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THE STRUCTURE OF ATOMS AND THE EVOLUTION OF THE ELEMENTS AS RELATED TO THE COMPOSITION OF THE NUCLEI OF ATOMS.

II

The elements have thus been found to fall into two series: first, those of even, and second, those of odd, atomic number. Now, if the theory presented for the structure of the atoms is correct, then it should be possible to find some difference between the two series with reference to their properties. Since, however, this part of the theory refers specifically to the structure of the nuclei of the atoms, and not to the arrangement of the external or non-nuclear electrons, it is evident that this difference should not be found in those properties due to the external electrons, that is in the chemical or physical properties. On the other hand, the difference should be found in any properties inherent in the nucleus, and the only property, aside from mass and weight (from which our system has been developed), which has thus far been discovered, and which is due to the structure of the nucleus of the atom, is that of atomic stability. Thus, if an atom loses outer electrons, it does not change its atomic number, and therefore does not change to another element, but if it loses nuclear electrons, it does change its nucleus, its atomic number is changed, and the atom is said to disintegrate—that is, it changes into the atom of another element.

Our theory therefore indicates a probable general difference in stability between the even- and odd-numbered elements. A consideration of the radioactive elements indicates that those which have odd atomic numbers have either shorter periods, or else are at present unknown. Now unfortunately there is no known method of testing the stability of the elements of low atomic number, but it might seem, at first thought, that the more stable atoms should be the more abundantly formed, and to a certain extent this is undoubtedly true. If then, at the stage of evolution represented by the solar system, or by the earth, it is found that the even-numbered elements are more abundant than the odd, as seems to be the case, then it might be assumed that the even-numbered elements are on the whole the more stable. However, there is at least one other factor than stability which must be considered in this connection. The formula of the even-numbered elements has been shown to be nHe'. Now, since that for the odd-numbered elements is $nHe' + H_3'$ it is evident that if the supply of the H_3' needed by the elements was relatively small at the time of their formation, not so much material would go into this system, and this would be true whether the H_3' represents three atoms of hydrogen or one atom of some other element.[3]

In studying the relative abundance of the elements the ideal method would be to sample one or more solar systems at the desired stage of evolution, and to make a quantitative analysis for all of the 92 elements of the ordinary system. Since this is evidently impossible, even in the case of the earth, it might be considered that sufficiently good data could be obtained from the earth's crust, or the lithosphere. However, the part of the crust to which we have access is relatively so thin, and has

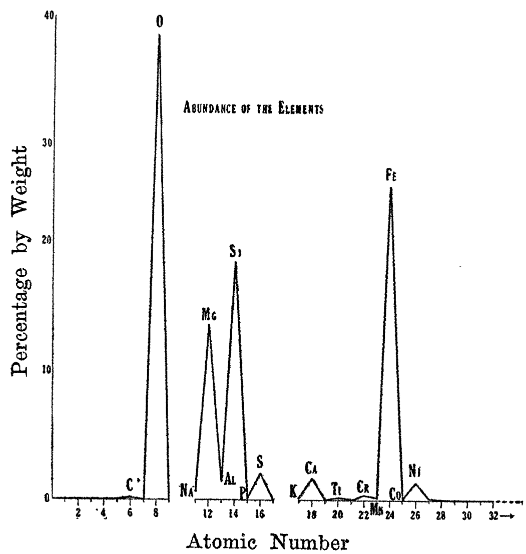

FIG. 2. The Periodic Variation in the Abundance of the Elements as the result of Atomic Evolution. The data are given for 125 stone meteorites, but the relations are true for meteorites in general. Note that *ten* elements of even atomic number make up 97.59 per cent. of the meteorites, and *seven* odd-numbered elements, 2.41 per cent., or 100 per cent. in all. Elements of atomic number greater than 29 are present only in traces.

been subjected to such far-reaching magmatic differentiation, and to such extensive solubility effects, that it seems improbable that the surface of the earth at all truly represents its composition as a whole. The meteorites, on the other hand, show much less evidence of differentiative effects, and undoubtedly represent more truly the average composition of our planetary system. At least it might seem proper to assume that the meteorites would

[3] With regard to the latter alternative, it is at least remarkable that the H_3 occurs 11 times in the system for the first 27 elements, while H_2 and H each occur only once, and it may also be mentioned that Fabry and Buisson have by interference methods determined the atomic weight of nebulium to be 2.7, and this they think indicates that its real atomic weight is 3. Also, Campbell has found that in the nebula N. G. C. Index 418, situated in the southern part of the constellation of Orion, the nebulium spectrum is found farther from the interior than that of helium, while the hydrogen spectrum extends out to a much greater distance still. This, he thinks, indicates that the atomic weight of nebulium lies between the values for hydrogen (1) and helium (4).

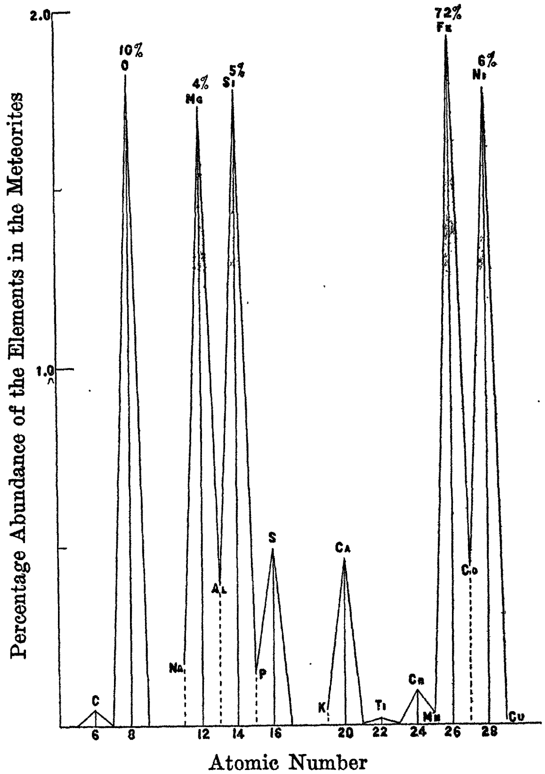

Fig. 3. The abundance of the elements in the meteorites. Every even-numbered element is more abundant than the two adjacent odd-numbered elements.

not exhibit any special fondness for the even-numbered elements in comparison with the odd, or, vice versa, any more than the earth or the sun as a whole, at least not unless there is an important difference between these two systems of elements, which is just what it is desired to prove. A study of the compilations made by Farrington, by Merrill, and by other workers of analyses of meteorites, has given some very interesting results.

The results show that in either the stone or the iron meteorites the even-numbered elements are very much more abundant than the odd. Thus in the iron meteorites there are about 127 times more atoms of even atomic number than of odd, while in the stone meteorites the even-numbered elements are about 47 times more abundant. If we average the 125 stone and 318 iron meteorites given by Farrington, it is found that the weight percentage is 98.78 for the even and 1.22 for the odd-numbered elements, or the even-numbered elements are about 81 times more abundant.

If we consider these same meteorites, 443 in all, and representing all of the different classes, it is found that the first seven elements in order of abundance are iron, oxygen, silicon, magnesium, calcium, nickel and sulphur, and *not only do all of these elements have even atomic numbers, but in addition they make up 98.6 per cent. of the material of the meteorites.*

Table IV. gives the average composition of these meteorites. The numbers before the symbols are the atomic numbers, and

TABLE IV

Average Composition of Meteorites Arranged According to the Periodic System

Series	Group 1 Odd	Group 2 Even	Group 3 Odd	Group 4 Even	Group 5 Odd	Group 6 Even	Group 7 Odd	Group 8		
								Even	Odd	Even
2				6C 0.04%		8O 10.10%				
3	11Na 2.17%	12Mg 3.80%	13Al 0.39%	14Si 5.20%	15P 0.14%	16S 0.49%				
4	19K 0.04%	20Ca 0.46%		22Ti 0.01%		24Cr 0.09%	25Mn 0.03%	26Fe 72.06%	27Co 0.44%	28Ni 6.50%
	29Cu 0.01%									

those below give the percentages of the elements. *It will be noted that the even-numbered elements are in every case more abundant than the* ADJACENT *odd-numbered elements.* The helium group elements form no chemical compounds, and are all gases, so they could not be expected to remain in large quantities in meteorites. For this reason, and also because the data are not available, the helium or zero group is omitted from the table.

From this table it will be seen that while *high percentages,* as great as 72 per cent. in one case, *are common among the even-numbered elements,* the highest percentage for any odd-numbered element is less than one per cent. (0.39 for aluminium).

If we now turn to the composition of the earth, it is found that the atoms of even atomic number are about ten times more abundant in the surface of the earth than those which are odd. Also, all of the five unknown elements, eka-cæsium, eka-manganese 1, eka-manganese 2 (dwi-manganese), eka-iodine and eka-neodymium, have odd atomic numbers. It should be mentioned in this connection, however, that there is some doubt as to whether element 72 has been discovered.

While the relative abundance of the elements in the lithosphere is undoubtedly much affected by differentiation, there is one group whose members are so closely similar in chemical and physical properties, that they would be much less affected in this way than any other elements. These are the rare earths. The only difficulty in this connection is that of making an accurate estimate of the relative abundance. In this the writer has been assisted by Professors C. James and C. W. Balke, but any errors in the estimate should not be attributed to them. In the table, which includes beside the rare earths a number of elements adjacent to them, the letter *c* indicates common in comparison with the adjacent elements, and *r* represents rare. *ccc* represents a relatively very common element, etc. The comparison is only a very rough one, but it indicates that the even-numbered elements are in general more abundant than the odd-numbered ones which are adjacent.

TABLE V

The Predominance of Even-numbered Elements Among the Rare Earths

Atomic Number	Abundance	Element	Atomic Number	Abundance	Element
55	c	Caesium	63	rr	Europium
56	ccc	Barium	64	r	Gadolinium
57	c	Lanthanum	65	rrr	Terbium
58	cc	Cerium	66	r	Dysprosium
59	r	Praseodymium	67	rrr	Holmium
60	c	Neodymium	68	r	Erbium
61	rrr	Unknown	69	rr	Thulium
62	c	Samarium			

The above results may be summarized in the statement that IN THE FORMATION OF THE ELEMENTS MUCH MORE MATERIAL HAS GONE INTO THE ELEMENTS OF EVEN ATOMIC NUMBER THAN INTO THOSE WHICH ARE ODD, either because the odd-numbered elements are the less stable, or because some constituent essential to their formation was not sufficiently abundant, or as the result of both causes.

It is easy to see, too, that in the evolution of the elements, the elements of low atomic number and low atomic weight have been formed almost exclusively, and this indicates either that the lighter atoms are more stable than those which are heavier, or else that the lighter atoms were the first to get the material, and their stability was at least sufficient to hold it.

It is possible that the heavier atoms have been formed in larger amounts than now exist, and that their abundance has been reduced by atomic disintegration. It is of course evident that the radio-active elements are now disintegrating, but the radio-active series of elements includes only those of atomic number 81 (thallium) to 92 (uranium); and lead (82) is the end of the series as now recognized. For our purposes, however, we still call the atoms of atomic numbers 1 to 29 the lighter atoms, and from 30 to 92 the heavier atoms. The following table indicates that when defined in this way the lighter atoms are extremely more abundant. In the table the weight percentages are given, but it is evident that if these same figures were calculated to atomic percentages they would show even smaller values for the heavier elements. The table shows that although the heavy atoms have been so defined as to include more than twice as many elements as the light atoms, their total abundance is so small as to be relatively insignificant. The data are taken from estimates by Clarke and by Farrington.

TABLE VI

Illustrating the Large Proportion in Various Materials of the Elements of Low Atomic Numbers (1–29)

Material	Percentage of Elements with Atomic Numbers 1–29	30–92
Meteorites as a whole	99.99	0.01
Stone meteorites	99.98	0.02
Iron meteorites	100.00	0.0
Igneous rocks	99.85	0.15
Shale	99.95	0.05
Sandstone	99.95	0.05
Lithosphere	99.85	0.15

It is thus seen that SO FAR AS THE ABUNDANCE OF THE ELEMENTS IS CONCERNED, THE SYSTEM PLAYS OUT AT ABOUT ELEMENT 30, and it is of great interest to note that it is just at this point that other remarkable changes occur. For example, up to this point nearly all of the atomic weights on the oxygen basis are very close to whole numbers. On the other hand the elements with higher atomic numbers (28 to 92) have atomic weights which are no closer to whole numbers than if they were wholly accidental. Also, just at this point the atomic weights cease to be those predicted by the helium-hydrogen theory of structure presented in this paper (Table III.). This does not mean, however, that the helium-hydrogen system fails at this point, but that the deviations in the atomic weights for the elements of higher number are produced by some complicating factor. This would be most easily explained on the hypothesis that isotopes are abundant among the elements of atomic number higher than 28. Such a hypothesis should, of course, be confirmed experimentally before it is given much credence. It is quite possible, too, that radioactive disintegrations have proceeded downward in the system as far as iron, and that iron is the end of a disintegration series. If this were true, it would explain the great abundance of iron in the meteorites. In whatever way we may average the analyses of the materials found in meteorites or on earth, the two most striking elements from the standpoint of abundance are oxygen, the most abundant of the elements of very low atomic number (8), and iron, which has the highest atomic number (26) of any very abundant element.

The fact that the elements which have heavy atoms (atomic numbers 30 to 92, or more than two thirds of the elements) have been formed in such minute amounts would be very much more striking to us if we lived on an earth with a perfectly uniform composition. On such an earth, formed without any segregation, it is probable that almost none of these elements would have been discovered. Quite certainly such elements as gold, silver, iodine and arsenic would not be known, and copper, lead, zinc and tin, if known at all, would be in the form of extremely small specimens.

In this connection it may be remembered that the earth has the highest density of any of the planets. The data given in Table V. show that in the meteorites, which vary in density from about 2.5 for the lightest stone, to more than eight for the heaviest iron meteorites, the increase in density is not brought about by an increase in the abundance of what have been defined as the heavy atoms, but only by a shift in the relative abundance of the light atoms. Thus in the less dense stone meteorites the average atomic percentage of oxygen, atomic weight 16, is 54.7 per cent., while that of iron, atomic weight 55.84, is 10.6 per cent. In the more dense iron meteorites, on the other hand, the percentage of oxygen is practically negligible, while that of iron has risen to 90.6 per cent.[4] A study of the densities of the elements and their compounds shows that the abundance of the elements does not seem to be related to this property. In fact the only apparent relation is to the atomic number, which indicates that the abundance relations are the result of evolution, that is of the factors involved in the formation and disintegration of the atoms.

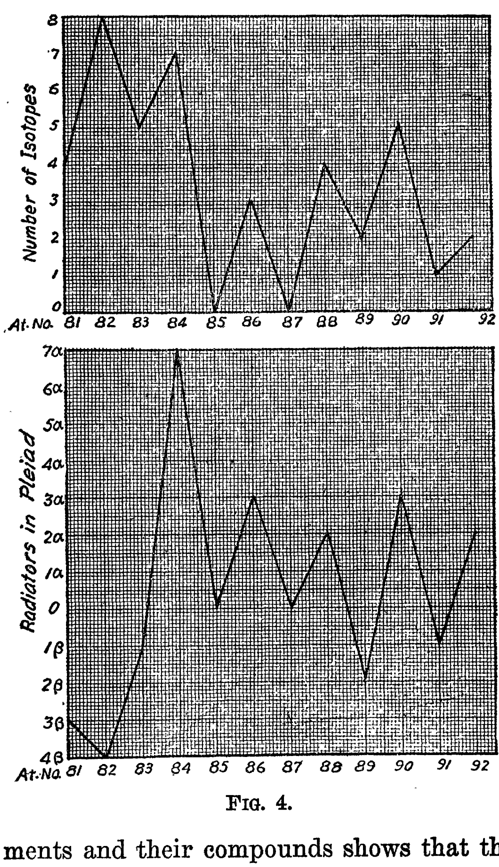

Fig. 4.

[4] For nickel, atomic weight 58.68, it is 8.5 per cent.

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Note: Since the presentation of the above paper it has been pointed out by Norris F. Hall that both the *isotopic complexity,* and the *number* of *predominant radiation* of the radio-active elements show a sharp alternation with increasing atomic number, and that this alternation is strictly in accord with the general hydrogen helium theory of atomic structure. The variation of these properties is illustrated in Figure 4 and it will be seen that the general form of these figures is the same as that of Figures 2 and 3 which represent the abundance of the elements.

THE CARE OF WOUNDED SOLDIERS

Many matters of importance touching upon American cooperative effort and activity along medical and surgical lines were developed during the past week in Chicago, when the general medical board and the State activities committee of the medical section of the Council of National Defense held stated meetings in conjunction with the annual meeting of the Clinical Congress of Surgeons of North America. Secretary of the Navy Daniels discussed the activities of the Navy directed toward the moral and intellectual welfare of the naval personnel, and Surgeon Generals Gorgas, Braisted, and Blue spoke for the Army, Navy, and Public Health Service, outlining the medical work in these respective branches.

Surgeon General Gorgas at a meeting of the general medical board, which preceded the clinical congress, outlined the efforts now being directed toward meeting medical needs on the fields of battle, at home, and also in