	66	1.5503	53.82	32	1.2334	26.09
99	1.8475	80.72	65	1.5390	53.00	31	1.2260	25.28
98	1.8460	79.90	64	1.5280	52.18	30	1.2184	24.46
97	1.8439	79.09	63	1.5170	51.37	29	1.2108	23.65
96	1.8410	78.28	62	1.5066	50.55	28	1.2032	22.83
95	1.8376	77.46	61	1.4960	49.74	27	1.1956	22.01
94	1.8336	76.65	60	1.4860	48.92	26	1.1876	21.20
93	1.8290	75.83	59	1.4760	48.11	25	1.1792	20.38
92	1.8233	75.02	58	1.4660	47.29	24	1.1706	19.57
91	1.8179	74.20	57	1.4560	46.48	23	1.1626	18.75
90	1.8115	73.39	56	1.4460	45.66	22	1.1549	17.94
89	1.8043	72.57	55	1.4360	44.85	21	1.1480	17.12
88	1.7962	71.75	54	1.4265	44.03	20	1.1410	16.31
87	1.7870	70.94	53	1.4170	43.22	19	1.1330	15.49
86	1.7774	70.12	52	1.4073	42.40	18	1.1246	14.68
85	1.7673	69.31	51	1.3977	41.58	17	1.1165	13.86
84	1.7570	68.49	50	1.3884	40.77	16	1.1090	13.05
83	1.7465	67.68	49	1.3788	39.95	15	1.1019	12.23
82	1.7360	66.86	48	1.3697	39.14	14	1.0953	11.41
81	1.7245	66.05	47	1.3612	38.32	13	1.0887	10.60
80	1.7120	65.23	46	1.3530	37.51	12	1.0809	9.78
79	1.6993	64.42	45	1.3440	36.69	11	1.0743	8.97
78	1.6870	63.60	44	1.3345	35.88	10	1.0682	8.15
77	1.6750	62.78	43	1.3255	35.06	9	1.0614	7.34
76	1.6630	61.97	42	1.3165	34.25	8	1.0544	6.52
75	1.6520	61.15	41	1.3080	33.43	7	1.0477	5.71
74	1.6415	60.34	40	1.2999	32.61	6	1.0405	4.89
73	1.6321	59.52	39	1.2913	31.80	5	1.0336	4.08
72	1.6204	58.71	38	1.2826	30.98	4	1.0268	3.26
71	1.6090	57.89	37	1.2740	30.17	3	1.0206	2.446
70	1.5975	57.08	36	1.2654	29.35	2	1.0140	1.63
69	1.5868	56.26	35	1.2572	28.54	1	1.0074	0.8154
68	1.5760	55.45	34	1.2490	27.72			
67	1.5648	54.63	33	1.2409	26.91			

TABLE V.

Table *of Muriatic (Hydrochloric) Acid, by Dr Ure.*[*]

Acid of 120 in 100.	Specific Gravity.	Chlorine.	Muriatic Gas.	Acid of 120 in 100.	Specific Gravity.	Chlorine	Muriatic Gas.	Acid of 120 in 100.	Specific Gravity.	Chlorine.	Muriatic Gas.
100	1.2000	39.675	40.777	66	1.1328	26.186	26.913	32	1.0637	12.697	13.049
99	1.1982	39.278	40.369	65	1.1308	25.789	26.505	31	1.0617	12.300	12.641
98	1.1964	38.882	39.961	64	1.1287	25.392	26.098	30	1.0597	11.903	12.233
97	1.1946	38.485	39.554	63	1.1267	24.996	25.690	29	1.0577	11.506	11.825
96	1.1928	38.089	39.146	62	1.1247	24.599	25.282	28	1.0557	11.109	11.418
95	1.1910	37.692	38.738	61	1.1226	24.202	24.874	27	1.0537	10.712	11.010
94	1.1893	37.296	38.330	60	1.1206	23.805	24.466	26	1.0517	10.316	10.602
93	1.1875	36.900	37.923	59	1.1185	23.408	24.058	25	1.0497	9.919	10.194
92	1.1857	36.503	37.516	58	1.1164	23.012	23.050	24	1.0477	9.522	9.786
91	1.1846	36.107	37.108	57	1.1143	22.615	23.242	23	1.0457	9.126	9.379
90	1.1822	35.707	36.700	56	1.1123	22.218	22.834	22	1.0437	8.729	8.971
89	1.1802	35.310	36.292	55	1.1102	21.822	22.426	21	1.0417	8.332	8.563
88	1.1782	34.913	35.884	54	1.1082	21.425	22.019	20	1.0397	7.935	8.155
87	1.1762	34.517	35.476	53	1.1061	21.028	21.611	19	1.0377	7.538	7.747
86	1.1741	34.121	35.068	52	1.1041	20.632	21.203	18	1.0357	7.141	7.340
85	1,1721	33.724	34.660	51	1.1020	20.235	20.796	17	1.0337	6.745	6.932
84	1.1701	33.328	34.252	50	1.1000	19.837	20.388	16	1.0318	6.348	6.524
83	1.1681	32.931	33.845	49	1.0980	19.440	19.980	15	1.0298	5.951	6.116
82	1.1661	32.535	33.437	48	1.0960	19.044	19.572	14	1.0279	5.554	5.709
81	1.1641	32.136	33.029	47	1.0939	18.647	19.165	13	1.0259	5.158	5.301
80	1.1620	31.746	32.621	46	1.0919	18.250	18.757	12	1.0239	4.762	4.893
79	1.1599	31.343	32.213	45	1.0899	17.854	18.349	11	1.0220	4.365	4.486
78	1.1578	30.946	31.805	44	1.0879	17.457	17.941	10	1.0200	3.968	4.078
77	1.1557	30.550	31.398	43	1.0859	17.060	17.534	9	1.0180	3.571	3.670
76	1.1536	30.153	30.990	42	1.0838	16.664	17.126	8	1.0160	3.174	3.262
75	1.1515	29.757	30.582	41	1.0818	16.267	16.718	7	1.0140	2.778	2.854
74	1.1494	29.361	30.174	40	1.0798	15.870	16.310	6	1.0120	2.381	2.447
73	1.1473	28.964	29.767	39	1.0778	15.474	15.902	5	1.0100	1.984	2.039
72	1.1452	28.567	29.359	38	1.0758	15.077	15.494	4	1.0080	1.588	1.631
71	1.1431	28.171	28.951	37	1.0738	14.680	15.087	3	1.0060	1.191	1.224
70	1.1410	27.772	28.544	36	1.0718	14.284	14.679	2	1.0040	0.795	0.816
69	1.1389	27.376	28.136	35	1.0697	13.887	14.271	1	1.0020	0.397	0.408
68	1.1369	26.979	27.728	34	1.0677	13.490	13.863				
67	1.1349	26.583	27.321	33	1.0657	13.094	13.456				

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[*] *Dictionary of Arts and Manufactures*, 873.

TABLE VI.

Dr Ure's* TABLE *of the Quantity of Real or Anhydrous Nitric Acid in* 100 *Parts of Liquid Acid, at different Densities.

Sp. Gr.	Real Acid in 100 parts of the liquid.	Sp. Gr.	Real Acid in 100 parts of the liquid.	Sp. Gr.	Real Acid in 100 parts of the liquid.
1.5000	79.700	1.3783	52.602	1.1895	26.301
1.4980	78.903	1.3732	51.805	1.1833	25.504
1.4960	78.106	1.3681	51.068	1.1770	24.707
1.4940	77.309	1.3630	50.211	1.1709	23.910
1.4910	76.512	1.3579	49.414	1.1648	23.113
1.4880	75.715	1.3529	48.617	1.1587	22.316
1.4850	74.918	1.3477	47.820	1.1526	21.519
1.4820	74.121	1.3427	47.023	1.1465	20.722
1.4790	73.324	1.3376	46.226	1.1403	19.925
1.4760	72.527	1.3323	45.429	1.1345	19.128
1.4730	71.730	1.3270	44.632	1.1286	18.331
1.4700	70.933	1.3216	43.835	1.1227	17.534
1.4670	70.136	1.3163	43.038	1.1168	16.737
1.4640	69.339	1.3110	42.241	1.1109	15.940
1.4600	68.542	1.3056	41.444	1.1051	15.143
1.4570	67.745	1.3001	40.647	1.0993	14.346
1.4530	66.948	1.2947	39.850	1.0935	13.549
1.4500	66.155	1.2887	39.053	1.0878	12.752
1.4460	65.354	1.2826	38.256	1.0821	11.955
1.4424	64.557	1.2765	37.459	1.0764	11.158
1.4385	63.760	1.2705	36.662	1.0708	10.361
1.4346	62.963	1.2644	35.865	1.0651	9.564
1.4306	62.166	1.2583	35.068	1.0595	8.767
1.4269	61.369	1.2523	34.271	1.0540	7.970
1.4228	60.572	1.2462	33.474	1.0485	7.173
1.4189	59.775	1.2402	32.677	1.0430	6.376
1.4147	58.978	1.2341	31.880	1.0375	5.579
1.4107	58.181	1.2277	31.083	1.0320	4.782
1.4065	57.384	1.2212	30.286	1.0267	3.985
1.4023	56.587	1.2148	29.489	1.0212	3.188
1.3978	55.790	1.2084	28.692	1.0159	2.391
1.3945	54.993	1.2019	27.895	1.0106	1.594
1.3882	54.196	1.1958	27.098	1.0053	0.797
1.3833	53.399				

TABLE VII.

TABLE *of Lowitz, showing the Quantity of Absolute Alcohol in Spirits of different Specific Gravities.*

100 Parts.		Specific Gravity.		100 Parts.		Specific Gravity.		100 Parts.		Sp. Gravity.	
Alcohol.	Water	At 68°.	At 60°.	Alcohol.	Water	At 68°.	At 60°.	Alcohol.	Water	At 68°.	At 60°.
100	0	0.791	0.796	66	34	0.877	0.881	32	68	0.952	0.955
99	1	0.794	0.798	65	35	0.880	0.883	31	69	0.954	0.957
98	2	0.797	0.801	64	36	0.882	0.886	30	70	0.956	0.958
97	3	0.800	0.804	63	37	0.885	0.889	29	71	0.957	0.960
96	4	0.803	0.807	62	38	0.887	0.891	28	72	0.959	0.962
95	5	0.805	0.809	61	39	0.889	0.893	27	73	0.961	0.963
94	6	0.808	0.812	60	40	0.892	0.896	26	74	0.963	0.965
93	7	0.811	0.815	59	41	0.894	0.898	25	75	0.965	0.967
92	8	0.813	0.817	58	42	0.896	0.900	24	76	0.966	0.968
91	9	0.816	0.820	57	43	0.899	0.902	23	77	0.968	0.970
90	10	0.818	0.822	56	44	0.901	0.904	22	78	0.970	0.972
89	11	0.821	0.825	55	45	0.903	0.906	21	79	0.971	0.973
88	12	0.823	0.827	54	46	0.905	0.908	20	80	0.973	0.974
87	13	0.826	0.830	53	47	0.907	0.910	19	81	0.974	0.975
86	14	0.828	0.832	52	48	0.909	0.912	18	82	0.976	0.977
85	15	0.831	0.835	51	49	0.912	0.915	17	83	0.977	0.978
84	16	0.834	0.838	50	50	0.914	0.917	16	84	0.978	0.979
83	17	0.836	0.840	49	51	0.917	0.920	15	85	0.980	0.981
82	18	0.839	0.843	48	52	0.919	0.922	14	86	0.981	0.982
81	19	0.842	0.846	47	53	0.921	0.924	13	87	0.983	0.984
80	20	0.844	0.848	46	54	0.923	0.926	12	88	0.985	0.986
79	21	0.847	0.851	45	55	0.925	0.928	11	89	0.986	0.987
78	22	0.849	0.853	44	56	0.927	0.930	10	90	0.987	0.988
77	23	0.851	0.855	43	57	0.930	0.933	9	91	0.988	0.989
76	24	0.853	0.857	42	58	0.932	0.935	8	92	0.979	0.990
75	25	0.856	0.860	41	59	0.934	0.937	7	93	0.991	0.991
74	26	0.859	0.863	40	60	0.936	0.939	6	94	0.992	0.992
73	27	0.861	0.865	39	61	0.938	0.941	5	95	0.994	
72	28	0.863	0.867	38	62	0.940	0.943	4	96	0.995	
71	29	0.866	0.870	37	63	0.942	0.945	3	97	0.997	
70	30	0.868	0.872	36	64	0.944	0.947	2	98	0.998	
69	31	0.870	0.874	35	65	0.946	0.949	1	99	0.999	
68	32	0.872	0.875	34	66	0.948	0.951	0	100	1.000	
67	33	0.875	0.879	33	67	0.950	0.953				

Specific Gravity of Essential and other Oils.

Oil of Anise-seed,	0.9958
“ “ Bergamot,	0.885
“ “ Cajeput,	0.948
“ “ Caraway,	0.975
“ “ Cassia,	1.071
“ “ Cinnamon,	1.035
“ “ Cloves,	1.061
“ “ Fennel,	0.997

Oil of Juniper,	0.911
“ “ Lavender,	0.898
“ “ Lemons,	0.8517
“ “ Nutmegs,	0.948
“ “ Peppermint,	0.899
“ “ of Roses, (Ottar of Roses)	0.832
“ “ Rosemary,	0.85

Oils of Fermented Liquors.

Oil of Grain Spirits,	0.835
“ “ Potato Spirits,	0.821

Tables of Weights and Measures, of the Correspondence between Fahrenheit's, Reaumur's, and the Centigrade Thermometers, and of Freezing Mixtures.

WEIGHTS AND MEASURES.

WEIGHTS.

The standard according to which the present system of weights is regulated, is the Troy brass pound.* It contains 5760 grains.

Imperial Standard Troy Weight.

24 grains = 1 pennyweight.
20 pennyweights = 1 ounce.
12 ounces = 1 pound.

or,

Grains.		Pennyweights.		Ounces.	Pound.
24	=	1	=	$\frac{1}{20}$	$\frac{1}{240}$
480	=	20	=	1	$\frac{1}{12}$
5760	=	240	=	12	

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* For important remarks on weights and measures and on the standard weights of the United States, see Hassler's *Reports to Congress*, 1837—8.

Avoirdupois Weight.

The pound avoirdupois contains 7000 grains, each of which is equal to a Troy grain, being thus heavier than the Troy pound by 1240 grains.

		1 drachm	=	27.34375 grains.
16 drachms	=	1 ounce	=	437.5
16 ounces	=	1 pound	=	7000
28 pounds	=	1 quarter	=	196000
4 quarters	=	1 cwt. or 112 lbs.	=	784000
20 cwts.	=	1 ton	=	15680000

or,

Pound.		Ounces.		Drachms.		
1	=	16	=	256	=	7000 grains.
$\frac{1}{16}$	=	1	=	16	=	437.5
$\frac{1}{256}$	=	$\frac{1}{16}$	=	1	=	27.34375

Apothecaries' Weight.

The pound in Apothecaries' Weight is equal to the Troy pound, containing 5760 grains, but is differently subdivided.

1 pound ℔	=	12 ounces	=	5760 grains.
1 ounce ℥	=	8 drachms	=	480
1 drachm ʒ	=	3 scruples	=	60
1 scruple ℈	=	20 grains	=	20

or,

Pound.		Ounces.		Drachms.		Scruples.		Grains.
1	=	12	=	96	=	288	=	5760
		1	=	8	=	24	=	480
				1	=	3	=	60
						1	=	20

The following tables show the correspondence between the Troy, Avoirdupois, and Apothecaries' Weights.

Troy Weight.		Avoirdupois.				Apothecaries'.
1 pound	=	13 oz.	2 dr.	17.8125 grs.	=	1 pound.
1 ounce	=	1	1	15.1562	=	1 ounce.
1 pennyweight	=	0	0	24.	=	1 scruple 4 grs.

Avoirdupois.		Troy Weight.					Apothecaries'.				
1 pound	=	1 ℔	2 oz.	11 dwt.	16 gr.	=	1 ℔	2 ℥	4 ʒ	2 ℈	
1 ounce	=	0	0	18	5.5	=	0	0	7	0	17.5 grs.
1 drachm	=	0	0	1	3.34	=	0	0	0	1	7.34

Apothecaries'.		Troy Weight.			Avoirdupois.		
1 pound	=	1 pound		=	13 oz.	2 dr.	17.8125 grains.
1 ounce	=	1 ounce		=	1	1	15.1562
1 drachm	=	2 dwt.	12 gr.	=	0	2	5.3125
1 scruple	=	0	20	=	0	0	20.

French Decimal Weight.—Gramme = 15.4063 *Troy Grains.*

Milligramme	=	0.0154 grains
Centigramme	=	0.1540
Decigramme	=	1.5406
Gramme	=	15.4063

MEASURES.

The Imperial Standard Gallon contains ten pounds Avoirdupois weight of distilled water, weighed in air at 62° Fahr. and 30° Barom., or 12 lb. 1 ounce 16 pennyweights and 16 grains Troy, = 70,000 grains weight of distilled water. A cubic inch of distilled water weighs 252.458 grains, and the imperial gallon contains 277 274 cubic inches.

Imperial Measure.

1 Quarter = 8 Bushels.
1 Bushel = 4 Pecks.
1 Peck = 2 Gallons.
1 Gallon = 4 Quarts.
1 Quart = 2 Pints.

or,

Distilled Water.								
Grains.	Avoird. lb.	Cub. Inch.	Pint.	Quart.	Galls.	Pecks.	Bush.	Qr.
8750	1.25	34.659	1					
17500	2.5	69.318	2	1				
70000	10	277.274	8	4	1			
140000	20	554.548	16	8	2	1		
560000	80	2218.192	64	32	8	4	1	
4480000	640	17745.536	512	256	64	32	8	1

Apothecaries' Measure (London Pharmacopœia).

The gallon of the former wine measure, and of the present Apothecaries' measure, contains 58333.31 grains weight of distilled water, or 231 cubic inches, the ratio to the imperial gallon being nearly as 5 to 6, or as 0 8331 to 1.

1 Gallon = 8 Pints.
1 Pint O = 16 Ounces.
1 Ounce f ℥ = 8 Drachms.
1 Drachm f ʒ = 60 Drops, or Minims.

or,

Gallon.	Pints.	Ounces.	Drachms.	Minims.	Gr. of Dist. Water.	Cub. Inch.
1	8	128	1024	61440	58333.31	231
	1	16	128	7680	7291.66	28.8
		1	8	480	455.72	1.8
			1	60	56.96	0.2

French Decimal Measure of Capacity, Litre = 61.02525 *British cubic inches, or* 15406.312 *grains of distilled water.*

Millilitre = 0.06102 cubic inches.
Centilitre = 0.61025
Decilitre = 6.10252
Litre = 61.02525

Table showing the Weight in Grains of various Measures (Apothecaries) of different Fluids.

	Specific Gravity.	Weight in Grains of			
		1 Pint.	1 Ounce.	1 Drachm.	1 Minim.
Distilled Water - - - - -	1.000	7291.66	455.72	56.96	0.947
Sulphuric Ether - - - - -	0.720	5249.99	328.12	41.01	0.683
Alcohol - - - - - - - -	0.796	5804.16	362.76	45.34	0.749
Solution of Ammonia - - -	0.925	6744.78	421.54	52.69	0.878
Muriatic acid - - - - - -	1.118	8152.07	509.50	63.68	1.061
Nitric acid - - - - - - -	1.480	10791.65	674.47	84.30	1.405
Sulphuric acid - - - - - -	1.848	13474.98	842.18	105.27	1.754

Fig. 1.

Apparatus for obtaining Potassium. Fig. 1, an iron pot made of the best malleable iron, about 12 inches long, and 5 or 6 in diameter; the iron at least three eighths of an inch thick. A lid is fitted accurately to it, and this is secured by an iron rod passing through two holes in the upper part of the pot. A gun-barrel passes from the cover to the receiver. The receiver consists of two pieces. It is made of tinned copper. The piece (Fig. 2) is a thin parallelopiped, 10 inches long, 5 or 6 broad, and 1½ thick. It is shut at the top and open at the bottom. It is divided by a diaphragm, *a*, to within one third of the bottom. On one side is a small hole into which the end of the gun-barrel enters, and to which it is luted air-tight, or, what is better, fitted by grinding. Opposite to it is another opening, fitted with a cork through which an iron wire passes air-tight. It passes also through a cork fitted into the hole in the diaphragm. The use of this wire is to keep the gun-barrel from being filled up during the process. Fig. 3 is the other part of the receiver, open above, and shut below. Fig. 2 fits it exactly. A few inches of naphtha are put into Fig. 3, and Fig. 2 is placed in it; being well luted with fat lute or putty to exclude air. A bent glass tube proceeds from 2 at *b*, Fig. 4, well luted, which plunges into a vessel filled with naphtha; to allow the escape of the gases.

Fig. 2.

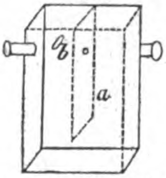


Fig. 3.

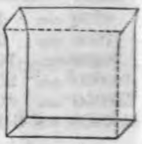


Fig. 4.

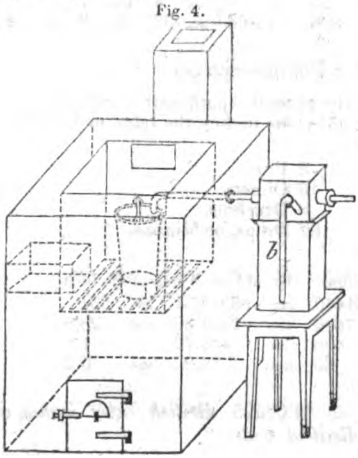


Fig. 4 shows the arrangement of the iron pot, receiver, and furnace. The iron pot should be luted before it is used, as it is apt to be melted; this is best done by binding it round with iron wire, covering it with a stiff clay lute mixed with about one fifteenth part of iron filings and charcoal, and a little thread cut into pieces about an inch in length. This is bound round again with wire, and the whole rubbed over with lute. It should be allowed to dry a day or two before using, and the cracks should be filled up.

The iron pot is placed, as represented, above a piece of fire-brick, and fixed to it with fine clay. The body of the furnace may be about 18 inches long, 15 broad, and 18 deep; the walls from 5 to 10 inches thick, and the flue 6 inches square (inside).

The upper part of the furnace is covered by a flat cast-iron plate about three fourths of an inch thick, and with an opening in the centre through which fuel is introduced, a moveable cover of the same metal being fitted to it by an iron bolt passing through a hole bored in it and in the plate; it allows us also to see very conveniently the state of the apparatus within the furnace Another opening is made on a level with the branders, to allow the fire to be withdrawn whenever it may be necessary; it is constructed in such a manner as to allow it to be easily closed up with a brick and a little mortar, which may be removed again with the same facility. A door is also placed below to regulate the admission of the air, and a damper in the vent to diminish the draught if this should be necessary. The aperture in the side of the furnace for the gun-barrel must not be forgotten.

After everything has been properly adjusted, the fire may be put on. A little water comes away when the apparatus becomes red-hot; soon after, carbonic oxide gas is evolved; and when it is at white heat, a very dense vapour is disengaged, which burns with a brilliant flame. The receiver intended to condense the potassium may then be fixed to the extremity of the gun barrel without the furnace. The receiver is that recommended by Berzelius, which should be kept cold by ice.

When the gas begins to be disengaged slowly, this arises in general from the tube being so obstructed as to prevent it from passing out readily; the plug is then taken out, and the obstructing matter removed as completely as possible, but if the gas does not appear then to increase in quantity, it will be better to withdraw the fire and allow the apparatus to cool. Too much caution cannot be taken in endeavouring to clear the tube either during the distillation or after the apparatus has been allowed to cool, for the tube being frequently obstructed while the materials are at a high temperature and still producing gas, it is obvious that a large quantity must be accumulated in a short time, and the moment the impediment to its free passage is removed, it often expands with explosive violence, and gives rise occasionally to serious accidents.*

The mixture of charcoal and potassa is prepared most easily by exposing six or seven pounds of cream of tartar (crude tartar may be used) to a red heat, in large earthen or iron crucibles, till no more gas is disengaged, reducing it to powder in a mortar, when cold. This is transferred immediately to an iron pot, that it may be prevented from attracting water from the air. Brunner states that when the tartar is mixed with one twelfth of its weight of charcoal a larger quantity of potassium is obtained. This additional quantity of charcoal is useful also in preventing the fusion of the carbonate of potassa at the high temperature to which it is afterwards exposed.

A powerful lamp (Fig. 5), where a large flame is required, may be formed by filling a ring of tin of an inch or more in diameter, and an inch in length, with wick yarn, and placing it in a shallow tin vessel, in the centre of which is a tube or cavity into which the ring fits loosely. The tube is soldered at the top to the body of the lamp, but a small space is left at the bottom to permit the passage of the alcohol with which the lamp is filled. The lamp is filled by pouring the alcohol upon the wick. The upper edge of the ring rises a little above the top of the lamp, as seen in the section Fig. 6.

Fig. 5.

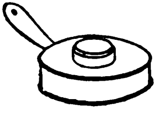
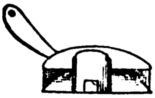


Fig. 6.

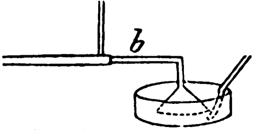


The power of different metals of conducting heat may be shown by the apparatus, Fig. 7. See paragraph 203.

Fig. 7.

Fig. 8 represents a convenient funnel for conveying gases into vessels the funnel being prolonged by a tube at right angles, and inverted in a basin of water, a small piece may be removed from the edge to admit the pipe from a retort.

Fig. 8.



Advantage will sometimes be gained by cementing a thin piece of wood to a cork made tapering, through both which tubes may be passed and secured, as in Fig. 9, for introducing into bottles and flasks.

Fig. 9.

Barium, Strontium, and Calcium. Dr Hare has recently obtained, by an improved process, all three of these metals. Saturated solutions of the chlorides were substituted for moistened oxides, and exposed to a powerful Voltaic circuit, in contact with mercury as a cathode; the resulting amalgams were distilled by means of vessels of iron. The avidity of the metals for oxygen was such, that, to see their bright metallic surfaces, it was necessary for the eye to follow closely the movements of the file or burnisher. They were brittle, and much harder than potassium or sodium. See *Amer. Jour.* Oct., 1839.

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* On one occasion when the apparatus was not touched till 36 hours after the fire had been withdrawn, on tapping the gun-barrel to remove it more easily, the whole of the glass tube was broken to pieces so excessively small that no trace of it could be found; a peculiar detonating compound indeed is formed within the tube, small quantities of which were found in almost every part of the room, and exploded with very little friction. Reid.

Absorption of Gases by Charcoal.

Saussure found that charcoal prepared from box-wood absorbs during the space of 24 to 36 hours, of

Ammoniacal gas,	90 times its vol.
Hydrochloric acid,	85
Sulphurous	65
Sulphuretted hydrogen,	81 (Henry.)
Nitrous Oxide,	40
Carbonic acid	35
Olefiant gas,	35
Carbonic oxide,	9.42
Oxygen,	9.25
Nitrogen,	7.5
Hydrogen,	1.75

GENERAL INDEX.

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* (n) signifies *note*.

INDEX

TO THE FIGURES OF APPARATUS, &c.

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* This also answers for decomposing hydrosulphuric acid gas by galvanism.