A SPHERICAL ARRANGEMENT OF THE CHEMICAL ELEMENTS*

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Chemical literature includes many periodic tables, charts, or other means of classifying the chemical elements. Some have involved a great deal of work. Others may not have been so laboriously prepared. But the purpose in them all has been to establish a satisfactory correlation of chemical knowledge as related to the physical and chemical properties of the elements.

A study of these various periodic arrangements will show common failings to be either that of placing different elements on the same position in the chart or placing a group of elements outside the chart, as is commonly done with the rare earths.

A few authors have attempted to overcome these difficulties. The spherical arrangement suggested by Friend (1) and the helical form proposed by Harkins (2) are outstanding. We have found, however, that a more desirable organization is obtained by using both helical and spherical arrangements together in the same system.

This arrangement is outlined below and takes the form of a sphere. The upper hemisphere includes most of the known elements. Only a few elements at the begining of the lower hemisphere are known, and thus it is largely theoretical and extrapolated on the basis of the following reasonable assumptions.

Assumptions.—The two assumptions on which the construction of the complete sphere is based are: first, that the actinide series, when completed, will resemble the lanthanide series (3); and second, that the pattern outlined in the upper hemisphere of the system will repeat itself, decreasing the way it built up, to an end. Here a hypothetical element with an atomic number of 172 would come in as the last element. This element would have an electronic configuration of: 2, 8, 8, 18, 18, 32, 32, 18, 18, 8, 8, 2. The equator of the sphere would arbitrarily come between the sixth and seventh periods.

The pattern.—The following description outlines the organization of the complete sphere, including both the top hemisphere containing the known elements and the extrapolated theoretical lower hemisphere.

The sphere is divided into twelve latitudes, six in each hemisphere. The first seven latitudes compose the seven known periods, the seventh being incomplete at present. The remaining five latitudes are theoretical and serve to complete the pattern on the sphere. There are eight longitudinal bands (groups), two of which originate and terminate in the first and last latitudes; these are groups I and VIII (the inert gases).[1]

* Presented before the Chemistry Section of the Illinois Academy of Science at Galesburg, May 6, 1949.

[1] Since the elements in the various groups hold group numbers corresponding to the number of electrons in their outermost shell, it seems reasonable to label the inert gas group as group VIII, for helium is the only inert gas without eight electrons in its outermost shell, having but two electrons; this eliminates the designation "zero." For simplicity, the nine elements of the so-called group VIII may be designated the "Triad System," of group VIIIB, for they lie between groups VIII and I, are not inert, and range in valence from one to eight. If C and D groups were attached to the triads, it would indicate that they are inert elements; and, of course, group VIII is the only group that can have inert elements in it.

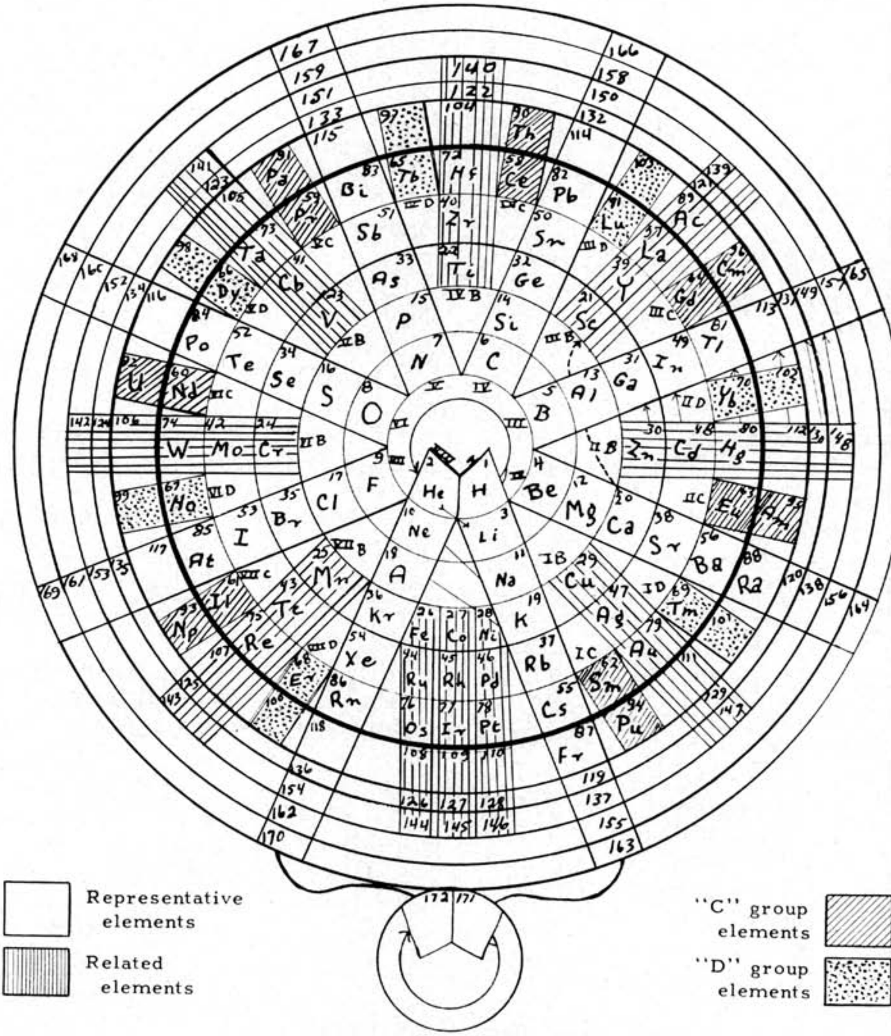

FIG. 1.—A polar projection.

The other groups originate and terminate in the second and eleventh latitudes. These eight longitudinal bands comprise the eight groups of representative elements. Group I, which cuts twelve latitudes, is immediately followed by groups II through VII, which cut ten latitudes, and then group VIII, which cuts twelve latitudes, as the first group. Between the eight main groups lie the ten B groups, originating in the fourth and ending in the ninth latitude, B groups eight, nine, and ten forming the triad system and lying between the main groups VIII and I. In each case the B group is placed after the main group to which it is related. Attached to the B groups (with the exception of the triad system) will be found the C and D groups on the left and right, respectively. These short groups, C and D, start in the sixth latitude and end in the seventh latitude, the latitudes on either side of the "equator." Each period has its beginning in group I with the elements placed in a counterclockwise order. The last element in each period is found in group VIII, with the inert gases.

The elements with atomic numbers 21 through 30, inclusive, might be thought of as the calcium series, since it is from that element in period four that there is the deviation into the B groups, even as the elements deviating from lanthanum are known as the lanthanide series. The rare earth elements fill the C and D groups of the sixth period. Going backwards one element from lanthanum, one finds barium, from which the twenty-four succeeding elements deviate from the main group. Hence, this could be considered the barium series, which would be composed of the lanthanide series and the ten elements in the B groups that are part of this period. The deviations in latitudes six and seven are the same, and the deviations in latitudes, or periods, four, five, eight, and nine would be the same.

The transition points.—The system starts with hydrogen in group I, period (and latitude) one, and rotates counterclockwise until it reaches helium, the first inert element and the end of the first period. From the end of a period the transition is consistently to the element in group I in the next lower latitude. When period four is reached, the transition is not so simple, involving a total of five types of transition points.

The first transition point is from helium to lithium, period one to period two. The second and third transition points are the connections between the representative elements and the related elements of group A and group B. In period four, group II is the first transition point of this type: from calcium to scandium, and returning to the main groups from zinc to gallium. Once transition is made into the B groups from the representative elements, only the B groups are touched in the counterclockwise rotation until group IIB is reached, where the normal transition is to the main group III and the period is completed with an inert gas. The fact that an element is in a B group would indicate inner building in the second from the outermost shell. (See fig. 2, cross-cut view of period five.) These transition points are involved in periods four through nine, inclusive.

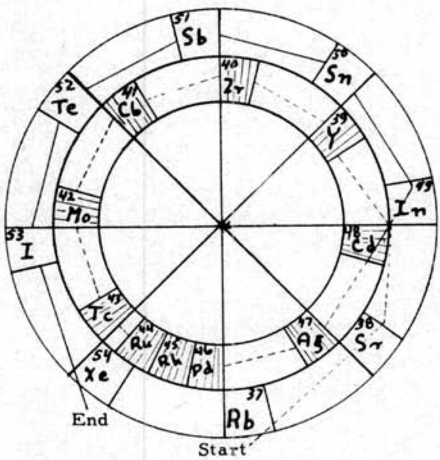

FIG. 2.—Period five, cross-cut view.

However, the transition points previously mentioned, although they apply to periods six and seven, become a little more complex with the introduction of transition points four and five. These transition points involve the departure from the B groups in group IIIB, period six, and the return from IIID to IVB. To illustrate: from lanthanum (IIIB, period six) to cerium (IVC,

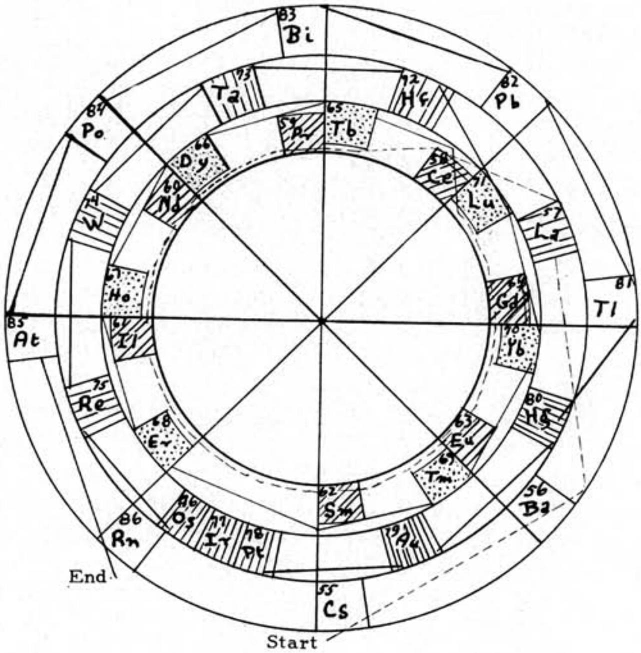

FIG. 3.—Period six, cross-cut view.

period six), and from lutecium (IIID, period six) to hafnium (IVB, period six). It is pointed out here that the transition from gadolinium (IIIC, period six) to terbium (IVD, period six) is not considered a transition point, since it is merely completing the lanthanide series. (See fig. 3.)

The fourth and fifth transition points form a system similar to the transition system involving the B groups, except that this group of the elements, C and D groups, gain electrons in the third from the outer shell. The last element in the lanthanide series ends with element number 71, and this element is in IIID, where both C and D groups are filled. The building in the third from the outermost shell is almost completed in this element. Next the B groups are filled and finally the main groups. Period seven, just across the equator of the system, is assumed to be similar to the sixth period. From period seven to twelve, the number of elements in each period decreases in the same manner in which they reach the maximum. The transition points of all periods of the same length are the same throughout the entire system.

Theoretical basis for the treatment of the lanthanides.—A certain degree of periodicity in valence is found when the lanthanides are plotted as they are in figure 4. This is in agreement with the periodicity brought out by Moeller's (4) atomic volume plot of the lanthanides, and in Van Rysselberghe's "New Periodic Table" (5). The circled valences in figure 4 indicate valence states either of minor importance or of those unobtainable in the presence

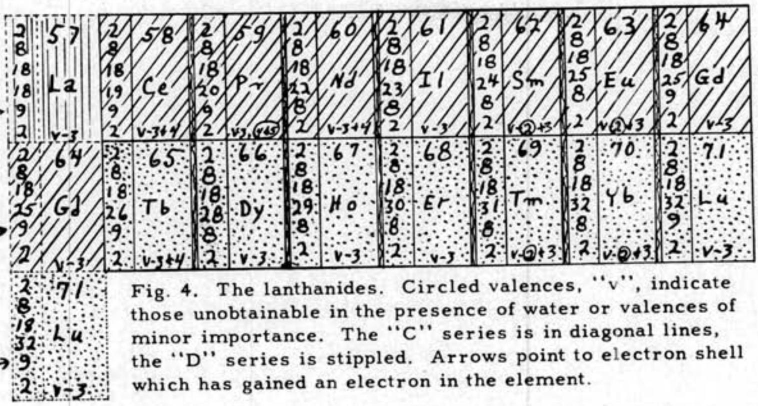

FIG. 4.—The lanthanides.

of water. These pairs of lanthanides were attached as C and D groups to the B groups in period six, excluding the triad system. Their variance in valence is generally similar to that of the B group to which they were attached; this is part of the basis for attachment to the B groups. The lanthanides are thus included in period six, which has 32 elements. Position in the C and D groups shows relation to the B groups and more or less remote relationship to the elements in the main groups.

Attention is called to gadolinium and lutecium, attached to lanthanum, because they gain an electron in the second from the outermost shell as does lanthanum. Lutecium is more closely related and similar to lanthanum because of the fact that its third shell is complete like that of lanthanum (6).

A letter in *Nature* (7) points out that divalent compounds of both europium and ytterbium exhibit a strong blue fluorescence when exposed to ultra-violet light; these elements are attached to group IIB in period six and are one of the pairs formed in figure 4.

Theoretical basis for the treatment of the actinides.—Certain of the actinides, attached immediately below the lanthanides and on the opposite side of the equator of the spherical system, have for some time been considered as properly belonging to the B groups of the related elements (8). For example, thorium has been considered to belong to group IVB. In the spherical system this element is appropriately attached in a C group, maintaining its relationship to group IV, and also in accord with the modern concept of thorium as part of the actinide series (9). This same relationship is observed in the case of protactinium, in group VC, and of uranium, in VIC, which are attached to their respective B groups.

The lanthanides and actinides are thus attached to the B groups in such a way that their relationship to the other elements is evident, and yet their individuality is retained by their placement in C and D groups.

Interpretation of the diagrams.—Figure 1 is a polar projection of the sphere. A study of it will show that the equator of the system lies between periods six and seven. The

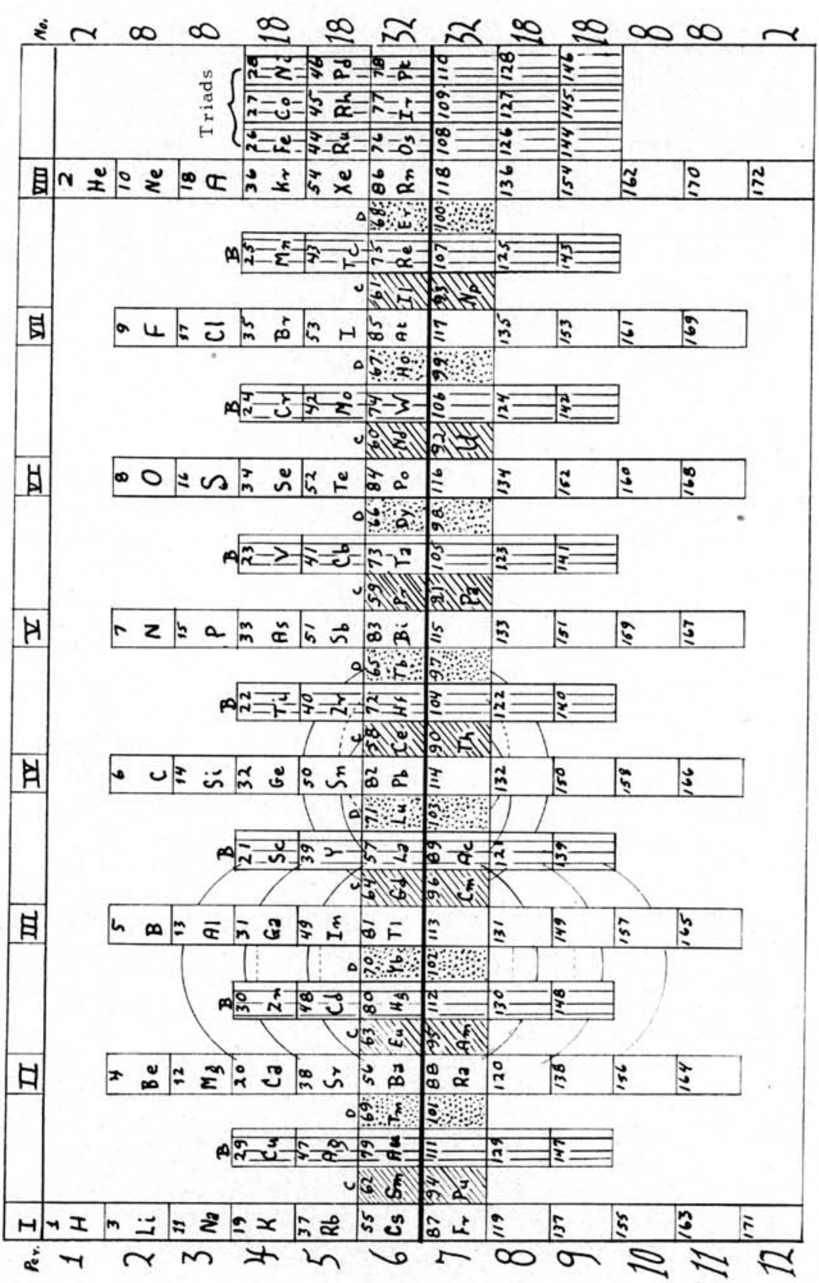

FIG. 5.—A Mercator projection.

pattern of the lower hemisphere is extended in a manner similar to the way in which the upper hemisphere built up to period six with its 32 elements, but in reverse: starting with the seventh period filling out to 32 elements and the following periods having 18, 18, 8, 8, and 2 elements. The key is the same in all the diagrams. A white background denotes the representative or main elements (A groups). A vertically lined background denotes the related elements (B groups), and slant-lined and stippled backgrounds denote the C and D series respectively of the "rare" elements, the lanthanide and actinide series. The heavy black line indicates the equator of the system. In figure 1, the theoretical, extrapolated periods eight, nine, ten, and eleven are reduced in size so that they may be included.

Figure 2 gives a cross-cut view of period five, and figure 3 of period six. These two diagrams show how the elements build up in the spherical system, and suggest analogous positions of electrons in the particular latitude of electrons building up.

Figure 4 shows the periodicity in the lanthanides in regard to valence; and the electrons in the various shells as well as the valence states are included in the diagram. Figure 5 is a Mercator projection of the spherical system.

Advantages.—a. The number of elements in each period is easily ascertained, since it is known that the periods contain respectively 2, 8, 8, 18, 18, and 32 elements.

b. The inert gases, elements which have all their electron shells filled, are placed at the end of their respective periods.

c. The representative elements, those with all but the outer shell filled, stand out clearly.

d. The related, or B group, elements are placed adjacent to and following the group to which they are related.

e. The "rare" elements, the lanthanide and actinide series, are placed in C and D groups showing three incomplete electron shells and showing their relation to the B group elements and through these to the representative elements. Elements in B groups show building in the second from the outer shell, and those in C and D groups show building in the third from the outer shell.

f. Interpretation of the periodicity of the elements, in terms of electronic configuration, is greatly facilitated, position in the sphere being directly related to electronic configuration.

g. Erroneous analogies between A and B group elements are avoided, and family relationships are clearly emphasized.

h. Elements of any specific group retain their distinctive characteristics, and at the same time show their relationship to the other elements in the group, as B, C, and D group elements.

i. The lanthanide series is included in the system in a satisfactory way, and its relation to the other elements and the periodic table is clearly shown.

j. There is a logical continuity within the system.

Summary.—A new arrangement of the atoms is described which has a combined helical and spherical organization. The system incorporates the representative, the related, and the rare earth elements in one sequence and in correct relationships to the other atoms. A theory concerning the electronic configuration of the undiscovered elements is presented.

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