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A MODIFIED ARRANGEMENT OF THE ELEMENTS UNDER THE NATURAL LAW.

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A quarter of a century has passed since the first announcement of the Natural Law and the publication of Mendelejeff's table. The truth of the law, in a general way, seemed to be accepted very readily by chemists. It was incorporated in text-books and there explained, but comparatively little use has been made of it in teaching the science. Even Mendelejeff himself, in his Principles of Chemistry, has not made the fullest use of it. Victor Meyer, in his lecture before the German Chemical Society more than a year ago, showed how it might be used, and how he used it himself, and, probably, this will do much towards popularizing its use.

There must be some reason why so great a help to scientific study, is not made more use of. Does it lie in a lingering distrust of the law itself or failure to accept it, or is it because of the imperfections in the arrangements of the elements offered by Mendelejeff and others? It is most probably due to the latter, and this paper is presented with the hope of clearing up some of these difficulties.

The modern chemical world has recognized in the discovery of Mendelejeff, the greatest step forward since the announcement of the Atomic Theory. It is too much to expect that so great a discovery should spring full-panoplied from the head of its author.

Doubtless many have observed the imperfections of the law's original form, or rather the table as first given out. Probably some have ventured to comment upon it. Such criticisms have, however, escaped me with one or two exceptions. It is with much hesitation, that I venture to point out what seem to me imperfections and blemishes, in so great a work. Few may agree with me in calling them imperfections. I do not purpose to detract one particle from the greatness and importance of the essential truths contained in this discovery. Mendelejeff's table, as we have it at present, is a great advance upon the first one published by him in 1869, which must be pronounced tentative only, and decidedly unsatisfactory. The table of Victor Meyer is far behind it in presenting the facts of the periodic law. There have been many attempts at devising a graphic representation of this law. I know of none which can be called a real aid to the student, or which do not introduce new ideas which, to say the least, have no basis in the facts as known to us at present. None of them can be regarded as a safe substitute for the simple table of Mendelejeff.

Taking this table I would venture to point out some obstacles to its full acceptance. These have been in part revealed to me by the effort at a presentation of these truths of nature to honest-minded, clear-sighted young men.

Before mentioning the difficulties which lie here in the path of a teacher, I must say, by way of preface, that my criticisms, are aimed at what I may be allowed to call the unessentials of the law. Mendelejeff's great feat was in seeing clearly, and announcing intelligently, that the properties of the elements are dependent upon and determined by the atomic weights. This is the essential of the Natural Law and is in accord with our fullest knowledge. The second part of the law, as usually stated, that these properties are periodic functions, attempts, in a measure, to define the dependence. It may also be true, but it is not fully proved and it is open to objections. It seems to me that this hypothetical portion could well be left in abeyance until fuller knowledge gave it a stronger footing, meanwhile substituting something less open to criticism, and which can not weaken the central truth.

TABLE I.

Group.	I	II	III	IV	V	VI	VII	VIII
Series 1	H	—	—	RH_4	RH_3	RH_2	RH	{ Hydrogen compounds.
" 2	Li .	Be .	B .	C .	N .	O .	F .	
" 3	. Na	. Mg	. Al	. Si	. P	. S	. Cl	
" 4	K .	Ca .	Sc .	Ti .	V .	Cr .	Mn .	Fe . Co . Ni . Cu
" 5	. (Cu)	. Zn	. Ga	. Ge	. As	. Se	. Br	
" 6	Rb .	Sr .	Y .	Zr .	Nb .	Mo .	— .	Ru . Rh . Pd . Ag
" 7	. (Ag)	. Cd	. In	. Sn	. Sb	. Te	. I	
" 8	Cs .	Ba .	La .	Ce .	Di? .	— .	— .	— — — —
" 9	. —	. —	. —	. —	. —	. —	. —	
" 10	— .	— .	Yb .	— .	Ta .	W .	— .	Os . Ir . Pt . Au
" 11	. (Au)	. Hg	. Te	. Pb	. Bi	. —	. —	
" 12	— .	— .	— .	Th .	— .	U .	— .	
	R_2O —	R_2O_2 RO	R_2O_3 —	R_2O_4 RO_2	R_2O_5 —	R_2O_6 RO_3	R_2O_7 —	Higher Oxides. RO_4

TABLE II.

Groups.	Higher salt-forming oxides.	Typical, or first small period.	Large periods.				
			1st.	2nd.	3rd.	4th.	5th.
I	R_2O	Li 7	K 39	Rb 85	Cs 133	—	—
II	RO	Be 9	Ca 40	Sr 87	Ba 137	—	—
III	R_2O_3	B 11	Sc 44	Y 89	La 138	Yb 173	—
IV	RO_2	C 12	Ti 48	Zr 90	Ce 140	—	Th 232
V	R_2O_5	N 14	V 51	Nb 94	—	Ta 182	—
VI	RO_3	O 16	Cr 52	Mo 96	—	W 184	U 240
VII	R_2O_7	F 19	Mn 55	—	—	—	—
			Fe 56	Ru 103	—	Os 191	—
VIII			Co 58.5	Rh 104	—	Ir 193	—
			Ni 59	Pd 106	—	Pt 196	—
I	R_2O	H = 1 Na 23	Cu 63	Ag 108	—	Au 198	—
II	RO	Mg 24	Zn 65	Cd 112	—	Hg 200	—
III	R_2O_3	Al 27	Ga 70	In 113	—	Te 204	—
IV	RO_2	Si 28	Ge 72	Sn 118	—	Pb 206	—
V	R_2O_5	P 31	As 75	Sb 120	—	Bi 208	—
VI	RO_3	S 32	Se 79	Te 125	—	—	—
VII	R_2O_7	Cl 35.5	Br 80	I 127	—	—	—
		2nd small period.	1st.	2nd.	3rd.	4th.	5th.

Take the tables from the first volume of Mendelejeff's Principles of Chemistry and examine them. First, we find two kinds of periods made use of—periods containing seven elements, and those containing seventeen. These latter are divided into sevens and threes. If it had only been possible to arrange all of the elements in sevens, as Newlands attempted to do, the periodic idea would have been most convincing, and the Law of Octaves, running through nature, would have seemed most wonderful. But these elements do not admit of being arranged in this way, and the use of periods of different lengths, is to a fresh young mind, unacquainted with mathematical expedients, somewhat forced.

Secondly, there is a very anomalous position assigned to the triads, or as sometimes written, the tetrads, Fe, Co, Ni, Cu, etc. They have been set off to themselves, clearly so as to make the other elements fall, even approximately, into their places, and into the proper sevens. I say approximately, for the student soon sees that although there is a similarity, there is also a wide difference between the elements of the first seven and the last in any period of seventeen.

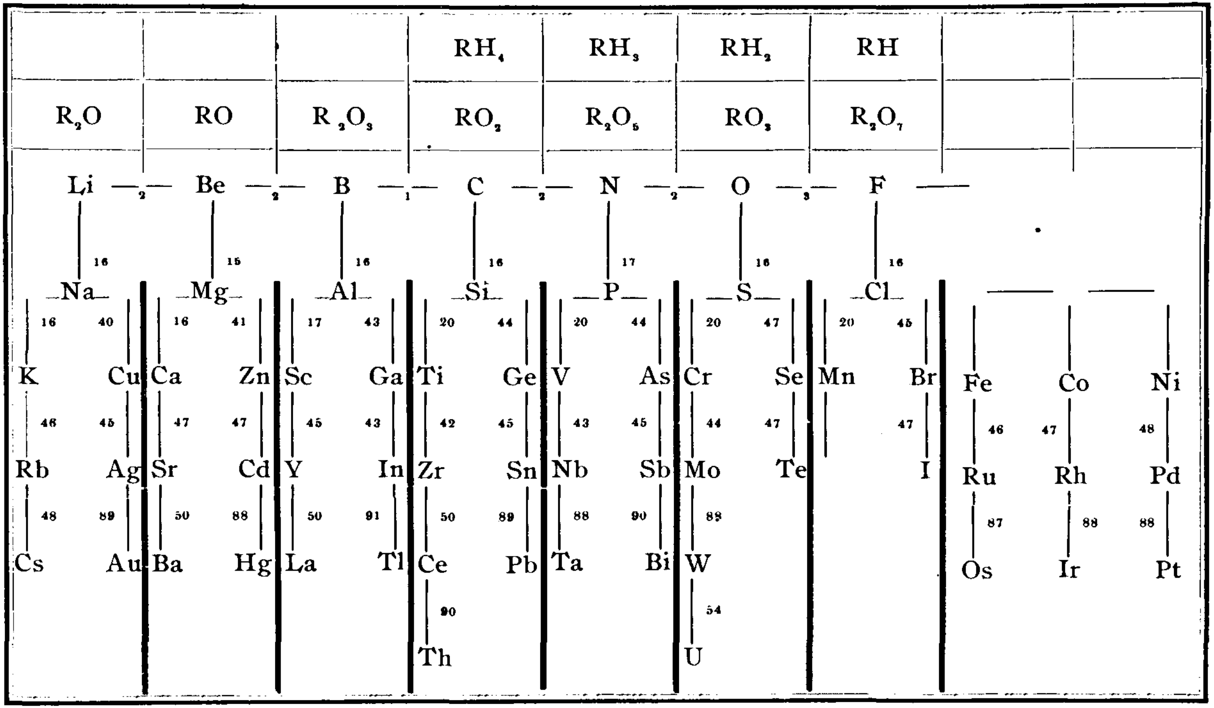
Thirdly, in the lower periods, in order to get elements to fall into their places, a great many unknown elements have to be interpolated. Thus between cerium and ytterbium, the next element in the list, there are blank places for sixteen elements. The third large period of seventeen has only four known elements in it, and the fifth has only two. That means that here we have a period actually constructed out of fifteen unknown elements and two known ones. This exceeds some of the triumphs of geology in the construction of skeletons of extinct animals. Of the five periods, only one is completely filled out. To say the least, this shows a very imperfect knowledge of the elements, or a great deal of guess work. In the table there are sixty-four known elements and thirty-five blanks for elements yet to be discovered. I hardly think it possible that the majority of chemists, believe that, after all of the diligent search for the past century, less than two-thirds of the elements have been discovered. Where are the others in hiding? Will they be discovered by the spectroscope among the rare earths? There is certainly hope of finding some of them there, but the number which this statement of the law would require us to find, is simply appalling. The average student thinks, in all honesty, that the coincidences of the first part of the table, will scarcely justify such forcing and wholesale interpolation. If our knowledge of the elements be so imperfect as that, we have no right to force them into periods, in fact, any law based upon their atomic weights would be of the most tentative character, and likely at any time to be overthrown by the discovery of the lost or unknown ones. How do we know that the big one-third, now unknown, may not upset all calculations, when found? Such a law ought rather to be called a working hypothesis. We are venturing a great deal upon a very imperfect knowledge of the ones we have in hand. For if one reckons up the number of elements, for which we have satisfactory determinations of the atomic weights, he will find that they are less than forty. The periodic idea may be true, but we do not know enough about these elements yet, to be able to give this idea a very prominent place in the Natural Law, and we ought to avoid the assumption of so many unknown elements unless it is absolutely necessary.

As I do not intend to tear down without some effort at rebuilding, I would, with much real diffidence, for I realize that I may be looked upon as one who would rush in where only the great masters of the science can safely tread, offer the following suggestions.

The first suggestion is that the wording of the Natural Law be so changed as to read: "The properties of the elements are dependent upon and determined by the atomic weights." The somewhat difficult idea of functions is simplified and periodicity is subordinated. Then the following table might be substituted for the one ordinarily given.

It is not greatly changed and not much originality is claimed for it, but, however slight the changes, I would insist upon their value, because they do away with the dependence upon periods and they certainly make the table easier, more intelligible, and more useful to the student. No very doubtful element is included in it. There is room for additional elements as discovered, but the table is not dependent upon them. Lastly the inter-relation is more clearly brought out.

TABLE III.


RH$_4$ RH$_3$ RH$_2$ RH
R$_2$O RO R$_2$O$_3$ RO$_2$ R$_2$O$_5$ RO$_3$ R$_2$O$_7$
Li 2 Be 2 B 1 C 2 N 2 O 3 F
16 15 16 16 17 16 16
Na Mg Al Si P S Cl
16 40 16 41 17 43 20 44 20 44 20 47 20 45
K Cu Ca Zn Sc Ga Ti Ge V As Cr Se Mn Br Fe Co Ni
46 45 47 47 45 43 42 45 43 45 44 47 47 46 47 48
Rb Ag Sr Cd Y In Zr Sn Nb Sb Mo Te I Ru Rh Pd
48 89 50 88 50 91 50 89 88 90 88 87 88 88
Cs Au Ba Hg La Tl Ce Pb Ta Bi W Os Ir Pt
90 54
Th U

I do not maintain that this table could ever have been discovered without the idea of periods, though I can see no reason why it might not. The periods still underlie it, but they are out of sight for the present, and are not necessary. The table is not dependent upon them.

The table is constructed as follows. There are seven group elements, having a mean increment of two in their atomic weights. It is by no means essential that there should be just seven of these. At present we do not know more, but I think there is possibly a place for one more, having the atomic weight twenty-one and differing widely from the others as it occupies a singular position.

These group elements are also to be called bridge elements, as they show marked gradation of properties from one to another and serve to bridge over the groups and connect one with the other. Linked to them by an increment of sixteen, are seven typical elements. These show the distinctive properties of the groups to which they belong and a wider divergence from the next group to them. From them can be deduced the properties of the remaining elements of the group. Thus, in group I, Li is the bridge or group element, and Na the type. From this type two lines of elements diverge, averaging three to the line. These triads would, of course, be changed into tetrads or pentads by the discovery of more elements. No importance can be attached to the fact that at present they are triads. There is a distinct increment for each line of elements. These can be averaged thus:

Fig. 1.

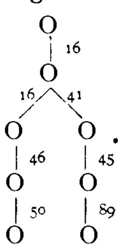


Fig. 2.

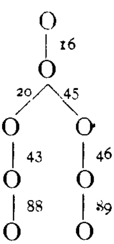


Figure 1 represents the arrangements and increments for the first three groups, and figure 2, that in the last four groups, the increments showing a variation. These increments could be averaged in all except one case, and the agreements with known atomic weights would be close enough to admit of the easy arrangement of · the elements in the prescribed order. Naming the triads right triad and left triad, respectively, we find that these averaged increments would be as follows: The increment from group to type element is sixteen; from type to first element in left triad is eighteen; to second element in left triad is sixty-three; to third element in left triad is 112. On the other side to first element in right triad is forty-four; to second element in right triad is eighty-nine; to third element in right triad is 177.

The one exception mentioned is in the increment from type to third element in right triad, in groups IV to VII. Instead of being 112, the increment here is 141.

To the right of group VII we have three triads which have the regular increments belonging to the left triads, namely, forty-seven and eighty-eight. They are without any type element. It seems most likely that they belong to one group. The group element would have an atomic weight of twenty-one, and the type one of thirty-seven.

The arrangement in the table then, is partly one based upon regular increments in the atomic weights, and, since these weights are but poorly known, partly upon our knowledge of the properties of the elements. When it is recalled that about one-half of the atomic weights are imperfectly known, it will be evident that these averaged increments are approximations only. It is impossible to bring out such perfect symmetry as is obtained in the homologous series in organic chemistry. And yet these groups should be something of the same kind. Following the analogy to the organic hydrocarbons a little further, may not the existence of an element in two different conditions as to valence, etc., as, for instance, copper, or mercury, or iron, be looked upon as a species of isomerism? Such speculations are of little use, however, and quite apart from our present purpose. I have found this table very useful in teaching elementary chemistry, and it can most profitably be made the basis of the entire course. Thus, in the first four groups, the left triads contain the elements most closely resembling the types. In the last three they are to be found in the right triads. As to natural occurrence of the elements, in the first four groups those in the left triads occur in the same compounds, and generally in connection with the type: those in the right triads occur as the type, or as sulphides, or free. In the last three groups this is reversed. The right triad elements occur as the types, and the left triad elements as the type or as oxides. So, too, the properties of the elements show this relation to the types. Take as an example the specific gravities in group II.

$$\begin{tikzcd}[column sep=small]
& \mathrm{Be} = 2.1 \arrow[d, dash] & \\
& \mathrm{Mg} = 1.75 \arrow[dl, dash] \arrow[dr, dash] & \\
\mathrm{Ca} = 1.5 \arrow[d, dash] & & \mathrm{Zn}\ \ 6.9 \arrow[d, dash] \\
\mathrm{Sr} = 2.5 \arrow[d, dash] & & \mathrm{Cd}\ \ 8.6 \arrow[d, dash] \\
\mathrm{Ba} = 3.6 & & \mathrm{Hg}\ \ 13.6
\end{tikzcd}$$

It is not necessary to pursue this part of the matter at greater length. The careful teacher will easily work out all of these comparisons for himself, and will find that chemistry taught by the table is shorter (so much repetition being saved) and is easier for the pupil, and its symmetry and beauty are much more easily brought out. There is no special claim for originality made here. The germs of such a table, or arrangement, can be found in several text-books, but I do not know of any in which the idea is fully developed, or such a table as this is given.[1] I offer the whole as a suggestion. Perhaps some may find it useful who have met the same difficulties which I have encountered. Others may have overcome these difficulties in a still better way than this. I think, at least, all will agree that there are difficulties, and very serious ones, in the use of Mendelejeff's table, or that of Victor Meyer, as given by their respective authors.

[1] The arrangements of Bayley, Hinrichs, and Wendt are somewhat similar, but the ideas which I would make prominent, are obscured by other considerations and speculations.