stars of the helium type to move. The black dots trace the path of the Milky Way. The paths sharply define a plane which is that of the stars used instead of the plane of the Milky Way, but in addition there are considerable tendencies of motion which carry the helium stars into other regions. In some cases this tendency seems to be the greater of the two. In the care of area 4 there is no tendency for a preference for motion in the Milky Way.

To summarize the conclusions drawn from the investigation of the systematic motions of the helium stars, there appears to be a strong tendency for these stars to move in their own plane, which should therefore be preserved, at least until the next step in the star's evolution. As a matter of fact the A-type stars, supposedly representing the next stage in evolution, exhibit a strong tendency to crowd toward this plane. But there are likewise strong tendencies for the stars of helium type to depart from the plane, so that the tendency for the stars to spread in every direction, so clearly manifest in advanced stages in the evolution of a star, has its birth in the helium stage of evolution. There is apparently nothing systematic in the motions directed away from the plane of the stars.

THE ABUNDANCE OF THE ELEMENTS IN RELATION TO THE HYDROGEN-HELIUM STRUCTURE OF THE ATOMS

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According to the theory already presented in a number of papers[1] the atoms of all the 91 elements of our ordinary system heavier than hydrogen are built up as intra-atomic (not chemical) compounds of hydrogen. The first of these 91 elements, helium, is the second in the system, and therefore has the atomic number 2. It has an atomic weight of 4.00, and may be considered to be composed of 4 hydrogen atoms. The element of atomic number 3, lithium, has an atomic weight of about 7. Now it has been found that in general among the elements of low atomic weight, the elements of even atomic number, beginning with helium, seem to be built up from helium atoms, and therefore may be said to have the general formula $n\mathrm{He}'$, where the prime is added to indicate that these elements are intra-atomic, not chemical, compounds. The odd numbered elements, beginning with lithium, seem in general to have the formula $n\mathrm{He}'+\mathrm{H}_3'$. Thus the elements seem to fall into two series which may be called the *even* and the *odd* series, or the helium and the lithium series, if each series is named for its first member. However, it should be noted that while the formula for the helium series is $n\text{He}'$, that for the lithium series is not $n\text{Li}'$.

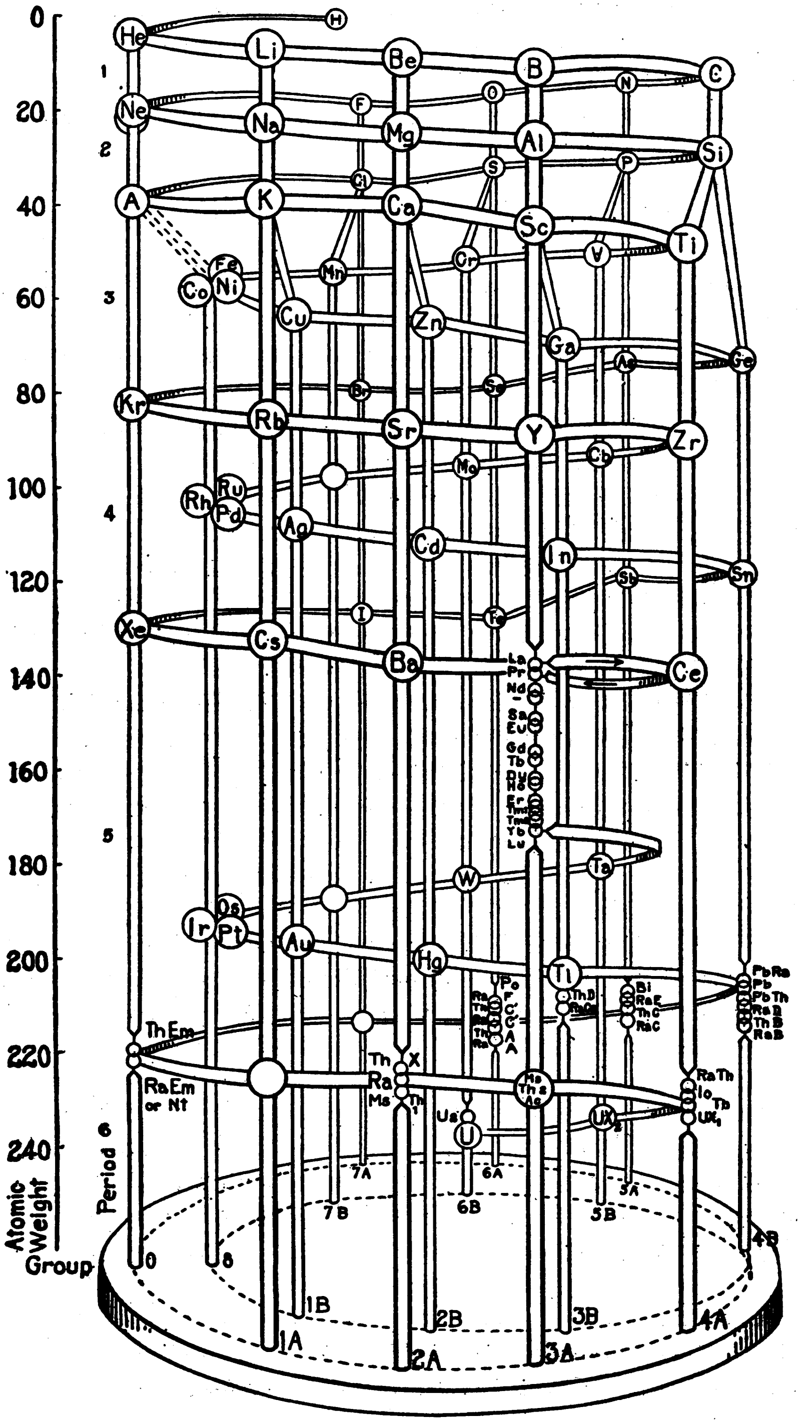
If the theory is correct it might be expected that some characteristic of the elements could be found, with respect to which there is a difference from odd to even and from even to odd, or in other words the elements should show variations in periods of 2 elements each.

In order to have a basis for the comparison of the elements in the study of this problem there has been constructed in space a periodic model of which the accompanying figure is a drawing. In this model the elements are represented by balls strung on a spiral in the order of their atomic numbers, which have recently been found to be much more characteristic of the elements than their atomic weights. The spiral is so arranged that the balls representing the elements belonging to one group and having the same maximum valence are strung on the same vertical rod. The balls are set at such heights that the vertical distance from the top down represents the atomic weight. This is essential, for otherwise the different kinds of atoms of one element, called by Soddy 'isotopes' cannot be represented. Thus in the lower right hand part of the table, on the lower part of Group 4B, the element lead is represented by 6 isotopes, with the atomic weights listed, as follows: lead from radium (uranio-Pb) 206.1; lead, 207.2; lead from thorium, 208.1; radium D, 210.1; thorium B, 212.1, and radium B, 214.1. Thus the different kinds of lead, which seem identical chemically and give the same spectrum, have atomic weights which differ by as much as 8 units, or by 4%. However, all of these isotopes have the same atomic number, 82, or according to the theory developed by various investigators, they have the same positive nuclear charge.

When arranged in this form of periodic table the elements other than hydrogen and helium are found to arrange themselves in periods as follows:

1. First short period	Li – Ne: $8 = 2 \times 2^2$ elements	Cycle 1 = 4^2
2. Second short period	Na – A : $8 = 2 \times 2^2$ elements	
3. First long period	K – Kr: $18 = 2 \times 3^2$ elements	Cycle 2 = 6^2
4. Second long period	Rb – Xe: $18 = 2 \times 3^2$ elements	
5. First very long period	Cs – Nt: $32 = 2 \times 4^2$ elements	Cycle 3 = 8^2
6. Second very long period	Eka – Cs: —— (incomplete)	

It is thus seen that these periods and cycles make up a numerical system of a remarkably simple form, and it seems evident that this system



Periodic Table by W.D.Harkins

must express something inherent in the structure of the atoms. However, what it is desired to emphasize here is that nearly all of the physical properties of the elements vary in periods which are either the same or nearly the same as these. The chemical properties also vary in rather long periods, which in the case of the short periods 1 and 2, are identical with those given.

From this it is seen that both the chemical and the physical properties of the elements vary in periods which are long in comparison with the change in periods of 2 elements as indicated by the division of the elements into the odd and even series. If now neither the physical nor the chemical properties vary according to these extremely short periods, what, it may be asked, is left which can so vary?

Now it might easily be shown that the hydrogen-helium system of the structure of the elements, which divides them into the odd and even series, is in reality more directly applicable to the structure of the nuclei of the atom than to the atom as a whole. If then the Rutherford theory that the nuclei of atoms are extremely minute, is used as a basis for reasoning, it would be expected that the variations in the structure of the nuclei should not cause variations in the properties of the elements except in so far as they influence the nuclear charge. This nuclear charge has been assumed to be equal to the atomic number, and therefore rises with perfect regularity from odd to even or from even to odd. It seems probable that the number of electrons external to the nucleus is equal to the nuclear charge, and that it is the change in their number and arrangement which causes the physical properties to vary according to the periods listed above. This question has been discussed in a previous paper.[2]

It might be expected, however, that the composition of the nucleus should affect its own stability, which from radioactive evidence means the stability of the atom. From this standpoint it might be reasonable to suppose that the atoms of one of the series, the even or the odd, should be more stable than those of the other. Now unfortunately there is no known method of testing the stability of the lighter atoms, but it might seem, at least 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 $n\mathrm{He}'$, which may be written $n(4\mathrm{H}')'$. Now, since the formula for the odd numbered elements is $n\mathrm{He}'+\mathrm{H}'_3$, or $n(4\mathrm{H}')+\mathrm{H}_3'$, it is evident that, if the supply of H_3 needed by the elements was relatively small at the time of their formation, not so much material would go into this system. This would be true whether the H_3 represents three atoms of hydrogen or one atom of some other element. 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[3] 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[4] has found that in the nebula N. G. C.[4] 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).

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 impossible, even in case of the earth, it might be considered that sufficiently good data could be obtained from the earth's crust, or the lithosphere. However, it seems probable that the meteorites represent more accurately the average composition of material at the stage of evolution corresponding to the earth than does the very limited part of the earth's material to which we have access. At least it might seem proper to assume that the meteorites would 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 preliminary study of the most recent analyses of meteorites of different classes showed that, either for any one class or for the meteorites as a whole *the even numbered or helium system elements are very much more abundant than those of the odd numbered or lithium system.* For a more detailed study use was made of the data collected by Farrington,[5] who suggests that the average composition of meteorites may represent the composition of the earth as a whole.

The results obtained by averaging the analyses of 318 iron and 125 stone meteorites, 443 in all, show that the first seven elements in order of abundance are iron, nickel, silicon, magnesium, sulphur, and calcium;

and not only do all of these elements have even atomic numbers, but in addition they make up 98.6% of the material of the meteorites: Of the remaining elements present to a great enough extent to have an appreciable effect upon the percentage values, 7 are odd and 5 are even, but in all only 1.22% are odd numbered, while 98.78% are even.

Of the iron meteorites 99.22% of the material is made up of even numbered elements, and of the stone meteorites, 97.50%. While the results for the earth's lithosphere are not so striking, they still show the same general tendency very strongly; for, of the six most abundant elements, only aluminum is odd numbered, and the elements of even atomic number make up about 86% of the material. The only odd numbered elements other than hydrogen present in the lithosphere in amounts over 0.2% are aluminum, sodium, and potassium.

Table 2 gives the average composition of iron and stone meteorites, arranged according to the periodic system. The numbers before the symbols represent the atomic numbers, and the numbers underneath give the percentage of the element. 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 probably not 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. The only criticism which could be made of the system of averaging, which is that of including all accurate analyses, is that it places undue emphasis upon the iron as compared with the stone meteorites. However, since the two relations shown in Table 1 are true for each class of meteorites separately it is evident that they will be true whatever system of averaging may be chosen.

TABLE 1

AVERAGE COMPOSITION OF METEORITES ARRANGED ACCORDING TO THE PERIODIC SYSTEM

SERIES	GROUP ODD 1	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 0.17%	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									

If attention is now turned to the heavier elements as shown in the model, it is seen that the five unknown elements eka-caesium, eka-manganese 1, eka-manganese 2 (dwi-manganese), eka-iodine, and eka-neodymium, have *odd* atomic numbers. (There is some doubt as to the discovery of thulium 2.) Not only are the unknown elements odd numbered, but among the radio-active elements, if the most stable isotope of each element is used for the comparison, the *odd* numbered elements are much less stable than the adjacent elements of even number.

If we consider the rare-earths—the elements which are most similar chemically, while at the same time their atomic numbers change in steps of one—the same result is obtained. In the following table, which includes, besides the rare-earths a number of elements adjacent to them, the letter *c* indicates common in comparison with the other elements in the table, and *r* indicates rare. *cc* represents very common, etc. The comparison is only a rough one, but it is sufficiently accurate for the purpose for it indicates that in every case the even numbered element is more abundant than the adjacent odd numbered element.

TABLE 2

ATOMIC NUMBER	ABUNDANCE	ELEMENT	ATOMIC NUMBER	ABUNDANCE	ELEMENT
55	c	Caesium	63	rr	Europium
56	ccc	Barium	64	r	Gadolimium
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 by the statement that in the evolution of the elements much more material has gone into the even numbered elements than into those which are odd, either because the odd numbered elements are less stable, or because some constituent essential to their formation was not sufficiently abundant, or both.

It is easy to see too that most of the material has been used up in the formation of the lighter elements. Table 2 shows that in the meteorites the most abundant elements are oxygen in series 2, the elements of series 3 except neon, and the members of the first eighth group triad (iron, cobalt, nickel). Clarke[6] has found that just these same elements are the most abundant in the lithosphere, although in the lithosphere potassium and calcium in series 4 are also moderately abundant. If the lithosphere were considered alone it might be considered that the abundance of these elements is due to changes which have taken place in the lithosphere, or to the rising to the surface of the lighter elements, but these objections are not so valid when the meteorites are found to show the same relations. The density of the earth's surface rock averages between 2.70 and 2.75, the mean density of the earth is 5.516, and the density of its center has been estimated by Lunn[7] as 9.6 on the basis of Roche's law of density, and on the supposition that the chemical composition of the earth is uniform. Stone meteorites vary in density from 2.5 to 5, and iron meteorites from about 6 to more than 8, with an average density of 7.8. According to Lunn[7] the pressure at the center of the earth is 2,800,000 atmospheres, and a possible central temperature is 16,610° when both are calculated on the basis of Roche's law, $\rho = \rho_0 (1 - cx^2)$. It seems probable that this law is much more in accord with the behavior of material than the simple Laplacian form usually used. Some writers have argued from the data that the center of the earth is mostly iron. However the extremely long range of extrapolation above the experimental values in both temperature and pressure, makes it seem impossible to get results in this connection which have the least value, however desirable it would be for such a problem as the one presented here if such a deduction could be properly made. Perhaps, then, the most that can be said is that in the three classes of material, the lithosphere, the stone meteorites, and the iron meteorites, in spite of variations in density from 2.5 to 8, the same two rules are found to hold, that (1) the even numbered elements, and (2) the elements of low atomic number and low atomic weight, are the elements which occur in abundance.

If an artificial line of division is made just after the first eighth group in the periodic model so as to classify the first 29 elements as of low atomic number and atomic weight, and the remaining 63 elements as of high atomic weight, then the following table, based upon data from analyses listed by Farrington and Clarke may be presented to emphasize the importance of the former class.

TABLE 3

PROPORTION IN VARIOUS MATERIALS OF THE ELEMENTS OF LOW ATOMIC NUMBERS

Material	Percentage of Elements with Atomic Numbers 1–29	Percentage of Elements with Atomic Numbers 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 may be said that, so far as the abundance of the elements goes, the system seems to play out at the end of the first eighth group in the periodic system. It may be of interest to note here, what has been pointed out in former papers, that it is just at this point in the system that the atomic weights cease any longer to be very close to whole numbers, as they are for the lighter weight elements. Also just at this point the exact formula given for the elements ceases to hold well. These facts do not mean however, that the system fails beyond the iron group of elements; for it is just among the heaviest elements that it received its verification by the actual decomposition of the elements into helium.

The complete paper of which this is an abstract, will be published later. I wish to thank Prof. C. W. Balke of the University of Illinois for suggestions in regard to the relative abundance of the elements of the rare earth group.

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[1] Harkins and Wilson, These PROCEEDINGS, 1, 276 (1915); *J. Amer. Chem. Soc.*, 37, 1367–1421 (1915); *Phil. Mag.*, 30, 723 (1915).

[2] Harkins and Hall, *J. Amer. Chem. Soc.*, 38, 186–8, 203–5, 211–14 (1916).

[3] H. Buisson, Ch. Fabry, and H. Bourget, *Astrophys. J.*, 40, 256 (1914). See also Dempster, *Ann. Physik.*, 47, 792 (1915).

[4] Wright, These PROCEEDINGS, 1, 590–5 (1915).

[5] Farrington, Publications 120 and 151, Field Columbian Museum, Chicago.

[6] Clarke, *The Data of Geochemistry*, Bulletin 491, Department of the Interior (1911); see also Bulletin 616 (1915).

[7] Lunn, in 'Tidal and Other Problems,' pp. 201–18, Carnegie Institution (1909).

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THE GENETIC RELATIONS OF CERTAIN FORMS IN AMERICAN ABORIGINAL ART

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One of the most difficult problems in anthropology has been the working out of successive steps in the origins of particular traits of culture. The most intensive effort seems to have been made in studies on the evolution of decorative designs. By arranging designs found upon prehistoric or other pottery in order of their increasing conventionality, series have resulted, showing a clearly realistic drawing at one end and an almost entirely geometrical one at the other. Such series suggest that all these forms were arrived at by first drawing from real life and then by successive conventionalizations arriving at a pure geometric form. The weak point in this interpretation is that there are no means of dating the units of the series, their arrangement being merely a matter of selection on the part of the observer. There are still