ON

THE DISCOVERY

OF

THE PERIODIC LAW,

AND ON

RELATIONS AMONG THE ATOMIC WEIGHTS.

BY

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PREFACE.

THIS little book contains an exact reprint of all the papers on Relations Among the Atomic Weights, and on the Periodic Law (provisionally termed the "Law of Octaves"), written by myself, and printed in the *Chemical News*, some years before M. Mendelejeff had published anything on the subject of the Periodic Law.

In the first paper the old atomic weights are employed, and in all the subsequent papers, those of Cannizzaro. It may also be stated that the word "equivalent" is in some of the papers used instead of "atomic weight."

The Appendix contains notes, &c., which have been published since the appearance of M. Mendelejeff's statements regarding the "periodic law."

Having been the first to publish the existence of the periodic law more than nineteen years ago, I feel, under existing circumstances, compelled to assert my priority in this matter.

That both D. Mendelejeff and Lothar Meyer have done a good deal to develop the periodic law is admitted, but this admission by no means assumes that either of these eminent chemists was the first discoverer of the law in question. As a matter of simple justice, and in the interest of all true workers in science, both theoretical and practical, it is right that the originator of any proposal or discovery should have the credit of his labour.

I will now proceed to give the dates of my several papers on the subject.

In a paper (*Chemical News*, vol. x. p. 59), July 30, 1864, I gave a list of all the then known elements in the order of atomic weight, which was the first ever published. Another table was appended, giving a horizontal arrangement of the more important elements, also in order of atomic weight, with blanks corresponding to some of the missing members of various groups. Thus, in the trivalent group, commencing with boron, there was a blank next below zinc, since filled by gallium, and another blank immediately below cadmium, since filled by indium. It was also pointed out that in the group containing carbon, silicon, titanium, and tin, there was an element wanting having an atomic weight of 73, being, in fact, the same missing element which M. Mendelejeff has recently predicted under the name of eka-silicium.

In an appendix to this paper (*Chemical News*, vol. x. p. 94), August 20, 1864, I announced the existence of a simple relation or law among the elements when arranged in the natural order of their atomic weights, to the effect that the eighth element, starting from a given one, was a sort of repetition of the first, or that elements belonging to the same group stood to each other in a relation similar to that between the extremes of one or more octaves in music. This was accompanied by a horizontal grouping arrangement.

In the *Chemical News*, vol. xii. pp. 83 and 94 (August 18 and 25, 1865), I published a full horizontal arrangement of the elements in order of atomic weight, and proposed to designate the simple relation existing between them by the provisional term "law of octaves." This law has since been called by M. Mendelejeff the "periodic law."

On March 1, 1866, I read a paper on this periodic law before the Chemical Society, and a notice of this appeared in the *Chemical News*, vol. xiii. p. 113, and also in many other journals. In the *Chemical News*, vol. xiii. p. 130 (March 16, 1866), I wrote as follows:—"I have endeavoured to describe relations actually subsisting among the atomic weights of the elements at present known, but am far from thinking that the discovery of new elements (or the revision of the atomic weights of those already known) will upset for any length of time the existence of a simple relation among the elements when arranged in the order of their atomic weights.

"The fact that such a simple relation exists now affords a strong presumptive proof that it will always continue to exist, even should hundreds of new elements be discovered. For, although the difference in the numbers of analogous elements might, in that case, be altered from 7, or a multiple of 7, to 8, 9, 10, 20, or any conceivable figure, the existence of a simple relation among the numbers of analogous elements would be none the less evident."

Years afterwards, the brilliant researches of Roscoe showed that the atomic weight of vanadium was 51·2, instead of 137. This reduction in the atomic weight of vanadium at once placed that metal in the same line as the phosphorus group, thereby confirming the periodic law. It may also be stated that in the *Chemical News*, vol. x. p. 95, I predicted that the atomic weight of indium might "prove to be identical, or nearly so, with those of zinc or cadmium."

To sum up: I claim to have been the first to publish a list of the elements in the order of their atomic weight, and also the first to describe the periodic law, showing the existence of a simple relation between them when so arranged.

I have applied this periodic law to the following among other subjects:—

1. Prediction of the atomic weight of missing elements, such as the missing element of the carbon group = 73, since termed eka-silicium by M. Mendelejeff.

2. Predicting the atomic weight of an element whose atomic weight was then unknown, viz., that of indium.

3. Selection of Cannizzaro's atomic weights, instead of those of Gerhardt, or the old system, which do not show a periodic law (*Chemical News*, vol. xiii. p. 113).

4. Predicting that the revision of atomic weights, or the discovery of new elements, would not upset the

harmony of the law—since illustrated by the case of vanadium.

5. Explaining the existence of numerical relations between the atomic weights (*Chemical News*, vol. xiii. p. 130).

6. Where two atomic weights were assigned to the same element, selecting that most in accordance with the periodic law: for instance, taking the atomic weight of beryllium as 9·4 instead of 14.

7. Grouping certain elements so as to conform to the periodic law instead of adopting the ordinary groups.

Thus, mercury was placed with the magnesium group, thallium with the aluminium group, and lead with the carbon group (*Chemical News*, vol. xiii. p. 113). Tellurium, on the other hand, I have always placed above iodine, from a conviction that its atomic weight may ultimately prove to be less than that of iodine.

8. Relation of the periodic law to physical properties—showing that similar terms from different groups, such as oxygen and nitrogen, or sulphur and phosphorus, frequently bear more physical resemblance to each other than they do to the remaining members of the same chemical group (*Chemical News*, vol. x. p. 60).

It is not denied that I was the first to publish a list of the elements in the natural order of their atomic weights, and Wurtz has written, in reference to the periodic law, that "it is a circumstance worthy of remark that such varied and unexpected developments arise from the simple idea of arranging bodies according to the increasing value of their atomic weights. This simple idea was a most important one" ('The Atomic Theory,' by A. Wurtz; Translation, p. 170; London, 1880).

ON

RELATIONS

AMONG THE

EQUIVALENTS.

From the 'Chemical News,' vol. vii. p. 70, Feb. 7, 1863.

ON RELATIONS AMONG THE EQUIVALENTS.

TO THE EDITOR.

SIR,—Many chemists, and M. Dumas in particular, have, on several occasions, pointed out some very interesting relations between the equivalents of bodies belonging to the same natural family or group; and my present purpose is simply to endeavour to proceed a little further in the same direction. I must, however, premise that many of the observations here collected together are well known already, and are only embodied in my communication for the purpose of rendering it more complete.

Before proceeding any further, I may also remark that in the difficult task of grouping the elementary bodies, I have been guided more by chemical characteristics than by physical appearances, and have therefore taken no notice of the ordinary distinction between metals and non-metallics. The numbers which I have attached to the various groups are merely for the purpose of reference, and have no further significance whatever. For the sake of perspicuity, I have employed the old equivalent numbers, these atomic weights being, with one or two exceptions, taken from the eighth edition of

'Fownes' Manual.' The following are among the most striking relations observed on comparing the equivalents of analogous elements. (In order to avoid the frequent repetition of the word "equivalent," I have generally used the names of the different elements as representing their equivalent numbers: thus, when I say that zinc is the mean of magnesium and cadmium, I intend to imply that the equivalent of zinc is the mean of those of magnesium and cadmium, and so on, throughout the paper):—

Group I. Metals of the alkalies:—Lithium, 7; sodium, 23; potassium, 39; rubidium, 85; cæsium, 123; thallium, 204.

The relation among the equivalents of this group (see *Chemical News*, January 10, 1863) may perhaps be most simply stated as follows:—

1 of lithium	+ 1	of potassium	=	2 of sodium.
1 ,,	+ 2	,,	=	1 of rubidium.
1 ,,	+ 3	,,	=	1 of cæsium.
1 ,,	+ 4	,,	=	163, the equivalent of a metal not yet discovered.
1 ,,	+ 5	,,	=	1 of thallium.

Group II. Metals of the alkaline earths:—Magnesium, 12; calcium, 20; strontium, 43·8; barium, 68·5.

In this group, strontium is the mean of calcium and barium.

Group III. Metals of the earths:—Beryllium, 6·9; aluminium, 13·7; zirconium, 33·6; cerium, 47; lanthanium, 47; didymium, 48; thorium, 59·6.

Aluminium equals two of beryllium, or one-third of the sum of beryllium and zirconium. (Aluminium also is one-half of manganese, which, with iron and chromium, forms sesquioxides, isomorphous with alumina.)

1 of zirconium	+ 1	of aluminium	=	1 of cerium.
1 ,,	+ 2	,,	=	1 of thorium.

Lanthanium and didymium are identical with cerium, or nearly so.

Group IV. Metals whose protoxides are isomorphous with magnesia:—Magnesium, 12; chromium, 26·7; manganese, 27·6; iron, 28; cobalt, 29·5; nickel, 29·5; copper, 31·7; zinc, 32·6; cadmium, 56.

Between magnesium and cadmium, the extremities of this group, zinc is the mean. Cobalt and nickel are identical. Between cobalt and zinc, copper is the mean. Iron is one-half of cadmium. Between iron and chromium, manganese is the mean.

Group V. Fluorine, 19; chlorine, 35·5; bromine, 80; iodine, 127.

In this group bromine is the mean between chlorine and iodine.

Group VI. Oxygen, 8; sulphur, 16; selenium, 39·5; tellurium, 64·2.

In this group selenium is the mean between sulphur and tellurium.

Group VII. Nitrogen, 14; phosphorus, 31; arsenic, 75; osmium, 99·6; antimony, 120·3; bismuth, 213.

In this group arsenic is the mean between phosphorus and antimony.

Osmium approaches the mean of arsenic and antimony, and is also almost exactly half the difference between nitrogen and bismuth, the two extremities of this group; thus $\frac{213 - 14}{2} = 99 \cdot 5$.

Bismuth equals 1 of antimony + 3 of phosphorus; thus, $120 \cdot 3 + 93 = 213 \cdot 3$.

Group VIII. Carbon, 6; silicon, 14·20; titanium, 25; tin, 58.

In this group the difference between tin and titanium is nearly three times as great as that between titanium and silicon.

Group IX. Molybdenum, 46; vanadium, 68·6; tungsten, 92; tantalium, 184.

In this group vanadium is the mean between molybdenum and tungsten.

Tungsten equals 2 of molybdenum, and tantalium equals 4 of molybdenum.

Group X. Rhodium, 52·2; ruthenium, 52·2; palladium, 53·3; platinum, 98·7; iridium, 99.

In this group the first three are identical, or nearly so, and are rather more than half of the other two. (I may mention, by the way, that platinum is rather more than the half of gold; thus, $98 \cdot 7 \times 2 = 197 \cdot 4$, gold being 197.)

Group XI. Mercury, 100; lead, 103·7; silver, 108.

Lead is here the mean of the other two.

If we deduct the member of a group having the lowest equivalent from that immediately above it, we frequently observe that the numbers thus obtained bear a simple relation to each other, as in the following examples:—

Member of Group having lowest Equivalent.		One immediately above the preceding.		Difference.
Magnesium	12	Calcium	20	8
Oxygen	8	Sulphur	16	8
Carbon	6	Silicon	14·2	8·2
Lithium	7	Sodium	23	16
Fluorine	19	Chlorine	35·5	16·5
Nitrogen	14	Phosphorus	31	17

A similar relation, though not quite so obvious as the above, may be shown by deducting the lowest member of a triad from the highest. The numbers thus obtained in the different triads correspond to a great extent. (By a triad I understand a group of three analogous elements, the equivalent of one of which is the mean of the other two.) Of this relation I append a few examples:—

Lowest Term of Triad.		Highest Term of Triad.		Difference.
Lithium	7	Potassium	39	32
Magnesium	12	Cadmium	56	44
Molybdenum	46	Tungsten	92	46
Sulphur	16	Tellurium	64·2	48·2
Calcium	20	Barium	68·5	48·5
Phosphorus	31	Antimony	120·3	89·3
Chlorine	35·5	Iodine	127	91·5

In the relation previously pointed out the difference between the lowest member of a group and the next above it was either 8, or $8 \times 2 = 16$; and in the first of these triads the difference is $8 \times 4 = 32$; in the next four it approaches $8 \times 6 = 48$; and in the two last triads it is nearly twice as great.

The difference between the highest member of the platinum group, viz. iridium, 99, and the lowest, rhodium, 52·2, is 46·8, a number which approximates very closely to those obtained in some of the above triads; and it therefore appears possible that the platinum metals are the extremities of a triad, the central term or mean of which is at present unknown.

I am, &c.,

J. A. R. N.

P.S.—With the view of economising space I have omitted most of the calculations, which, however, are very simple, and can be verified in a moment by the reader. The equivalents thus obtained by calculation will be found to approximate to those procured by experiment, as closely as can be expected in such cases.

I also freely admit that some of the relations above pointed out are more apparent than real; others, I trust, will prove of a more durable and satisfactory description.

From the 'Chemical News,' vol. x. p. 59, July 30, 1864.

RELATIONS BETWEEN EQUIVALENTS.

TO THE EDITOR.

SIR,—In your impression of the 2nd inst., a correspondent, under the name of "Studiosus," has called attention to the existence of a law to the effect "that the atomic weights of the elementary bodies are, with few exceptions, either exactly or very nearly multiples of eight."

Now, in a letter "On Relations among the Equivalents," which was signed with my initials, and inserted in the *Chemical News* of February 7, 1863, I called attention to the numerical differences between the equivalents of certain allied elements, and showed that such differences were generally multiples of eight, as in the following examples:—

Member of a Group having lowest Equivalent.		One immediately above the preceding.		Difference.	
				H = 1.	O = 1.
Magnesium	24	Calcium	40	16	1
Oxygen	16	Sulphur	32	16	1
Lithium	7	Sodium	23	16	1
Carbon	12	Silicon	28	16	1
Fluorine	19	Chlorine	35·5	16·5	1·031
Nitrogen	14	Phosphorus	31	17	1·062
Lowest Term of Triad.		**Highest Term of Triad.**			
Lithium	7	Potassium	39	32	2
Magnesium	24	Cadmium	112	88	5·5
Molybdenum	96	Tungsten	184	88	5·5
Phosphorus	31	Antimony	122	91	5·687
Chlorine	35·5	Iodine	127	91·5	5·718
Potassium	39	Cæsium	133	94	5·875
Sulphur	32	Tellurium	129	97	6·062
Calcium	40	Barium	137	97	6·062

In the last of the above columns the difference is given referred to 16, the equivalent of oxygen, as unity, and it will be seen that, generally speaking, the equivalent of oxygen is the unit of these differences, just as the equivalent of hydrogen, in "Prout's law," is the unit of the atomic weights. Exceptions there are, however, in both cases, which render it necessary to take one-half or one-quarter of the equivalent of oxygen in the one case, and of hydrogen in the other, in order to represent all the numbers obtained as multiples by a whole number of the given standard.

Now, if the law of "Studiosus" had any real existence, the above facts would resolve themselves into particular cases of its application. For if "the atomic weights are multiples of eight," any differences between them must also be divisible by eight.

We have here the symbols and the atomic weights of sixty-one elements, placed in their numerical order, and in the third column is the difference between each atomic weight and the one immediately preceding it :—

H	1		Ca	40	1	Ce	92	2·5	V	137	0
Li	7	6	Ti	50	10	La	92	0	Ta	138	1
G	9	2	Cr	52·5	2·5	Di	96	4	W	184	46
B	11	2	Mn	55	2·5	Mo	96	0	Nb	195	11
C	12	1	Fe	56	1	Ro	104	8	Au	196	1
N	14	2	Co	58·5	2·5	Ru	104	0	Pt	197	1
O	16	2	Ni	58·5	0	Pd	106·5	2·5	Ir	197	0
Fl	19	3	Cu	63·5	5	Ag	108	1·5	Os	199	2
Na	23	4	Y	64	0·5	Cd	112	4	Hg	200	1
Mg	24	1	Zn	65	1	Sn	118	6	Tl	203	3
Al	27·5	3·5	As	75	10	U	120	2	Pb	207	4
Si	28	0·5	Se	79·5	4·5	Sb	122	2	Bi	210	3
P	31	3	Br	80	0·5	I	127	5	Th	238	28
S	32	1	Rb	85	5	Te	129	2			
Cl	35·5	3·5	Sr	87·5	2·5	Cs	133	4			
K	39	3·5	Zr	89·5	2	Ba	137	4			

Now, it will be observed that in all the above differences the number eight occurs but once, and we never meet with a multiple of eight, whereas if the law of "Studiosus" were true, the equivalents of the elements, in whatever order they might be placed, should, when not identically the same, differ either by eight or by some multiple of eight in every case.

While upon the subject of "relations among the equivalents," I may observe that the most important of these may be seen at a glance in the following table :—

			Triad.			
			Lowest Term.	Mean.	Highest Term.	
I.		Li 7	+17 =Mg 24	Zn 65	Cd 112	
II.		B 11				Au 196
III.		C 12	+16 =Si 28		Sn 118	
IV.		N 14	+17 =P 31	As 75	Sb 122	+88=Bi 210
V.		O 16	+16 =S 32	Se 79·5	Te 129	+70=Os 199
VI.		F 19	+16·5=Cl 35·5	Br 80	I 127	
VII.	Li 7	+16=Na 23	+16 =K 39	Rb 85	Cs 133	+70=Tl 203
VIII.	Li 7	+17=Mg 24	+16 =Ca 40	Sr 87·5	Ba 137	+70=Pb 207
IX.			Mo 96	V 137	W 184	
X.			Pd 106·5		Pt 197	

This table is by no means so perfect as it might be; in fact I have some by me of a more complete character, but as the position to be occupied by the various elements is open to considerable controversy, the above only is given as containing little more than those elementary groups the existence of which is almost universally acknowledged.

I now subjoin a few explanatory remarks on the different groups contained in the above table, the number attached to each group being merely for the purpose of reference.

Group II. Boron is here classed with gold, both these elements being triatomic, although the latter is sometimes monatomic.

Group III. Silicon and tin stand to each other as the extremities of a triad. Titanium is usually classed along with them, and occupies a position intermediate between silicon and the central term or mean of the triad, which is at present wanting; thus $\frac{\text{Si } 28 + \text{Sn } 118}{2}$ $= 73$, mean of triad, and $\frac{\text{Si } 28 + \text{mean of triad } 73}{2} =$ 50·5, the eq. of Ti being 50.

Group IV. The equivalent of antimony is nearly the mean of those of phosphorus and bismuth; thus, $\frac{31 + 210}{2} = 120 \cdot 5$, the eq. of Sb being 122.

Group VII. The relations which M. Dumas has pointed out between the members of this group are well known; a slight alteration must be made, owing to the atomic weight of cæsium having been raised. The relations, then, will be thus:—

Li + K =	2 Na,	or in figures,	7 + 39 = 46
Li + 2 K =	Rb	,,	7 + 78 = 85
2 Li + 3 K =	Cs	,,	14 + 117 = 131
Li + 5 K =	Tl	,,	7 + 195 = 202
3 Li + 5 K =	2 Ag	,,	21 + 195 = 216

The equivalent of silver is thus connected with those of the alkali metals. It may also, which amounts to the same thing, be viewed as made up of the equivalents of sodium and rubidium; thus, 23 + 85 = 108. It is likewise nearly the mean between rubidium and cæsium, thus, $\frac{85 + 133}{2} = 109$.

Group VIII. If lithium may be considered as connected with this group as well as with the foregoing (and by some chemists its oxide is viewed as a connecting link between the alkalies and the alkaline earths), we may perform the same calculations in this group that M. Dumas has done in the preceding, thus,

Li + Ca =	2 Mg,	or in figures,	7 + 40 = 47
Li + 2 Ca =	Sr	,,	7 + 80 = 87
2 Li + 3 Ca =	Ba	,,	14 + 120 = 134
Li + 5 Ca =	Pb	,,	7 + 200 = 207

Again, there are two triads in the group of alkali metals, one which has been long known, viz. lithium, sodium, and potassium, and the other, which was pointed out by Mr. C. W. Quin, in the *Chemical News* of November 9, 1861, viz. potassium, rubidium, and cæsium.

Potassium is thus the highest term of one triad and the lowest term of another.

In like manner, if we include lithium, we shall have among the metals of the alkaline earths two triads, the first comprising lithium, magnesium, and calcium, and the second calcium, strontium, and barium, calcium standing at the top of one triad and at the bottom of the other.

The element lead occupies a position in relation to the metals of the alkaline earths similar to that filled by thallium in the group of alkali metals. Osmium appears to play a similar part in the sulphur group, and bismuth in the phosphorus group. The analogous term in the chlorine group is not yet known.

Thallium, in its physical properties, bears some resemblance to lead, and it frequently happens that similar terms taken from different groups, such as oxygen and nitrogen, or sulphur and phosphorus, bear more physical resemblance to each other than they do to the members of the groups to which, for chemical reasons, we are compelled to assign them.

It will be observed that the difference between the equivalents of tellurium and osmium, cæsium and thallium, and barium and lead respectively is the same in each case, viz. 70.

Group X. Palladium and platinum appear to be the extremities of a triad, the mean of which is unknown.

So frequently are relations to be met with among the equivalents of allied elements, that we may almost predict that the next equivalent determined, that of indium, for instance, will be found to bear a simple relation to those of the group to which it will be assigned.

In conclusion, I may mention that the equivalents I have adopted in this letter were taken from the highly interesting and important paper by Professor Williamson, lately published in the Journal of the Chemical Society.

I am, &c.,

July 12, 1864. JOHN A. R. NEWLANDS.

From the 'Chemical News,' vol. x. p. 94, Aug. 20, 1864.

ON RELATIONS AMONG THE EQUIVALENTS.

TO THE EDITOR.

SIR,—In addition to the facts stated in my late communication, may I be permitted to observe that if the elements are arranged in the order of their equivalents, calling hydrogen 1, lithium 2, glucinum 3, boron 4, and so on (a separate number being attached to each element having a distinct equivalent of its own, and where two elements happen to have the same equivalent, both being designated by the same number), it will be observed that elements having consecutive numbers frequently either belong to the same group or occupy similar positions in different groups, as in the following examples :—

		No.		No.		No.		No.		No.
Group *a*	N	6	P	13	As	26	Sb	40	Bi	54
,, *b*	O	7	S	14	Se	27	Te	42	Os	50
,, *c*	Fl	8	Cl	15	Br	28	I	41	—	—
,, *d*	Na	9	K	16	Rb	29	Cs	43	Tl	52
,, *e*	Mg	10	Ca	17	Sr	30	Ba	44	Pb	53

Here the difference between the number of the lowest member of a group and that immediately above it is 7; in other words, the eighth element starting from a given one is a kind of repetition of the first, like the eighth note of an octave in music. The differences between the numbers of the other members of a group are frequently twice as great; thus in the nitrogen group, between N and P there are seven elements; between P and As, 13; between As and Sb, 14; and between Sb and Bi, 14.

In conclusion, I may remark that just as we have several examples of the apparent existence of triads, the extremities of which are known, whilst their centres are wanting (such as the metals of the platinum group, which may be conceived to be the extremities of three distinct triads, and perhaps also silver and gold may be related to each other in this manner), so we may look upon certain of the elements, e. g. Mn, Fe, Co, Ni, and Cu, as the centres of triads, the extremes of which are at present unknown, or, perhaps, in some instances only unrecognised.

I am, &c.,

August 8, 1864. JOHN A. R. NEWLANDS.

From the 'Chemical News,' vol. x. p. 95, Aug. 20, 1864.

EQUIVALENT OF INDIUM.

TO THE EDITOR.

SIR,—In reply to "Inquirer," who asks me to give him some idea of the equivalent of indium, I am afraid that our knowledge of this metal is too imperfect to enable us to give a satisfactory answer to such a question.

Professor Roscoe has stated (*Chemical News*, June 25, 1864) that indium "in its chemical relations resembles zinc, with which it is associated in nature," and taking this statement as the best existing basis on which to build our notions regarding its equivalent, we should expect to find that the atomic weight of indium bears some simple relation to those of the zinc group, including under that term magnesium, zinc, cadmium, and, perhaps, mercury. The equivalent of indium, then, may prove to be identical, or nearly so, with those of zinc or cadmium. I leave magnesium out of the question, as it is not likely that indium, from its known properties, has an equivalent lower than 50. It is also just possible that indium may occupy a position in the zinc group similar to that of thallium among the alkali metals, in which case the equivalent of indium would be 182, or thereabouts.

I am, &c.,

August 15, 1864. JOHN A. R. NEWLANDS.

From the 'Chemical News,' vol. x. p. 240, Nov. 12, 1864.

ON THE EQUIVALENT OF INDIUM.

TO THE EDITOR.

SIR,—From the equivalent of indium given in your last impression (viz. 463·4, O = 100 ; or 74·14, O = 16), it seems probable that that metal is the mean of a triad consisting of silicon, indium, and tin ; or perhaps, of another triad composed of aluminium, indium, and uranium.

If we regard indium as belonging to the same group as zinc, it will form one of a series of elements having consecutive equivalents, including Cr, Mn, Fe, Co, Ni, Cu, Zn, and In ; the equivalent of zinc being the mean of those of iron and indium.

We must, however, wait for further details of the properties of this newly discovered element, and especially of its atomicity, before it can be safely assigned to any particular group.

It will be seen that the equivalent of indium is next in numerical order to that of zinc, and but slightly below that of arsenic ; and we have already observed that "elements having consecutive equivalents frequently either belong to the same group or occupy similar positions in different groups."

I am, &c.,

Nov. 8, 1864. JOHN A. R. NEWLANDS.

From the 'Chemical News,' vol. xii. p. 83, Aug. 18, 1865.

ON THE LAW OF OCTAVES.

TO THE EDITOR.

SIR,—With your permission, I would again call attention to a fact pointed out in a communication of mine, inserted in the *Chemical News* for August 20, 1864. If the elements are arranged in the order of their equivalents, with a few slight transpositions, as in the accompanying table, it will be observed that elements belonging to the same group usually appear on the same horizontal line.

	No.		No.		No.		No.		No.		No.		No.		No.
H	1	F	8	Cl	15	Co & Ni	22	Br	29	Pd	36	I	42	Pt & Ir	50
Li	2	Na	9	K	16	Cu	23	Rb	30	Ag	37	Cs	44	Tl	53
G	3	Mg	10	Ca	17	Zn	25	Sr	31	Cd	38	Ba & V	45	Pb	54
Bo	4	Al	11	Cr	19	Y	24	Ce & La	33	U	40	Ta	46	Th	56
C	5	Si	12	Ti	18	In	26	Zr	32	Sn	39	W	47	Hg	52
N	6	P	13	Mn	20	As	27	Di & Mo	34	Sb	41	Nb	48	Bi	55
O	7	S	14	Fe	21	Se	28	Ro & Ru	35	Te	43	Au	49	Os	51

NOTE.—Where two elements happen to have the same equivalent, both are designated by the same number.

It will also be seen that the numbers of analogous elements generally differ either by 7 or by some multiple of seven; in other words, members of the same group stand to each other in the same relation as the extremities of one or more octaves in music. Thus, in the nitrogen group, between nitrogen and phosphorus there are 7 elements; between phosphorus and arsenic, 14; between arsenic and antimony, 14; and lastly, between antimony and bismuth, 14 also.

This peculiar relationship I propose to provisionally term the "Law of Octaves."

I am, &c.,

August 8, 1865. JOHN A. R. NEWLANDS.

From the 'Chemical News,' vol. xii. p. 94, Aug. 25, 1865.

ON THE CAUSE OF NUMERICAL RELATIONS AMONG THE EQUIVALENTS.

TO THE EDITOR.

SIR,—By way of addition to my last letter, I will, with your permission, endeavour to show that all the numerical relations among the equivalents pointed out by M. Dumas and others, including the well-known triads, are merely arithmetical results flowing from the existence of the "law of octaves," taken in connection with the fact of the equivalents forming a series of numbers approaching to the natural order, as may be observed by an inspection of the following table :—

Symbol.	No.	Eq.	Eq. ÷ No.	Symbol.	No.	Eq.	Eq. ÷ No.
H	1	1	1	Br	29	80	2·758
Li	2	7	3·5	Rb	30	85	2·833
G	3	9	3	Sr	31	87·5	2·823
Bo	4	11	2·75	Zr	32	89·5	2·797
C	5	12	2·4	Ce	33	92	2·788
N	6	14	2·333	Di	34	96	2·824
O	7	16	2·286	Ro	35	104	2·971
F	8	19	2·375	Pd	36	106·5	2·958
Na	9	23	2·555	Ag	37	108	2·919
Mg	10	24	2·4	Cd	38	112	2·947
Al	11	27·5	2·5	Sn	39	118	3·026
Si	12	28	2·333	U	40	120	3
P	13	31	2·385	Sb	41	122	2·975
S	14	32	2·286	I	42	127	3·024
Cl	15	35·5	2·367	Te	43	129	3
K	16	39	2·437	Cs	44	133	3·023
Ca	17	40	2·353	Ba	45	137	3·044
Ti	18	50	2·778	Ta	46	138	3
Cr	19	52·5	2·763	W	47	184	3·915
Mn	20	55	2·75	Nb	48	195	4·062
Fe	21	56	2·667	Au	49	196	4
Co	22	58·5	2·659	Pt	50	197	3·94
Cu	23	63·5	2·761	Os	51	199	3·902
Yt	24	64	2·667	Hg	52	200	3·846
Zn	25	65	2·6	Tl	53	203	3·83
In	26	72	2·769	Pb	54	207	3·833
As	27	75	2·778	Bi	55	210	3·818
Se	28	79·5	2·839	Th	56	238	4·25

In this table the first column of figures gives the numbers of the elements; the second, their equivalents; and the third, the product obtained by dividing the equivalent of an element by its number. It will be seen that the number of an element is nearly equal to its equivalent divided by a certain sum, which varies, however, as we ascend the scale, thus:—

From 4 to 17, the No. = Eq. ÷ 2·5
From 18 to 34, the No. = Eq. ÷ 2·75
From 35 to 46, the No. = Eq. ÷ 3
From 47 to 56, the No. = Eq. ÷ 4

Now, as the equivalents correspond more or less closely in their rate of increase to the numbers of the elements, anything that is true of the latter must, with a certain amount of latitude, be true of the former also; and, therefore, if the number of one element is the mean of those of two others (whether belonging to the same group or not), its equivalent will also be the mean of their equivalents.

Thus the number of Ti, 18, is the mean of those of F, 8, and Se, 28, and the equivalent of Ti = 50 is also the mean of those of F = 19 and Se = 79·5, thus:—

$$\frac{19 + 79{\cdot}5}{2} = 49{\cdot}25.$$

This is only one example of many that I might adduce of elements, whether analogous or not, possessing intermediate numbers, and also intermediate equivalents.

Now, in conformity with the "law of octaves," elements belonging to the same group generally have numbers differing by seven or by some multiple of seven,—that is to say, if we begin with the lowest member of a group, calling it 1, the succeeding members will have the numbers 8, 15, 22, 29, 36, &c., respectively.

But 8 is the mean between 1 and 15; 15 is the mean between 8 and 22; 22 is the mean between 15 and 29, &c., and, therefore, as an arithmetical result of the "law of octaves," the number of an element is often the exact mean of those of two others belonging to the same group, and consequently its equivalent also approximates to the mean of their equivalents.

The real triad exists in the numbers of analogous elements, as a consequence of their differing by some multiple of a regularly recurring number, viz. 7. The triad of M. Dumas is only an approximation to the former, and is due to the partial concordance between the equivalents of the elements and their respective numbers.

A similar train of reasoning will explain why it is that on deducting the equivalent of the lowest member of a group from that immediately above it we obtain a constant number (about 16). For we find that if, instead of taking elements of the same group (that is, elements whose numbers differ by 7), we perform a similar calculation with elements whose numbers differ by 8 or by 9, &c., we obtain in each case numbers quite as constant as in the above. The difference of about 16 merely expresses the average difference for an interval of seven elements in the lower part of the scale of equivalents.

The above remarks are merely offered as an attempt to indicate, in a general manner, the mode in which the existence of arithmetical relations among the equivalents may, at any rate, be partially explained.

I am, &c.,

August 15, 1865. JOHN A. R. NEWLANDS.

From the 'Chemical News,' vol. xiii. p. 113, Mar. 9, 1866.

EXTRACT FROM REPORT OF MEETING OF THE CHEMICAL SOCIETY, MARCH 1, 1866. PROFESSOR A. W. WILLIAMSON IN THE CHAIR.

Mr. John A. R. Newlands read a paper entitled "The Law of Octaves, and the Causes of Numerical Relations among the Atomic Weights." The author claims the discovery of a law according to which the elements analogous in their properties exhibit peculiar relationships, similar to those subsisting in music between a note and its octave. Starting from the atomic weights on Cannizzaro's system, the author arranges the known elements in order of succession, beginning with the lowest atomic weight (hydrogen) and ending with thorium (= 231·5); placing, however, nickel and cobalt, platinum and iridium, cerium and lanthanum, &c., in positions of absolute equality or in the same line. The fifty-six elements so arranged are said to form the compass of eight octaves, and the author finds that chlorine, bromine, iodine, and fluorine are thus brought into the same line, or occupy corresponding places in his scale. Nitrogen and phosphorus, oxygen and sulphur, &c., are also considered as forming true octaves. The author's supposition will be exemplified in Table II., shown to the meeting, and here subjoined :—

TABLE II.—ELEMENTS ARRANGED IN OCTAVES.

	No.		No.		No.		No.		No.		No.		No.		No.
H	1	F	8	Cl	15	Co & Ni	22	Br	29	Pd	36	I	42	Pt & Ir	50
Li	2	Na	9	K	16	Cu	23	Rb	30	Ag	37	Cs	44	Os	51
G	3	Mg	10	Ca	17	Zn	24	Sr	31	Cd	38	Ba & V	45	Hg	52
Bo	4	Al	11	Cr	19	Y	25	Ce & La	33	U	40	Ta	46	Tl	53
C	5	Si	12	Ti	18	In	26	Zr	32	Sn	39	W	47	Pb	54
N	6	P	13	Mn	20	As	27	Di & Mo	34	Sb	41	Nb	48	Bi	55
O	7	S	14	Fe	21	Se	28	Ro & Ru	35	Te	43	Au	49	Th	56

Dr. Gladstone made objection on the score of its having been assumed that no elements remain to be discovered. The last few years had brought forth thallium, indium, cæsium, and rubidium, and now the finding of one more would throw out the whole system. The speaker believed there was as close an analogy subsisting between the metals named in the last vertical column as in any of the elements standing on the same horizontal line.

Professor G. F. Foster humorously inquired of Mr.

Newlands whether he had ever examined the elements according to the order of their initial letters? For he believed that any arrangement would present occasional coincidences, but he condemned one which placed so far apart manganese and chromium, or iron from nickel and cobalt.

Mr. Newlands said that he had tried several other schemes before arriving at that now proposed. One founded upon the specific gravity of the elements had altogether failed, and no relation could be worked out of the atomic weights under any other system than that of Cannizzaro.

From the 'Chemical News,' vol. xiii. p. 130, Mar. 16, 1866.

ON THE "LAW OF OCTAVES."

TO THE EDITOR.

SIR,—Will you allow me to make a few remarks in reply to the objections which were offered to my paper, read at the meeting of the Chemical Society on the 1st inst.?

The rule followed by the elements when arranged and numbered off, in the order of their atomic weights, was expressed as follows:—"The numbers of analogous elements, when not consecutive, differ by 7, or by some multiple of 7." The clause "when not consecutive" was introduced for the purpose of embracing certain analogous elements whose atomic weights are consecutive, e. g. the series containing chromium No. 19, manganese No. 20, iron No. 21, nickel and cobalt No. 22, copper No. 23, and zinc No. 24.

Now, it appears to be difficult to construct any arrangement founded upon numerical data, which could bring the above-named elements into closer connection than the one which I have adopted; yet it has been condemned on the score of its placing "so far apart manganese and chromium, or iron from nickel and cobalt." I readily grant "that any arrangement may present occasional coincidences;" but, at the same time, take leave to observe that the coincidences which I have pointed out are the rule, and not the exception. I have endeavoured to describe relations actually subsisting among the atomic weights of the elements at present known, but am far from thinking that the discovery of new elements (or the revision of the atomic weights of those already known) will upset, for any length of time, the existence of a simple relation among the elements, when arranged in the order of their atomic weights.

The fact that such a simple relation exists now, affords a strong presumptive proof that it will always continue to exist, even should hundreds of new elements be discovered. For, although the difference in the numbers of analogous elements might, in that case, be altered from 7, or a multiple of 7, to 8, 9, 10, 20, or any conceivable figure, the existence of a simple relation among the numbers of analogous elements would be none the less evident.

As a proof, however, that new discoveries are not very likely to destroy such relationship, I may mention that when the existence of the "law of octaves" was first pointed out (*Chemical News*, August 20, 1864), the difference between the numbers of P and As was 13 instead of 14, as between As and Sb, and also between Sb and Bi. Since then, by the determination of the atomic weight of indium, the difference of the numbers of P and As has been made to be 14, as in the other cases adduced.

I am, &c.,

March 12, 1866. JOHN A. R. NEWLANDS.

APPENDIX.

The following notes, &c., have been published since the appearance of M. Mendelejeff's statements regarding the "periodic law."

From the 'Chemical News,' vol. xxv. p. 252, May 24, 1872.

RELATIONS BETWEEN THE ATOMIC WEIGHTS OF CANNIZZARO.

TO THE EDITOR.

SIR,—As several papers have recently appeared both in this country and on the Continent, on the subject of "Relations between the Atomic Weights of Cannizzaro," may I be permitted to remind your readers that most of these relations were pointed out in a paper written by myself, and published in the *Chemical News* for July 30, 1864 (vol. x. p. 59). In a subsequent paper, published in the *Chemical News* for August 20, 1864 (vol. x. p. 94), I showed that the elements belonging to the same group stood to each other in a relation similar to that between the extremes of one or more octaves in music. In the *Chemical News* for August 18 and 25, 1865 (vol. xii. pp. 83 and 94), I discussed the whole question; and on March 1, 1866, read a paper on the subject before the Chemical Society, when I showed that it was only with the atomic weights of Cannizzaro that such extremely simple relationship could be observed, thereby constituting an independent argument in favour of this system of atomic weights.

As a former not unfrequent writer in your Journal, may I request the insertion of the above few lines to vindicate my priority in this matter.

I am, &c.,

May 21, 1872. JOHN A. R. NEWLANDS.

From the 'Chemical News,' vol. xxvi. p. 19, July 12, 1872.

ON A RELATION BETWEEN THE CHEMICAL GROUPING OF CERTAIN ELEMENTS AND THE QUANTITIES IN WHICH THEY EXIST UPON THE EARTH'S SURFACE.

BY JOHN A. R. NEWLANDS.

If a list be made of the fourteen principal elements which occur on the earth's surface (including the ocean and the atmosphere) in the largest quantities, which are also most widely distributed, and which appear essential to vegetable or animal life, it will be observed that they comprise two representatives of each of the chief chemical groups. Thus we have :—

1. Hydrogen and chlorine.
2. Sodium and potassium.
3. Magnesium and calcium.
4. Aluminium and iron.
5. Carbon and silicon.
6. Nitrogen and phosphorus.
7. Oxygen and sulphur.

Hydrogen and chlorine are here classed together on account of their mutual replaceability, with but a slight change of properties, in many chemical compounds, such as trichloracetic acid, &c. The position, too, of hydrogen in the list of elements, when arranged in the order of atomic weights, indicates that it is really the lowest member of the chlorine group.

From the 'Chemical News,' vol. xxvii. p. 318, June 27, 1873.

EXTRACT FROM REPORT OF MEETING OF CHEMICAL SOCIETY, JUNE 19, 1873. DR. ODLING, PRESIDENT, IN THE CHAIR.

The following paper, a "Note on Relations among the Atomic Weights," by J. A. R. Newlands, was then read by the author.

In the June number of the Journal of the Chemical Society is a paper by L. Meyer, "On the Systemisation of Organic Chemistry," in which reference is made to M. Mendelejeff as having shown that certain properties of the elements appear "as a regular periodical function of the atomic weight, if the elements are arranged in the natural system, or according to the numerical values of their atomic weights." Now, in a paper read before this Society on March 1, 1866, I showed that, when "the elements were arranged in the order of their atomic weights, a simple relation existed between them, those belonging to the same group standing to each other in a relation similar to that between the extremes of one or more octaves in music." I had also previously published the same statement in the *Chemical News*, vol. x. p. 94, and on other occasions. As my paper was not printed in the Journal of the Chemical Society, and therefore a question of priority may arise, I have to request, as a simple matter of justice, the insertion of this brief note in the Society's Journal.

The President said that the reason why Mr. Newlands' paper on this subject in 1866 had not been published by the Society was that they had made it a rule not to publish papers of a purely theoretical nature, since it was likely to lead to correspondence of a controversial character.

From the 'Chemical News,' vol. xxxii. p. 21, July 16, 1875.

On Relations among the Atomic Weights of the Elements when arranged in their Natural Order.

By John A. R. Newlands.

It is a singular circumstance that handbooks of chemistry which contain tables of various data, such as boiling-points, melting-points, specific gravities, latent heat, specific heat, conducting powers for heat and electricity, &c., in the natural order, should in reference to the atomic weights of the elements, give no similar table, but merely contain an alphabetical arrangement.

The principal object of the present paper is to call attention to this striking omission, which will doubtless be soon remedied by the introduction into treatises on chemistry, of a table of the atomic weights of the elements in their natural order, in addition to the usual convenient alphabetical arrangement.

I now offer a table of this description; the different columns of the table give as follows:—1st, the ordinal number; 2nd, the symbol; 3rd, the atomic weight; and 4th, the difference between each atomic weight and that preceding it. All the atomic weights except that of thallium, and also five marked as doubtful, viz. those of yttrium, didymium, cerium, erbium, and lanthanum, are taken from 'Fownes' Chemistry,' 11th edition, 1873.

TABLE I.—ELEMENTS IN ORDER OF ATOMIC WEIGHT.

No.	Symb.	At. Wt.	Diff.	No.	Symb.	At. Wt.	Diff.
1	H	1	..	15	Cl	35·5	3·5
2	Li	7	6	16	K	39·1	3·6
3	Be	9·4	2·4	17	Ca	40	0·9
4	B	11	1·6	18	Ti	50	10
5	C	12	1	19	V	51·2	1·2
6	N	14	2	20	Cr	52·2	1
7	O	16	2	21	Mn	55	2·8
8	F	19	3	22	Fe	56	1
9	Na	23	4	23	Ni	58·8	2·8
10	Mg	24	1	24	Co	58·8	0
11	Al	27·4	3·4	25	Cu	63·4	4·6
12	Si	28	0·6	26	Zn	65·2	1·8
13	P	31	3	27	As	75	9·8
14	S	32	1	28	Se	79·4	4·4

TABLE I.—ELEMENTS IN ORDER OF ATOMIC WEIGHT—*continued.*

No.	Symb.	At. Wt.	Diff.	No.	Symb.	At. Wt.	Diff.
29	Br	80	0·6	47	Ba	137	4
30	Rb	85·4	5·4	48	Di	138 (?)	1
31	Sr	87·6	2·2	49	Ce	140 (?)	2
32	Y	88 (?)	0·4	50	Er	178 (?)	38
33	Zr	89·6	1·6	51	La	180 (?)	2
34	Nb	94	4·4	52	Ta	182	2
35	Mo	96	2	53	W	184	2
36	Rh	104·4	8·4	54	Au	197	13
37	Ru	104·4	0	55	Pt	197·4	0·4
38	Pd	106·6	2·2	56	Ir	198	0·6
39	Ag	108	1·4	57	Os	199·2	1·2
40	Cd	112	4	58	Hg	200	0·8
41	In	113·4	1·4	59	Tl	203·6	3·6
42	Sn	118	4·6	60	Pb	207	3·4
43	Sb	122	4	61	Bi	210	3
44	I	127	5	62	Th	235	25
45	Te	128	1	63	U	240	5
46	Cs	133	5				

On carefully examining this table many interesting facts may be observed, and a few of these will now be briefly indicated. If we start with the fifth element we find that it and all the following elements up to and including No. 17, are elements of great importance from their being widely diffused in the earth, the ocean, or the atmosphere, forming a large proportion of the earth's crust, and being essential to animal and vegetable life. Their very names recall the constituents most frequently mentioned in analyses of soils, waters, &c., as carbon, nitrogen, oxygen, fluorine, sodium, magnesium, aluminium, silicon, phosphorus, sulphur, chlorine, potassium, and calcium. If to these we add hydrogen and iron such a list will include all the most important elements. If we omit fluorine, which is perhaps not so important as the rest, the list will comprise two representatives of each of the seven principal groups of elements, thus (see *Chemical News*, vol. xxvi. p. 19) :—

Monads	Sodium and potassium.
Dyads	Magnesium and calcium.
Triads	Aluminium and iron.
Tetrads	Carbon and silicon.
Triads (or pentads)	Nitrogen and phosphorus.
Dyads (or hexads)	Oxygen and sulphur.
Monads (or heptads)	Hydrogen and chlorine.

Another remarkable circumstance to which I first called attention in the *Chemical News*, vol. x. p. 94, August 20, 1864, is the fact of a simple relation existing between all the known elements when arranged in the natural order of their atomic weights. This fact may be perhaps most simply stated in the following manner :—" Elements belonging to the same group stand to each other in a relation similar to that between the extremes of one or more octaves in music." Thus, if we commence counting at lithium, calling it 1, sodium will be 8, and potassium 15, and so on. To save the trouble of counting in each individual case, and also to render the relationship obvious at a glance, it is convenient to adopt a horizontal arrangement, as in Table II.

In this table the unoccupied spaces may be filled up by elements at present undiscovered, or even by known elements whose atomic weights have not yet been accurately determined. Although the position occupied by certain of the elements is open to dispute, this table will yet be found to give a good general idea of the chief chemical groups, whilst preserving the natural order of the atomic weights.

The quantivalence of the elements on the different horizontal lines is usually as follows :—

Line *a*. Monads.	Line *e*. Triads (or pentads).
,, *b*. Dyads.	,, *f*. Dyads (or hexads).
,, *c*. Triads.	,, *g*. Monads (or heptads).
,, *d*. Tetrads.	

TABLE II.—ELEMENTS IN ORDER OF ATOMIC WEIGHT.—HORIZONTAL ARRANGEMENT.

1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.
a. —	Li 7·0	Na 23·0	K 39·1	—	Cu 63·4	Rb 85·4	—	Ag 108	Cs 133·0	—	—	Au 197·0	—	—	—
b. —	Be 9·4	Mg 24·0	Ca 40·0	—	Zn 65·2	Sr 87·6	—	Cd 112	Ba 137·0	—	—	—	Hg 200·0	—	—
c. —	B 11·0	Al 27·4	—	Fe 56·0	—	Y 88·0 (?)	—	In 113·4	Di 138·0 (?)	—	Er 178·0 (?)	—	Tl 203·6	—	—
d. —	C 12·0	Si 28·0	Ti 50·0	—	—	Zr 89·6	Rh 104·4	Sn 118·0	Ce 140·0 (?)	—	La 180·0 (?)	Pt 197·4	Pb 207·0	—	Th 235·0
e. —	N 14·0	P 31·0	V 51·2	—	As 75·0	Nb 94·0	Ru 104·4	Sb 122·0	—	—	Ta 182·0	Ir 198·0	Bi 210·0	—	—
f. —	O 16·0	S 32·0	Cr 52·2	Ni 58·8	Se 79·4	Mo 96·0	Pd 106·6	Te 128·0	—	—	W 184·0	Os 199·2	—	—	U 240·0
g. H 1	F 19·0	Cl 35·5	Mn 55·0	Co 58·8	Br 80·0	—	—	I 127·0	—	—	—	—	—	—	—

To face page 26.

There are, however, several exceptions to this rule.

It frequently happens that the atomic weights of allied elements differ by about 16, or some other multiple of 8, as in the following cases :—

Lithium	7 + 16	= Sodium	23
Sodium	23 + 16·1	= Potassium	39·1
Magnesium	24 + 16	= Calcium	40
Carbon	12 + 16	= Silicon	28
Oxygen	16 + 16	= Sulphur	32

Other examples of the same fact may be found in papers by the author in the *Chemical News*, vol. vii. p. 70, Feb. 7, 1863, and vol. x. p. 59, July 30, 1864.

If the atomic weights of the elements really followed the strictly natural order, they would coincide with their ordinal numbers, provided, of course, that the atomic weight chosen as the unit was the true unit, and not some multiple or fraction of the true unit.

Now, granting that the eighth element reckoning from a given one, such as potassium from sodium, is the next member of the same group, their atomic weights should, if following the natural order, differ by 7, just as their ordinal numbers differ by 7, whereas the actual difference is 16·1; so that the atomic weights are equal to the natural numbers multiplied by 2·3, for $7 \times 2{\cdot}3 = 16{\cdot}1$.

If, therefore, we divide all the atomic weights by 2·3, or, what amounts to the same thing, if we make a table of the atomic weights taking that of sodium as 10, the atomic weights so obtained will be found to approach pretty closely to the natural order, especially when we compare the differences between elements in such parts of the list as are probably more complete than the others.

In Table III. such a list is given, and although no one would wish to abandon for most purposes the ordinary atomic weights founded upon hydrogen as unity, still it is both interesting and instructive to regard such familiar data from a new point of view.

TABLE III.—ELEMENTS IN ORDER OF ATOMIC WEIGHT, TAKING THE ATOMIC WEIGHT OF SODIUM AS 10.

No.	Symb.	At. Wt.	No.	Symb.	At. Wt.
1	H	0·435	33	Zr	38·96
2	Li	3·04	34	Nb	40·87
3	Be	4·09	35	Mo	41·74
4	B	4·80	36	Rh	45·39
5	C	5·22	37	Ru	45·39
6	N	6·09	38	Pd	46·35
7	O	6·96	39	Ag	46·96
8	F	8·26	40	Cd	48·70
9	Na	10·00	41	In	49·30
10	Mg	10·43	42	Sn	51·30
11	Al	11·91	43	Sb	53·04
12	Si	12·20	44	I	55·22
13	P	13·48	45	Te	55·65
14	S	13·91	46	Cs	57·83
15	Cl	15·43	47	Ba	59·57
16	K	17·00	48	Di	60·00 (?)
17	Ca	17·39	49	Ce	60·87 (?)
18	Ti	21·74	50	Er	77·39 (?)
19	V	22·26	51	La	78·26 (?)
20	Cr	22·70	52	Ta	79·13
21	Mn	23·91	53	W	80·00
22	Fe	24·35	54	Au	85·65
23	Ni	25·57	55	Pt	85·83
24	Co	25·57	56	Ir	86·09
25	Cu	27·57	57	Os	86·61
26	Zn	28·35	58	Hg	86·96
27	As	32·61	59	Tl	88·52
28	Se	34·52	60	Pb	90·00
29	Br	34·78	61	Bi	91·30
30	Rb	37·13	62	Th	102·17
31	Sr	38·09	63	U	104·35
32	Y	38·26 (?)			

June 18, 1875.

From the 'Chemical News,' vol. 37, p. 255, June 21, 1878.

ON RELATIONS AMONG THE ATOMIC WEIGHTS OF THE ELEMENTS.

BY JOHN A. R. NEWLANDS.

Besides the relations among the atomic weights of the elements when arranged in their natural order which are now comparatively well known in connection with the periodic law, there are others of considerable interest, some of which will be briefly alluded to in the present communication.

In Table I. four separate scales of atomic weights are given, the first row of figures being the atomic weights taking hydrogen = 1; the second row, taking sodium = 10; the third, taking chlorine = 15, nearly; and the fourth, taking carbon = 5.

TABLE I.

Symbol.	At. Wt.	At. Wt. ÷ 2·3, or Na = 10.	At. Wt. ÷ 2·37, or Cl = 15 nearly.	At. Wt. ÷ 2·4, or C = 5.
H	1·0	0·435	0·422	0·417
Li	7·0	3·04	2·95	2·92
Be	9·4	4·09	3·97	3·92
B	11·0	4·80	4·64	4·58
C	12·0	5·22	5·06	5·00
N	14·0	6·09	5·91	5·83
O	16·0	6·96	6·75	6·67
F	19·0	8·26	8·02	7·92
Na	23·0	10·00	9·70	9·58
Mg	24·0	10·43	10·13	10·00
Al	27·4	11·91	11·56	11·42
Si	28·0	12·20	11·81	11·67
P	31·0	13·48	13·08	12·92
S	32·0	13·91	13·50	13·33
Cl	35·5	15·43	14·98	14·79
K	39·1	17·00	16·50	16·29
Ca	40·0	17·39	16·88	16·67
Ti	50·0	21·74	21·09	20·83
V	51·2	22·26	21·60	21·33
Cr	52·2	22·70	22·03	21·75

TABLE I.—*continued.*

Symbol.	At. Wt.	At. Wt. ÷ 2·3, or Na = 10.	At. Wt. ÷ 2·37, or Cl = 15 nearly.	At. Wt. ÷ 2·4, or C = 5.
Mn	55·0	23·91	23·21	22·92
Fe	56·0	24·35	23·63	23·33
Ni	58·8	25·57	24·81	24·50
Co	58·8	25·57	24·81	24·50
Cu	63·4	27·57	26·75	26·42
Zn	65·2	28·35	27·51	27·17
Ga	69·9	30·39	29·49	29·12
As	75·0	32·61	31·65	31·25
Se	79·4	34·52	33·50	33·08
Br	80·0	34·78	33·76	33·33
Rb	85·4	37·13	36·03	35·58
Sr	87·6	38·09	36·96	36·50
Y	88·0 (?)	38·26	37·13	36·67
Zr	89·6	38·96	37·81	37·33
Nb	94·0	40·87	39·66	39·17
Mo	96·0	41·74	40·51	40·00
Rh	104·4	45·39	44·05	43·50
Ru	104·4	45·39	44·05	43·50
Pd	106·6	46·35	44·98	44·42
Ag	108·0	46·96	45·57	45·00
Cd	112·0	48·70	47·26	46·67
In	113·4	49·30	47·85	47·25
Sn	118·0	51·30	49·79	49·17
Sb	122·0	53·04	51·48	50·83
I	127·0	55·22	53·59	52·92
Te	128·0	55·65	54·01	53·33
Cs	133·0	57·83	56·12	55·42
Ba	137·0	59·57	57·81	57·08
Di	138·0 (?)	60·00	58·23	57·50
Ce	140 0 (?)	60·87	59·07	58·33
Er	178·0 (?)	77·39	75·11	74·17
La	180·0 (?)	78·26	75·95	75·00
Ta	182·0	79·13	76·79	75·83
W	184·0	80·00	77·64	76·67
Au	197·0	85·65	83·12	82·08
Pt	197·4	85·83	83·29	82·25
Ir	198·0	86·09	83·54	82·50
Os	199·2	86·61	84·05	83·00
Hg	200·0	86·96	84·39	83·33
Tl	203·6	88·52	85·91	84·83
Pb	207·0	90·00	87·34	86·25
Bi	210·0	91·30	88·61	87·50
Th	235·0	102·17	99·16	97·92
U	240·0	104·35	101·27	100·00

Starting with the ordinary atomic weights, the sum total of those of the known elements is 6227·9, and this sum divided by the number of elements in the table, viz. 64, gives an average atomic weight of 97·31 for each element, when hydrogen is taken as unity.

The atomic weights at present known do not correspond to the natural order, but appear to be a multiple of the latter; so that any calculation which may be made with a multiple of the ordinal numbers may also be made, though somewhat roughly, with the atomic weights.

In Table II. the elements are arranged in sevens, the atomic weight of sodium being taken as 10. The atomic weights given in this table approach pretty closely to the ordinal numbers, and if the ordinal numbers are considered as forming a straight line, the atomic weights will form a curved line, crossing and re-crossing the straight line at certain intervals, but not deviating widely therefrom. The average atomic weight in this table is 42·31, and the average ordinal number 42·36.

All our views upon the subject of the ordinal numbers to be attached to various elements are liable to be corrected by the light of future experience. There may be elements having atomic weights as much above uranium as uranium is above hydrogen, and, on the other hand, there may be elements having atomic weights as much below hydrogen as hydrogen is below uranium. In the latter case, such an element would almost escape detection by gravimetric analysis, though it might considerably influence the character of the compounds into which it entered.

But though there is no fixed limit to either the maximum or minimum atomic weight which may belong to unknown elements, such as those above alluded to, it is interesting to observe how, by simply dividing the ordinary scale of atomic weights of known elements by one and the same number, we obtain figures almost identical with the ordinal numbers.

This agreement is perhaps more evident in Table III., where the elements are arranged in sevens and tens, the atomic weights being divided by 2·37, or that of chlorine being taken as 15, nearly.

May 25, 1878.

I now subjoin a few brief notes on certain questions connected with the atomic weights.

1. Are the atomic weights invariable? This question must most probably be answered in the affirmative. If the atomic weight of an element varies, such variation is most likely very slight, otherwise the simple relation between the atomic weights of the elements when arranged in their natural order would be liable to be disturbed.

2. Possibility of one element being contained in another. Admitting that each element has an invariable atomic weight, and also that the combining weight of a compound is the sum of those of its constituents, it would follow that elements of higher atomic weight (should they prove to be really compounds) might contain those of lower atomic weight, but not the reverse.

3. If we view all matter as really composed of various modifications of one elementary substance, consisting of physical atoms, we may regard the atomic weight of each element as expressing the relative number of physical atoms contained in the chemical atom. The same number of physical atoms differently arranged might form two or more distinct elements which might then be regarded as isomeric. Perhaps cobalt and nickel are thus related.

4. With reference to Prout's law, it has been shown that though it is not true that all the atomic weights are multiples of the atomic weight of hydrogen, it is nevertheless the case that the number of elements whose atomic weights approach within experimental errors to

TABLE II.—HORIZONTAL ARRANGEMENT IN SEVENS. AT. WTS. ÷ 2·3, or Na = 10·00.

No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.
	2. Li 3·04	9. Na 10·00	16. K 17·00	23. — —	30. Cu 27·57	37. Rb 37·13	44. — —	51. Ag 46·96	58. Cs 57·83	65. — —	72. — —	79. — —	86. Au 85·65	93. — —	100. — —
	3. Be 4·09	10. Mg 10·43	17. Ca 17·39	24. — —	31. Zn 28·35	38. Sr 38·09	45. — —	52. Cd 48·70	59. Ba 59·57	66. — —	73. — —	80. — —	87. Hg 86·96	94. — —	101. — —
	4. B 4·80	11. Al 11·91	18. — —	25. Fe 24·35	32. Ga 30·39	39. Y 38·26	46. — —	53. In 49·30	60. Di 60·00	67. — —	74. Er 77·39	81. — —	88. Tl 88·52	95. — —	102. — —
	5. C 5·22	12. Si 12·20	19. Ti 21·74	26. — —	33. — —	40. Zr 38·96	47. Rh 45·39	54. Sn 51·30	61. Ce 60·87	68. — —	75. La 78·26	82. Pt 85·83	89. Pb 90·00	96. — —	103. Th 102·17
	6. N 6·09	13. P 13·48	20. V 22·26	27. — —	34. As 32·61	41. Nb 40·87	48. Ru 45·39	55. Sb 53·04	62. — —	69. — —	76. Ta 79·13	83. Ir 86·09	90. Bi 91·30	97. — —	104. — —
	7. O 6·96	14. S 13·91	21. Cr 22·70	28. Ni 25·57	35. Se 34·52	42. Mo 41·74	49. Pd 46·35	56. Te 55·65	63. — —	70. — —	77. W 80·00	84. Os 86·61	91. — —	98. — —	105. U 104·35
1. H 0·435	8. F 8·26	15. Cl 15·43	22. Mn 23·91	29. Co 25·57	36. Br 34·78	43. — —	50. — —	57. I 55·22	64. — —	71. — —	78. — —	85. — —	92. — —	99. — —	106. — —

TABLE III.—HORIZONTAL ARRANGEMENT IN SEVENS AND TENS. AT. WTS. ÷ 2·37, or Cl = 15 nearly.

No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.	No.
	2. Li 2·95	9. Na 9·70	16. K 16·50	26. Cu 26·75	36. Rb 36·03	46. Ag 45·57	56. Cs 56·12	66. — —	76. — —	86. Au 83·12	96. — —
	3. Be 3·97	10. Mg 10·13	17. Ca 16·88	27. Zn 27·51	37. Sr 36·96	47. Cd 47·26	57. Ba 57·81	67. — —	77. — —	87. Hg 84·39	97. — —
	4. B 4·64	11. Al 11·56	18. — —	28. Ga 29·49	38. Y 37·13	48. In 47·85	58. Di 58·23	68. — —	78. Er 75·11	88. Tl 85·91	98. — —
	5. C 5·06	12. Si 11·81	19. Ti 21·09	29. — —	39. Zr 37·81	49. Sn 49·79	59. Ce 59·07	69. — —	79. La 75·95	89. Pb 87·34	99. Th 99·16
	6. N 5·91	13. P 13·08	20. V 21·60	30. As 31·65	40. Nb 39·66	50. Sb 51·48	60. — —	70. — —	80. Ta 76·79	90. Bi 88·61	100. — —
	7. O 6·75	14. S 13·50	21. Cr 22·03	31. Se 33·50	41. Mo 40·51	51. Te 54·01	61. — —	71. — —	81. W 77·64	91. — —	101. U 101·27
1. H 0·422	8. F 8·02	15. Cl 14·98	22. Mn 23·21	32. Br 33·76	42. — —	52. I 53·59	62. — —	72. — —	82. — —	92. — —	102. — —
			23. Fe 23·63	33. — —	43. Rh 44·05	53. — —	63. — —	73. — —	83. Pt 83·29	93. — —	103. — —
			24. Ni 24·81	34. — —	44. Ru 44·05	54. — —	64. — —	74. — —	84. Ir 83·54	94. — —	104. — —
			25. Co 24·81	35. — —	45. Pd 44·98	55. — —	65. — —	75. — —	85. Os 84·05	95. — —	105. — —

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exact multiples of hydrogen is far greater than it should be on the theory of probabilities.

5. It sometimes happens that the atomic weight of one element when doubled gives a number identical, or nearly so, with the atomic weight of another element, as in the following cases :—

Li 7	× 2 = 14 N
C 12	× 2 = 24 Mg
N 14	× 2 = 28 Si
O 16	× 2 = 32 S
Al 27·4	× 2 = 54·8, or Mn 55, nearly
Si 28	× 2 = 56 Fe
Ca 40	× 2 = 80 Br
Cr 52·2	× 2 = 104·4 Rh and Ru
Fe 56	× 2 = 112 Cd
Ni and Co 58·8	× 2 = 117·6, or Sn 118, nearly
Cu 63·4	× 2 = 126·8, or I 127, nearly

In most of these cases there is very little resemblance between the first and second element. Oxygen and sulphur, however, belong to the same chemical group, and certain compounds of manganese resemble those of aluminium. In the case of Li 7, the atomic weight occurs doubled—firstly, as N 14; secondly, as Si 28; thirdly, as Fe 56; fourthly, as Cd 112. Almost the only resemblance, however, between these five elements is that some of the ferrous salts are isomorphous with those of cadmium.

6. It frequently happens that out of three elements having common properties, the atomic weight of one approaches the mean of the other two, as in the well-known triplet-groups, formerly called triads. Thus, we have—

Lower element.	Mean.	Higher element.
Li 7	Na 23	K 39·1
Mg 24 ..	Cd 112	Hg 200

Generally, however, the central term differs from the exact mean to a greater extent than can be attributed to experimental errors. There are several instances where the atomic weight of one element is almost exactly the mean of the atomic weights of two elements with which it has little or no connection. Thus—

Lower element.	Mean.	Higher element.
H 1 ..	.. C 12 ..	.. Na 23
H 1 ..	.. O 16 ..	.. P 31
H 1 ..	.. Si 28 ..	.. Mn 55
C 12 ..	.. N 14 ..	.. O 16
N 14 ..	.. Na 23 ..	.. S 32
O 16 ..	.. Mg 24 ..	.. S 32
O 16 ..	.. Si 28 ..	.. Ca 40

7. Two atomic weights taken from the lower part of the series when added together frequently equal the atomic weight of some other element, though no general rule appears to be applicable to such cases.

Sometimes, though rarely, an atomic weight added to the next following in numerical order, equals an atomic weight further on in the series; thus—

B 11 + C 12 = Na 23.

There are also cases in which an atomic weight added to the next but one in numerical order, equals an atomic weight further on in the series; thus—

C 12 + O 16 = Si 28; and
O 16 + Na 23 = 39, or K 39·1, nearly.

The following table contains the atomic weight of each element from H 1 to Cl 35·5, added to the next but two in numerical order, and it will be observed that atomic weights higher in the series are, in this way, not unfrequently obtained.

H 1	+ B 11	= C 12
Li 7	+ C 12	= F 19
Be 9·4	+ N 14	= 23·4
B 11	+ O 16	= 27
C 12	+ F 19	= P 31
N 14	+ Na 23	= 37
O 16	+ Mg 24	= Ca 40
F 19	+ Al 27·4	= 46·4
Na 23	+ Si 28	= 51, or V 51·2, nearly
Mg 24	+ P 31	= Mn 55
Al 27·4	+ S 32	= 59·4
Si 28	+ Cl 35·5	= 63·5, or Cu 63·4, nearly
P 31	+ K 39·1	= 70·1, or Ga 69·9, nearly
S 32	+ Mg 40	= 72
Cl 35·5	+ Sc 44	= 79·5

In like manner, by adding two atomic weights taken in numerical order, but separated by some definite interval, atomic weights higher in the series may not unfrequently be obtained.

8. Taking the three lowest known atomic weights, those of H 1; Li 7; and Be 9·4; many of the higher atomic weights may be arithmetically derived from them by various combinations; thus—

B	11	= Li + 4 H
C	12	= B + H
N	14	= 2 Li
O	16	= N + 2 H
F	19	= Li + C
Na	23	= B + C, or Li + O
Mg	24	= 2 C
Al	27·4	= Li + Be + B
Si	28	= 2 N
P	31	= C + F
S	32	= 2 O
Cl	35·5	= Be + C + N, nearly
K	39·1	= O + Na nearly, or Li + S nearly
Ca	40	= O + Mg
Sc	44	= C + S

9. If we take a certain number of elements whose atomic weights may be supposed to be consecutive, say the first 28 elements on the list, and arrange them in two columns, the first column of half these elements being in the order of atomic weight, and the second half being in inverse order; then on adding each member of the first column to the corresponding member of the second column, a number is obtained which should be identical in every case provided that the atomic weights corresponded either to the natural order of numbers, or to some multiple of such order. As a matter of fact, the numbers thus obtained are by no means uniform, but vary within considerable limits; thus—

H 1	+ Ga 69·9	= 70·9
Li 7	+ Zn 65·2	= 72·2
Be 9·4	+ Cu 63·4	= 72·8
B 11	+ Co 58·8	= 69·8
C 12	+ Ni 58·8	= 70·8
N 14	+ Fe 56	= 70·0
O 16	+ Mn 55	= 71·0
F 19	+ Cr 52·2	= 71·2

Na 23	+ V 51·2	= 74·2
Mg 24	+ Ti 50	= 74·0
Al 27·4	+ Sc 44	= 71·4
Si 28	+ Ca 40	= 68·0
P 31	+ K 39·1	= 70·1
S 32	+ Cl 35·5	= 67·5

10. It has already been stated, p. 19, that "no simple relation could be worked out of the atomic weights under any other system than that of Cannizzaro," and if we attempt to introduce various equivalents of one and the same element into the table, they seem out of place, as do also the combining weights of quasi-elements, such as ammonium, or cyanogen.

11. If any data, such as specific heats or vapour densities, should prove ultimately to be, without exception, either directly or inversely as the atomic weights, a list of the elements arranged according to such data would, of course, also show a periodic law.

12. Although all the elements yet discovered appear to take their places in accordance with the periodic law, it is quite conceivable that various series of elements may exist not very simply related to each other.

13. Among the bodies which have fallen on the earth from outer space, no element has hitherto been detected different from those known to exist upon the earth's surface. The evidence of the spectroscope also shows the presence of terrestrial elements in various celestial bodies. Looking, however, at the densities of the various planets, it might be thought that elements of a lighter or, in some cases, of a heavier kind than those at present known might enter into their composition. In the 'Handbook of Descriptive Astronomy,' by Geo. F. Chambers, 3rd ed. 1877, the densities of the planets, &c., are given as follows, taking water as unity :—

Mercury	7·03	Sun	1·43
Venus	5·23	Moon	3·57
Earth	5·67		
Mars	2·93		
Jupiter	1·23		
Saturn	0·68		
Uranus	0·99		
Neptune	0·96		

Again, on considering the difference between the density of the earth and that of the earth's crust, which is much lighter, it might be thought that elements of higher specific gravity are contained in the interior of the earth.

Various explanations may, however, be given to account for these great differences in density without assuming the presence of large quantities of elements of either a lighter or heavier kind than those already known to science.

Any communications on the subject of this work may be addressed to the author, at the laboratory, 9, Mincing Lane, London, E.C.

As evidence of the opinion of various writers on the subject of the Periodic Law, the following may be quoted :—

M. Mendelejeff (*Chemical News*, vol. xliii. p. 15):—"It is possible that Newlands has prior to me enunciated something similar to the periodic law, but even this cannot be said of H. L. Meyer."

Dr. Odling, Lecture on Gallium, before the British Association in 1877:—"Mr. Newlands was the first chemist to arrange the elements in such a seriation that new ones might be predicted to exist where certain gaps are observed in the seriation of atomic weights."—*Pharmaceutical Journal*, August 25, 1877, p. 144.

'Fownes' Chemistry,' vol. i., 12th ed., 1877, p. 265:—"This relation of the elementary bodies, which is called the 'periodic law,' was first pointed out by Newlands in 1864, and afterwards developed by Odling and Mendelejeff."

Miller's 'Elements of Chemistry,' part ii., 6th ed., 1878, p. 974:—"Periodic law of Newlands and Mendelejeff." "This periodic law was first pointed out by Newlands in 1864."

Roscoe and Schorlemmer's 'Chemistry,' vol. ii., part ii., 1879, p. 506:—"The first attempt to point out that the properties of the elements varied periodically, was made by Newlands in 1863." "The law of periodicity was afterwards further developed by Meyer and Mendelejeff."

'Watts' Dictionary,' vol. viii., 1879, 3rd Supplement, part i., p. 729:—"The idea of a periodic relation between the atomic weights of the elementary bodies and their quantivalence and other properties, developed by Mendelejeff in the manner already described (2nd Supplement, 462), was first suggested by J. R. Newlands in 1864."

Dr. T. Carnelley, *Philosophical Magazine,* vol. viii. 5th series, 1879, p. 305:—"It was not, however, till within the last fifteen years that these relations were first traced in a systematic manner; and it is to Newlands, and especially to Mendelejeff, that we owe a new field of research and a new and powerful method of attacking chemical problems. The importance of the work of Newlands and Mendelejeff cannot be easily overrated. The principle proposed independently by each of them will serve in the future, and has done to some extent already, to indicate those directions in which research is most needed, and in which there is most promise of interesting results. The application of this principle will also enable us to make predictions of phenomena still unknown, and will at the same time prevent many fruitless researches. It is and will be, in fact, for some time to come, the finger-post of chemical science."

Page 306:—"In 1864, Newlands made the first great step in advance, which advance was increased and placed on a firmer basis by Mendelejeff in 1869."

Dr. Tilden, 'Chemical Philosophy,' 2nd ed., 1880, p. 246:—"In the year 1866 a very curious observation was made by Mr. Newlands to the effect that when the elements are arranged in a continuous series in the order of their atomic weights, commencing with hydrogen, there is at equal intervals in the series a recurrence of the same or similar general characters, both physical and chemical. This periodic revival of characteristics occurs, with a few exceptions, at about every eighth member of the series, as will presently be shown. This discovery has been elaborately studied by Mendelejeff and Lothar Meyer, and that which has long been vaguely recognised is now fully established, namely, that the properties of the elements stand in a definite relation to their atomic weights."

Sir John Lubbock's Address to the British Association, in 1881 (*Chemical News*, vol. xliv. p. 120):—"A periodicity in the atomic weights of elements belonging to the same class had been pointed out by Newlands about four years before the publication of Mendelejeff's memoir."

Mr. Thos. Bayley, 'Proc. Royal Irish Academy,' 2nd ser., vol. iii. p. 793, June 1883:—"The law, originated by Newlands, and called by him the law of octaves, and subsequently developed by Mendelejeff and L. Meyer under the name of the periodic law."

Dr. Gladstone's Address to the Chemical Section of the British Association, 1883:—"But this is not the largest generalisation in regard to the peculiarities of these atomic weights. Newlands showed that, by arranging the numbers in their order, the octaves presented remarkable similarities, and, on the same principle, Mendelejeff constructed his well-known table."

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