# TYPES *of* GRAPHIC CLASSIFICATIONS *of the* ELEMENTS*

### *III. Spiral, Helical, and Miscellaneous Charts*

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SPIRAL ARRANGEMENT (BAUMHAUER TYPE)

THE ARRANGEMENTS classified in this division are all flat spirals. Although two or three tables do not strictly comply with the definition, the authors have considered their general character such that "spiral arrangement" best describes them. Were it not for the fact that Hinrichs did not recognize the periodicity among elements, his "Chart of the Elements" should surely have the honor of first place in the class of flat spiral arrangements.

BAUMHAUER—1870 (*71*): Baumhauer's spiral (Figure 14) shows the elements arranged in order of increasing atomic weight beginning with H at the center. Similar elements fall in line from the center to the periphery, causing the whole to be divided into seven segments. Many of the chemical families are clearly shown, and in the more difficult arrangements, Baumhauer has attempted to indicate relationships of elements by means of arrows.

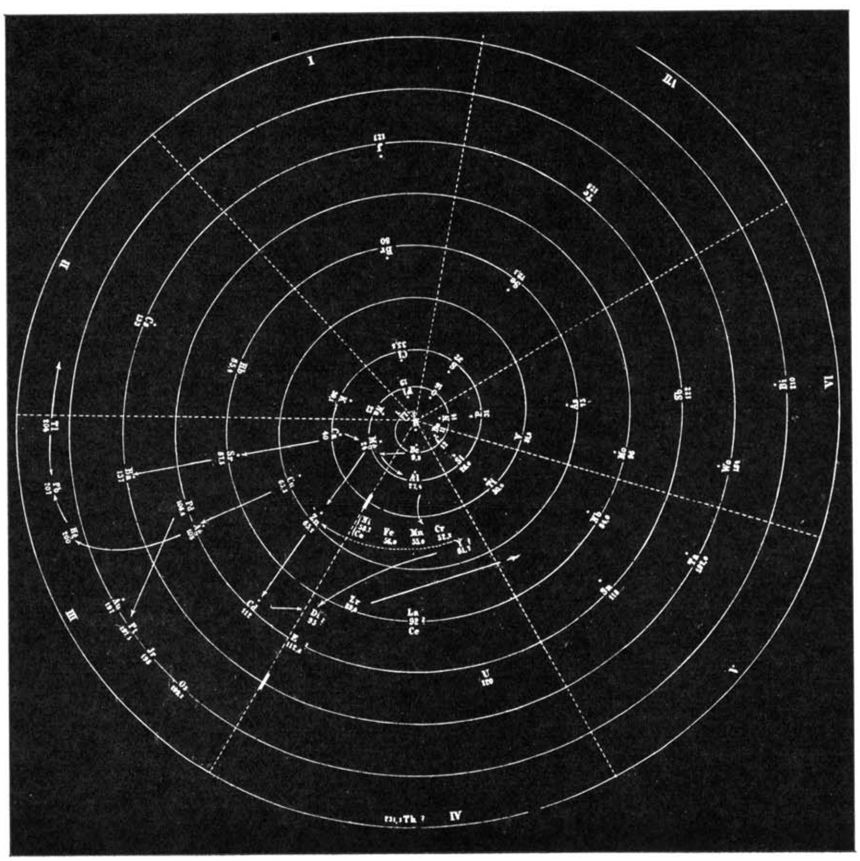

FIGURE 14.—BAUMHAUER'S SPIRAL

VON HUTH—1884 (*72*): von Huth followed the plan of Baumhauer in developing a spiral in order of increasing atomic weights. From the center, seven radii diverge, each representing the location of a group of elements. Li is placed on the first radius, 7 mm. from the center; then Be on the second, at 9 mm. The intersection of a radius by the spiral gives the location of an element. In the case of the "eighth group elements," the clusters of elements are placed in a single position. The Mendeléeff families, or subgroups, are shown by listing the elements on each side of each radius, the "Iron-Platinum" and "Halogens" constituting the seventh radius. Von Huth also observed that his spiral could be divided into areas of "acid formers," "indifferent elements," and "base formers."

LOEW—1897 (*73*): Loew represented the positions of elements by points on an Archimedean spiral in which $V = \phi = \sqrt{W}$, where "$W$" is the atomic weight, "$V$" the radius vector, and $\phi$ the polar angle. If the spiral is cut by a line passing through the origin, the segments contain lists of elements of which corresponding members form related chemical groups, as P, As, and Sb, Bi. F and

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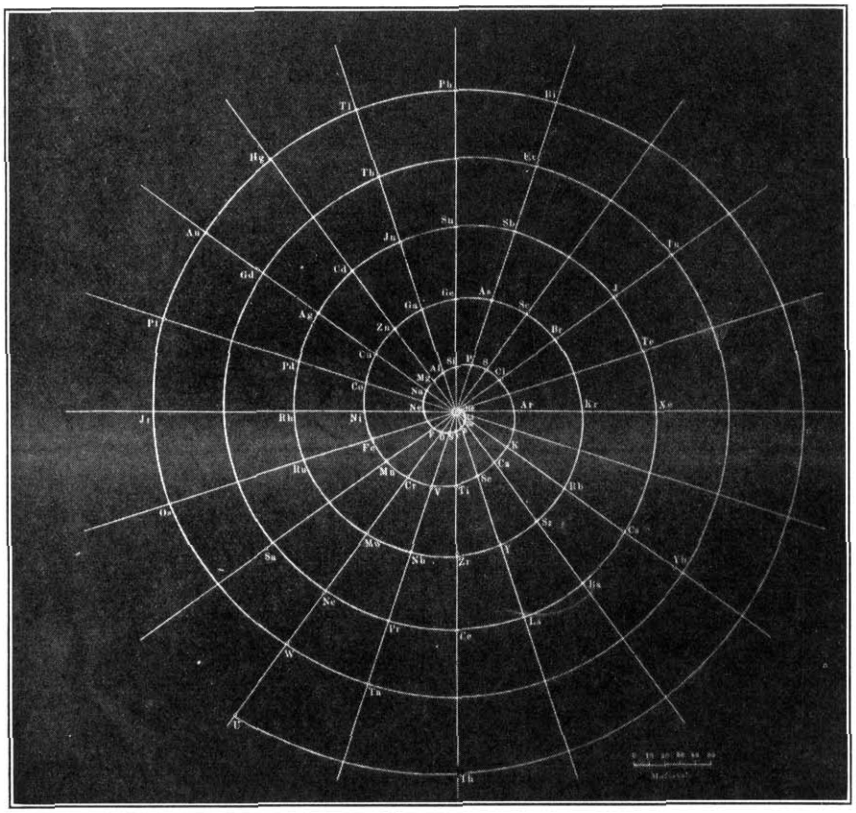

FIGURE 15.—ERDMANN'S SPIRAL TABLE

A, however, are classified with the iron and platinum groups. The many exceptions make the usefulness of the system doubtful.

STONEY—1902 (*74*): Stoney designed a logarithmic spiral, in which the atomic weights were indicated by volumes of concentric spheres; the radii of these spheres were used as radii vectors of a polar diagram. The author claimed that the spiral afforded the same information as the Mendeléeff table and noted the absence of elements on a particular sesqui-radius, the positions on which have since been filled by the "inert elements." On the sixteen radii are shown a number of definite families, but a number of inconsistencies are very apparent; among these may be mentioned, F and Mn on the same radius; Na, Cu, Ag, Au; O, Cr, Mo, W, U. The quadrants are alternately labeled "electropositive" and "electronegative."

ERDMANN—1902 (*75*): Erdmann arranged the elements around hydrogen in the clockwise direction (Figure 15) making one turn for a long period and one for the two short periods, thereby causing Na to fall on a radial line with Cu, Ag, Au. Each of the twenty radial lines locates a family, the distance from the center representing the atomic weight of each element. In this arrangement Co follows Ni; and Te follows I, thus causing Te to occupy a special radial line and to lose its connection with the sulfur family.

RYDBERG—1914 (*76*): Rydberg's spiral is not a spiral in the true sense of the term, but a series of concentric circles. The ratios of the radii are 1:4:9:16. The center is occupied by E, and H is the first point on the first circle. The second circle contains the elements of the two short periods; the third, the elements of the two long periods; and the outermost circle, which is incomplete, consists of the Cs and the "87" periods. On the X-axis are placed the "inert elements." Horizontal lines above and below the X-axis cut the circles at positions of elements of the same groups, as arranged in Rydberg's short-type table (*22*).

WELLS—1918 (*77*): The elements in Wells' spiral are arranged in the angular order of their atomic numbers, and the distances from the center are proportional to the atomic weights. The periodicity is of eight instead of sixteen, as in the Stoney spiral (*74*). Each group is radially arranged; the sub-groups are slightly displaced as in the Mendeléeff tables. The eighth group and "zero group" elements constitute a single group.

NODDER—1920 (*78*): Nodder claimed no essentially novel features for his spiral arrangement (Figure 16), which he stated "is practically the Harkins' spiral arrangement (*92*) adapted for a representation in one plane." Missing elements are indicated; dotted lines point out

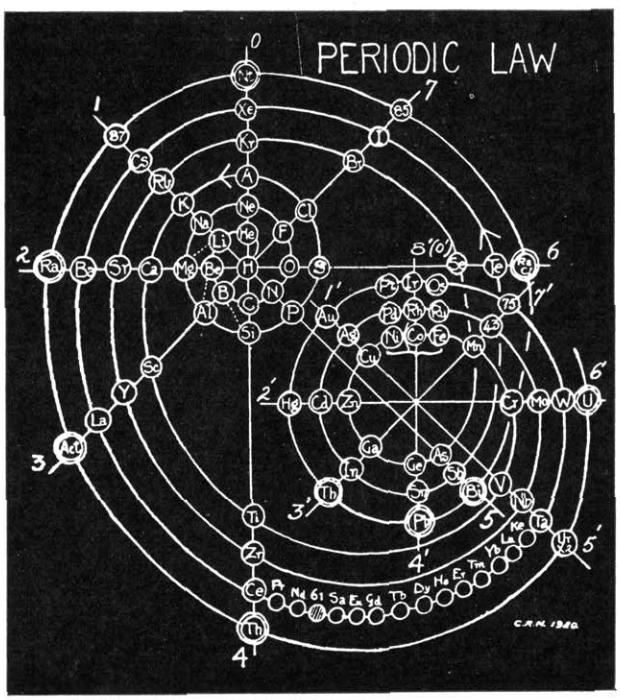


FIGURE 16.—NODDER'S PERIODIC TABLE

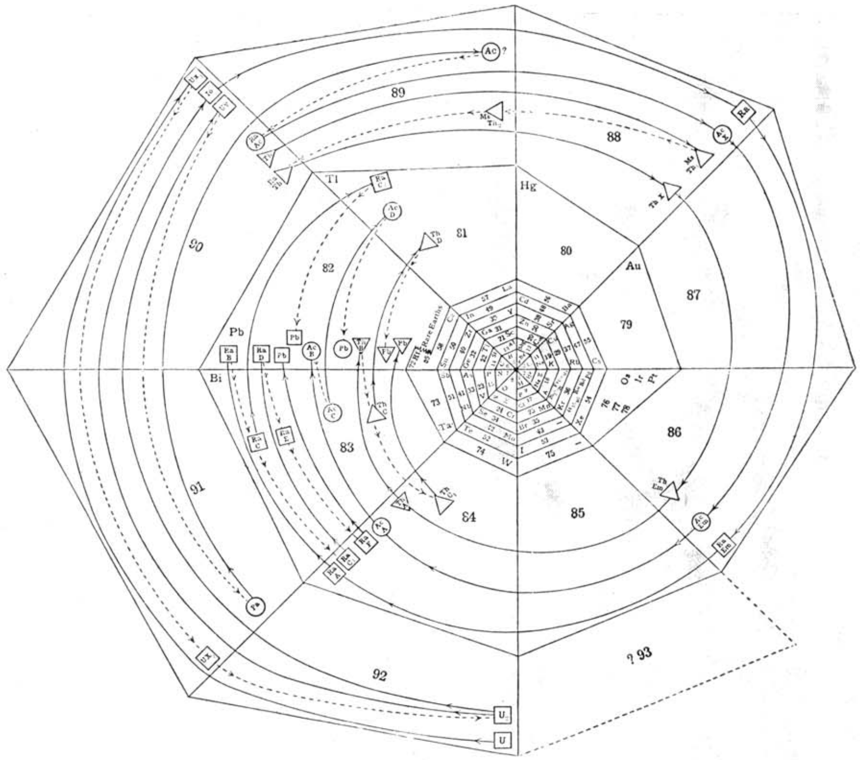


FIGURE 17.—PARTINGTON'S PERIODIC ARRANGEMENT OF THE ELEMENTS

interesting resemblances, such as Li and Mg; double circles represent pleiads of isotopes; and barbs are placed between elements out of order with respect to atomic weights.

PARTINGTON—1920 (*79*): The central portion of this spiral (Figure 17) is a simple arrangement with H at the center and the elements enumerated in a counter-clockwise direction. The arrangement is divided into eight segments by eight radial lines, along which are placed the elements of families in order of increasing atomic weight. The position of rare-earth elements is indicated. The outer part of the spiral displays the Soddy-Fajans relation between isotopes of radioactive elements in a unique diagrammatical manner.

TANSLEY—1921 (*80*): Tansley's spiral is divided by eighteen radii (subgroups), 20° each, giving each group equal importance. Unlike Stoney's arrangement (*74*), the elements are plotted, as they decrease in atomic weight, in a counter-clockwise direction. The spiral starts with U at the center and ends with H at the end of the halogen radius. The corresponding elements of the eighth group are given separate radii. The author concluded his discussion with, "A great amount of space is left for new elements."

STEWART—1928 (*81*): The elements are arranged in a clockwise direction in order of their atomic numbers, starting with H at the center. The spiral is divided into eight segments. About the pole of the spiral, and through each member of the zero group, appear broken-line circles which mark the position of "isoteric forms of many of the elements whose atoms change during ionization, so that they have an extra-nuclear electronic arrangement similar to that of the particular zero group element through which the circle passes." The rare-earth elements fail to fall into an orderly arrangement and the family relationships, generally, are very obscure.

HACKH—1929 (*82*): By means of a continuous clockwise curve, starting with H at the center, Hackh

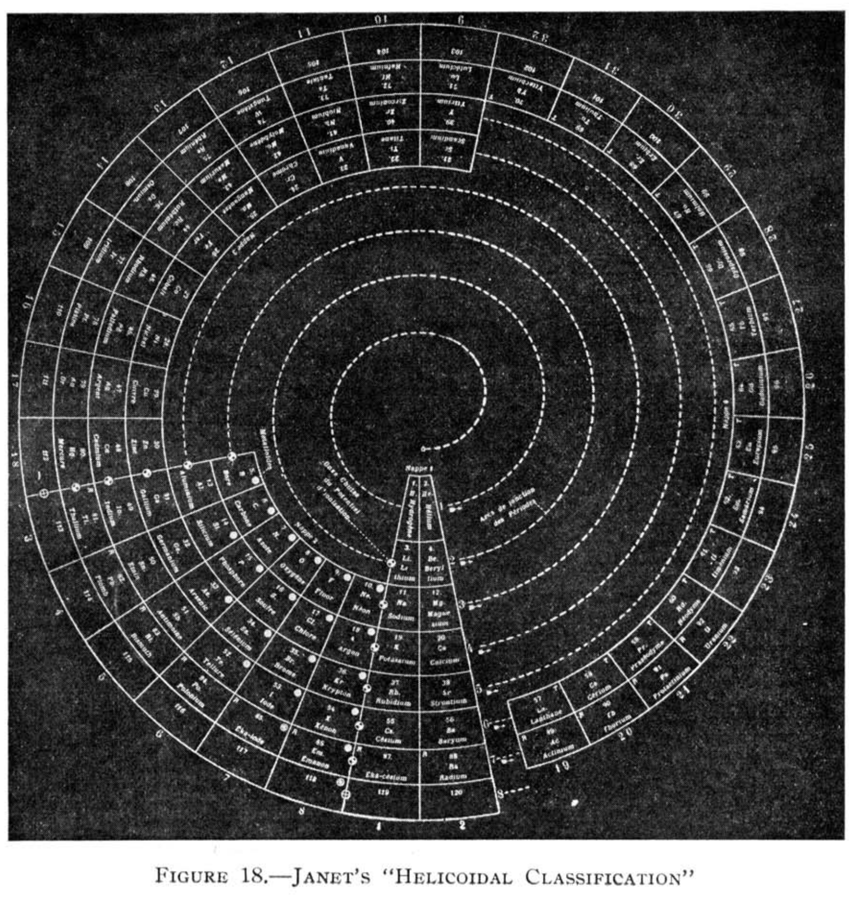

FIGURE 18.—JANET'S "HELICOIDAL CLASSIFICATION"

has caused seven major families to radiate into the upper half of the table in regular order. The long periods cause the elements in the middle zone to droop, forming two parallel lines for the K and Rb periods, while the rare earths cause the Cs period to droop still lower. By this arbitrary arrangement, the strong electronegative elements are found in the upper left region, while the weak negatives are in the lower left; the strong electropositive in the upper right, and the weak in the lower right. The amphoteric elements are in the lower part of the so-called spiral. The orbital arrangement of electrons is shown with the "inert elements" on the upper central radius. The tabular arrangement of Hackh's table will be discussed under "Miscellaneous."

JANET—1929 (*83*): This spiral-like chart (Figure 18) appears to be a long chart shaped into a disc-like arrangement much as Courtines shaped his flat chart into a cylindrical arrangement (*56*). The "spiral," separated on a line between F and Ne, instead of Ba and La, would appear like an improved Chauvièrre chart in which the rare-earth elements are arranged "Werner-like." Helium, of course, would be placed above Ne as usual. The author states that his arrangement is in harmony with modern theories of atomic structures, and it accounts for the position of the metalloids.

CASWELL—1929 (*84*): The elements are represented on a spiral by points 20° apart. The inert gases lie on one radial line at 0°, alkali metals at 20°, Be, Mg, and alkali-earth metals at 40°, the rare earths together at 60°, B and Al at 260°, and, finally, the halogens on the 340° line. Unlike Janet's chart, the rare earths occupy the position of one element and the division occurs between Be and B.

CLARK—1933 (*85*): Clark's chart appears to be a modification of the Hackh spiral (*82*). The cesium period has been shortened by merely writing the words "rare earths" between La and Hf, thus clearly restoring the other elements to their proper places in sub-groups. The "main groups" and "subgroups" are given the typical Mendeléeff group numbers at the outer edge of the spiral, and an attempt has been made to show the degrees of relationship by lengths of dotted and solid lines. Unfortunately, the latter effort has been hampered by insistence on symmetry. Be and Mg are shown to be closely related to Ca, Sr, Ba, and very distantly related to Zn and Cd. Likewise, B and Al are shown to be far more closely related to Sc than to Ga. H is shown to be related to both Li and F, but more closely to the former by relative length of dotted line.

## CONCLUSIONS

The spiral arrangements may be classified in several ways. In the charts by Loew, Erdmann, Wells, Stewart, Hackh, and Clark, the elements are arranged in the clockwise direction, while the counter-clockwise arrangement was used by Baumhauer, von Huth, Stoney, Rydberg, Nodder, Tansley, Partington, and Janet. Of those having radial lines, two have seven radii, two have eight radii, and one each has sixteen, eighteen, and twenty radii. Five of the charts cited do not use radial lines to assist in showing the positions and relationships of elements.

The resultant symmetry of the arrangements has in several instances placed some of the members of the first two periods in unusual positions with respect to groups, and the pairs of elements Be–Mg and B–Al in many instances have been placed in positions not in accord with the facts.

## HELICAL ARRANGEMENT (HARKINS TYPE)

The "Harkins arrangement" is typical of the cylindrical systems, but this division also includes three helical systems which are screwlike in character. In all cases the authors have endeavored to show physical, as well as chemical relationship more clearly by extending the spiral into a third dimension.

DE CHANCOURTOIS—1863 (*86*): On the assumption that the difference between atomic weights of adjacent members of an orderly series must be constant, de Chancourtois arranged the elements in order of atomic weights along the generatrix of a vertical cylinder, the circumference of whose base he divided into sixteen equal parts. Figure 19 is a portion of the cylinder, "telluric screw," unfolded. When the atomic weights failed to conform to prime numbers, he imagined new varieties of simple bodies which he called "secondary characteristics." Although led to many mistaken analogies by enthusiasm and an active imagination, de Chancourtois deserves the credit for producing the first helical arrangement based on the fundamental idea of periodicity.

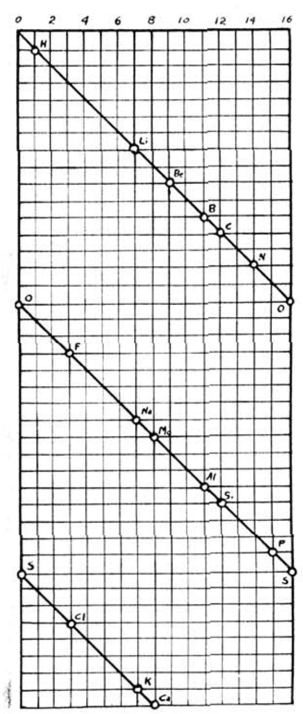

FIGURE 19.—THE TELLURIC SCREW

CROOKES—1898 (*87*): The elements are arranged in order of atomic weights on a line which traces out a figure-eight spiral (Figure 20). Each of the successive loops is divided into eight equal parts and an element, or a cluster of elements (eighth group elements), is placed at each point of division. Analogous elements are found on the same vertical rod at distances proportional to their atomic weights. The blank spaces following Ce and preceding Ta are reminiscent of Mendeléeff's short horizontal chart (11). The arrangement has space for the "inert elements."

SCHIRMEISEN—1900 (*88*): Schirmeisen represented the elements in a system of circles, defining a cylinder, the angular displacement in a clockwise direction from the highest point being proportional to the excess of

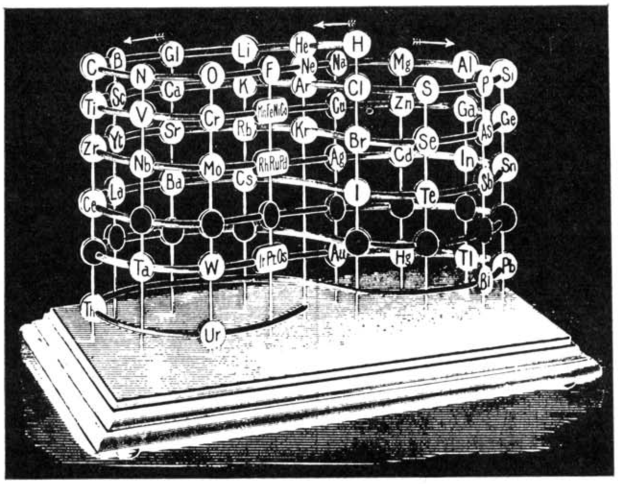


FIGURE 20.—CROOKES' PERIODIC TABLE

atomic weight above the initial value. The first circle consists of He to F, Li at 68.8° and F at 337.7°; in the second circle are Ne to Cl; the angular displacement of Na is 64.4° and of Cl, 325.3°; the third and fourth circles form a figure-eight arrangement, K—32.7°, Co—337.8°, Cu—45.7°, Br—269.7°. The succeeding circles can be constructed similarly from the angular displacements given in degrees.

EMERSON—1911 (*89*): This helical arrangement (Figure 21), which, according to the author, is based on Crookes' spiral (*87*), involves two symmetrical groups of eight elements each (octaves) in two circles, four groups of sixteen elements each (double octaves) in four circles, and, finally, the first quadrant of a larger circle of thirty-two elements. Preceding the first octave circle is shown a group of four elements, hydrogen to helium, in a full circle and a first group of two, ether and coronium, in a half circle. The elements are placed in order of increasing atomic weights on successive coils; the distances between elements on the helix, the interspaces, are proportional to the successive increments in atomic weight. The average increment is two units for the octaves, three for the double octaves, and four for the quadruple octaves. A slightly modified helix by the same author appeared seventeen years later (*90*).

SODDY—1914 (*91*): Soddy's helix is a modified Crookes' figure-eight arrangement (*87*) brought up to date. H and He are treated independently and the first two periods are arranged around the same helical core. The "inert elements" are located at the sharp turns of one helix while the eighth-group elements are arranged along slow turns of the other, showing the "differences in the rate of change of properties in the passage from one place to the next." The rare-earth elements are arranged along the surface in the position occupied by Group III.

HARKINS AND HALL—1916 (*92*): Unlike Crookes (*87*) and Soddy (*91*) who used the figure-eight arrangement, Harkins and Hall developed two concentric helices (Figure 22), the central helix being formed by the long periods. The rare earths and the isotopes of the radioactive elements are arranged vertically in positions determined by the atomic-weight scale, reading from the top to the base. Each vertical rod of the model represents a group, and the relation of subgroups is indicated by a bridge near the top.

STINTZING—1916 (*93*): Instead of constructing double cylinders as did Crookes (*87*), Soddy (*91*), and Harkins and Hall (*92*), Stintzing increased the radius of a single spiral as the periods lengthened. This screw-like figure represents the elements on axes radiating from a center point. Certain unsymmetrical periodic insertions correspond to the peculiar relations of the rare earths, the radioactive elements, and the eighth group.

VOGEL—1918 (*94*): Vogel's contribution was fragmentary in that his proposal dealt with more justifiable arrangements of the rare-earth elements, and eighth-group triads in the periodic system. He proposed a subsidiary loop for the rare earths by causing the spiral to change its course after passing Ba, to form a loop of rare-earth elements, rejoining the larger spiral at Ta. Similar subsidiary loops were suggested for each of the eighth-group triads.

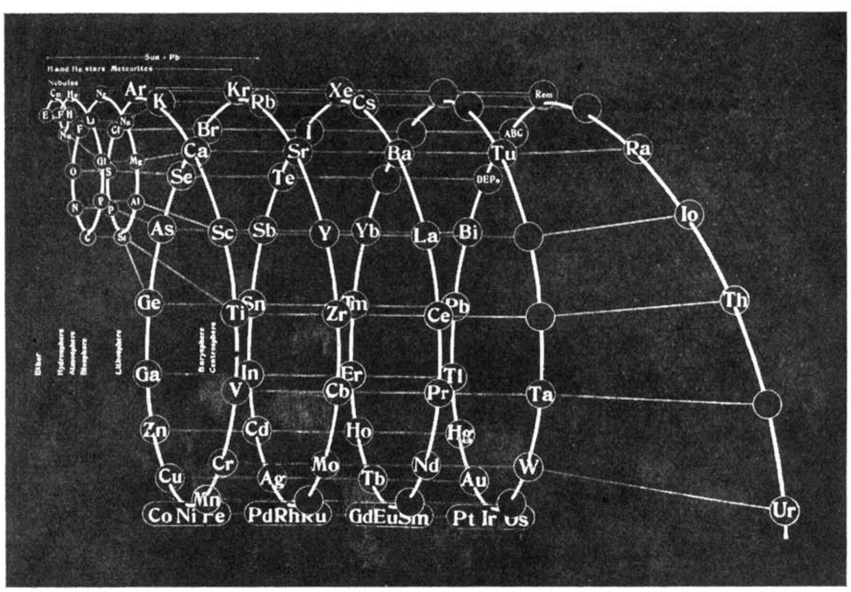


FIGURE 21.—EMERSON'S HELIX

SCHALTENBRAND—1920 (*95*): In this unusual table (Figure 23) the elements are arranged in order of atomic weights on an eccentric spiral. The four sets of curves include positions of similar elements. The first small turn carries H and He; the remainder of the "inert elements" and the halogens are on successive

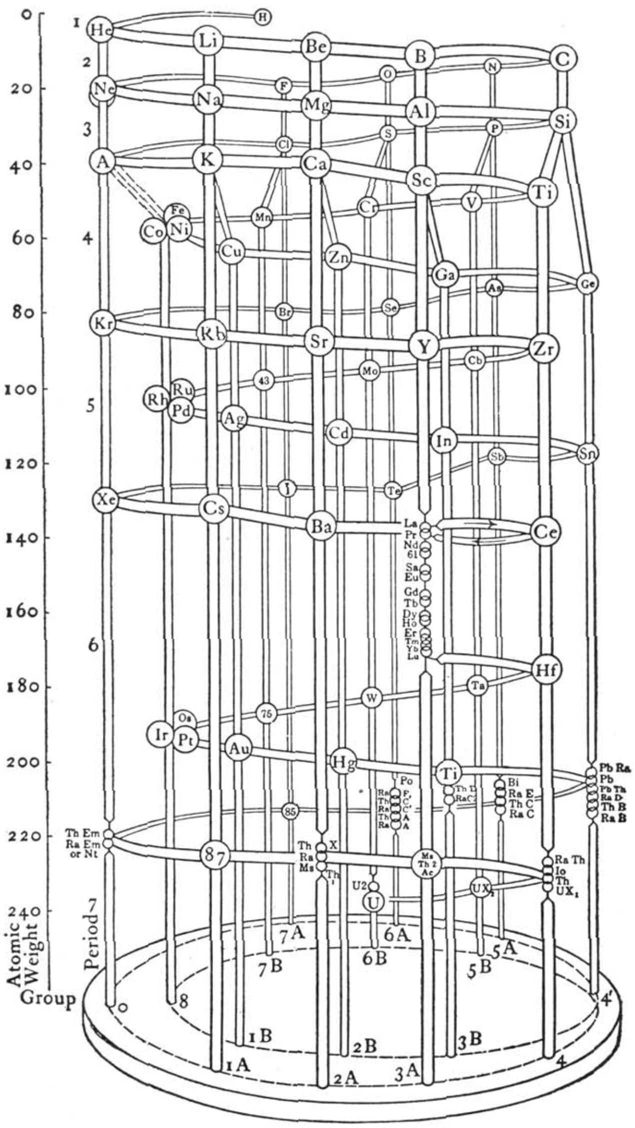


FIGURE 22.—PERIODIC TABLE BY HARKINS AND HALL

small turns in analogous positions. On the next larger turn are found the alkali, alkaline-earth, and aluminum family elements. The long periods require larger turns and the period containing the rare-earth elements requires the longest turn of all. Elements of the same group are found in the same plane passing through the axis of the spiral.

MONROE AND TURNER—1926 (*96*): The principle of this arrangement is quite similar to that of Schaltenbrand (*95*). Four sets of concentric loops are supported by 2, 6, 10, and 14 rods, respectively, from the center to the outer edge. The two central rods support the elements of the helium and alkaline-earth families, headed by H; the rods of the second loop are headed by Be, B, C, N, O, and F; rods of the third by Sc, Ti, U, Cr, Mn, Fe, Co, Ni, Cu, and Zn; and the rods of the fourth by Ce, Pr, Nd, and eleven single rare-earth elements.

STEWART—1928 (*81*): Stewart designed a three-dimensional screw-like arrangement from his flat

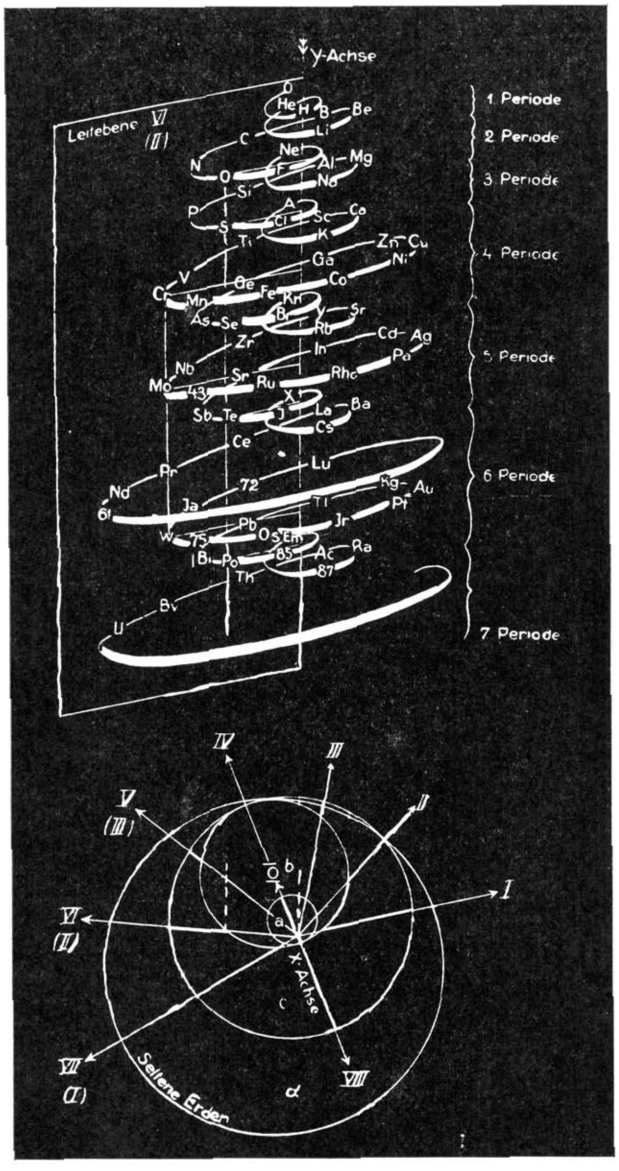


FIGURE 23.—SCHALTENBRAND'S PERIODIC TABLE

spiral, in which isotopes were represented by clusters of lead shot.

RIXON—1933 (*97*): The Rixon spiral (Figure 24) has a horizontal axis and combines in a simple graphic manner the advantages of the Thomsen table (*61*), the Soddy helix (*91*), and the Harkins cylinder (*92*). The author has attempted to develop the idea of periodicity

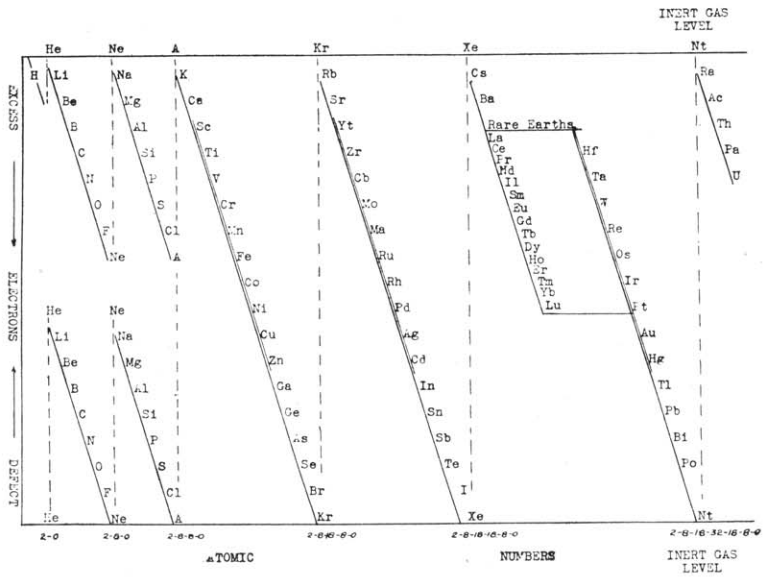


FIGURE 24.—RIXON'S DIAGRAM OF THE PERIODIC TABLE

of elements in the light of their atomic structure. The two short periods and the two long periods seem to be patterned after the Emerson helix (*89*). The great or Cs period gives the effect of a double period by an offset caused by the rare-earth elements. The attempt to place in line, parallel to the axis, elements having similar outer electronic arrangements has been quite successful. Transition elements are indicated by a thin secondary line running parallel to the spiral.

### CONCLUSIONS

The helical arrangements cited above may be reclassified into five subdivisions: the plain spirals (cylindrical and screw-like), the double cylinders (placed end to end), the figure-eight arrangement, the concentric cylinders, and the helices consisting of several sets of curves per period.

### MISCELLANEOUS (INDIVIDUAL CLASSIFICATION)

The arrangements of this division might lend themselves to classification into distinct types, but the authors are content to consider them in their chronological order. In some instances they show marks of resemblance to one or more of the preceding five types and are deserving of serious consideration; the uniqueness of some may mark the beginning of new approaches to the study of graphical arrangements based on the periodic law.

GIBBES—1875 (*98*): L. R. Gibbes developed a crude table and spiral representing most of the important principles of the periodic law. The vertical table reading from top to bottom in "series," was made into a spiral by rolling it in much the same manner as that suggested by Lothar Meyer in his "Modern Theories of Chemistry" (*13*).

SPRING—1881 (*99*): W. Spring of the University of Liége prepared the diagram (Figure 25) without accompanying notes. It was the precursor of similar tables by Reynolds (*100*) and Crookes (*101*).

REYNOLDS—1886 (*100*): Reynolds' expanding curve vibrated to either side of a central line cutting what we now know as the positions of the inert gases. Three of the ten nodal positions are held by the eighth-group elements which the author called "interperiodic bodies." The bends in the curve take place along lines equally distant from and parallel with the axis, instead of along lines approaching a common point at the top, as in Spring's diagram (*99*). Reynolds excluded Mendeléeff's twelfth series. The atomic weights are indicated on the central line, starting with zero at the bottom. The first two periods constitute the first wave; the third and fourth periods occupy one wave each; and the Cs period, almost one and one-half waves because of the long vacant line from Di to Ta.

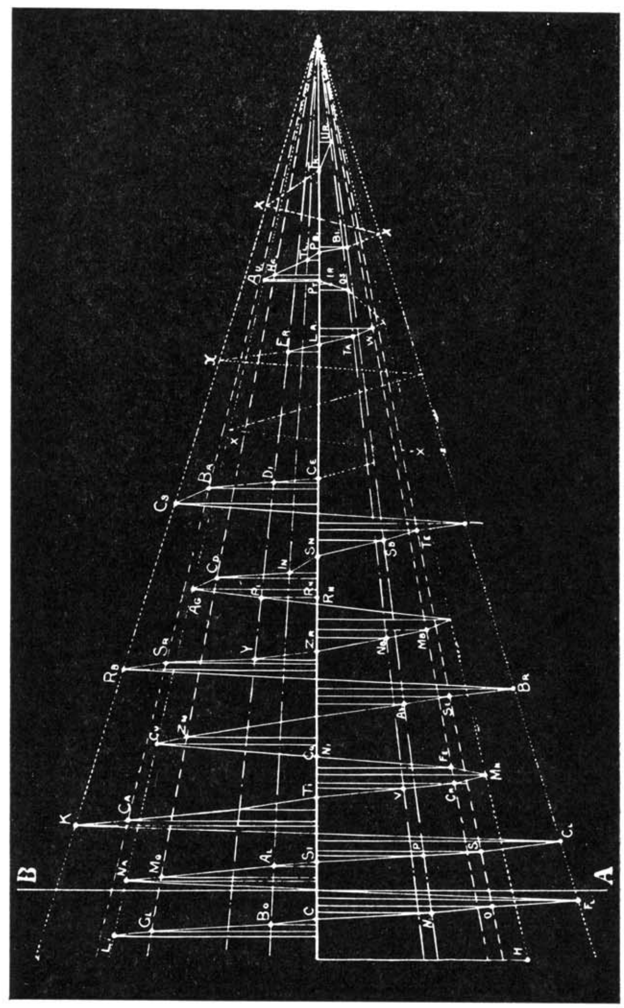


FIGURE 25.—SPRING'S DIAGRAM

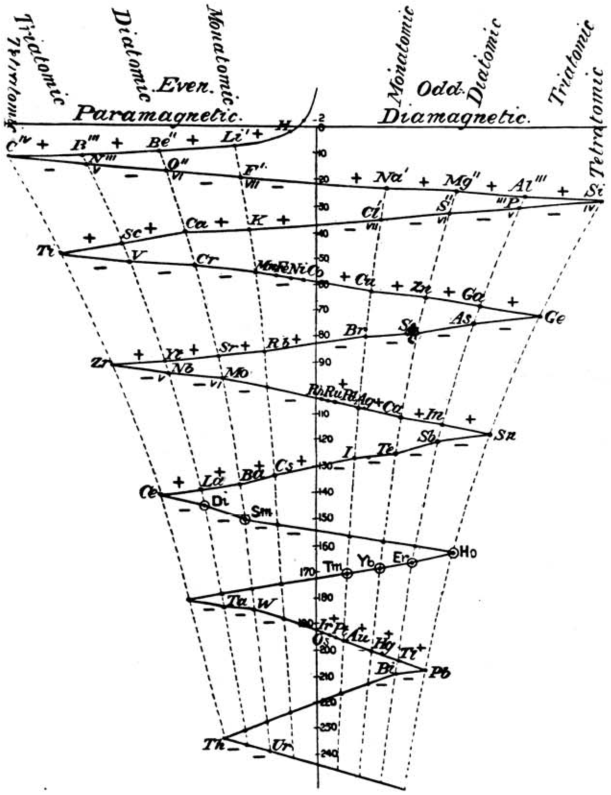


FIGURE 26.—CROOKES' PERIODIC TABLE

CROOKES—1886 (*101*): The arrangement by Crookes (Figure 26) is quite similar to the one by Reynolds (*100*), turned through ninety degrees and extended to include Th and U. H is placed between the axis and Li (Reynolds placed these elements on opposite sides of the axis), and several additional elements are shown. While Reynolds' diagram was rectangular in character, Crookes' is fan-shaped and he likened it to a pendulum swing declining in amplitude.

FLAVITZKY—1887 (*102*): Flavitzky stated that the arrangements of Bayley (*59*), von Huth (*72*), Spring (*99*), and Reynolds (*100*) could not be represented by single mathematical equations and sought to show that the periodic law must be represented by some function of tangent or cotangent. Figure 27 illustrates Flavitzky's idea in a schematic manner. The function fails with the eighth group and the lack of conformity in the higher periods he assumed to be caused by the greater complexity of the molecules of the elements.

VAN DEN BROEK—1911 (*103*): This author arranged the elements in order of increasing atomic weight in a rectangular parallelopiped, five spaces deep, three wide, and eight long. The top surface consists of three rows, He to F, Ne to Cl, and A to Mn. The next lower layer consists of Fe to Zn (three blank spaces), "blank space" to Br (three blank spaces), and Kr to Ru; the next three layers are similarly arranged. The table provides for 120 spaces. Van den Broek pointed out that spaces are provided for rare earths, radioactive elements and their decomposition products, and that Na, Cu, Ag, and Au are not placed in the same vertical column.

LORING—1915 (*104*): Loring has attempted to illustrate by means of an irregular spiral-like arrangement his theory that elements may be "possibly evolved out of whirls of energy" and are formed "when there are time breaks in the continuity of the flow of energy."

HACKH—1918 (*105*): The table (Figure 28) was derived from a spiral previously described in this paper (*82*). The upper half contains elements possessing high electropotential, simple spectra, and colorless ions, while the lower has low electropotential, complex spectra, and colored ions. On the left side are the electropositive, on the right, the electronegative, elements. The central lower half contains the amphoteric elements. Similar elements are found in the upper half in the vertical direction, while similarity is

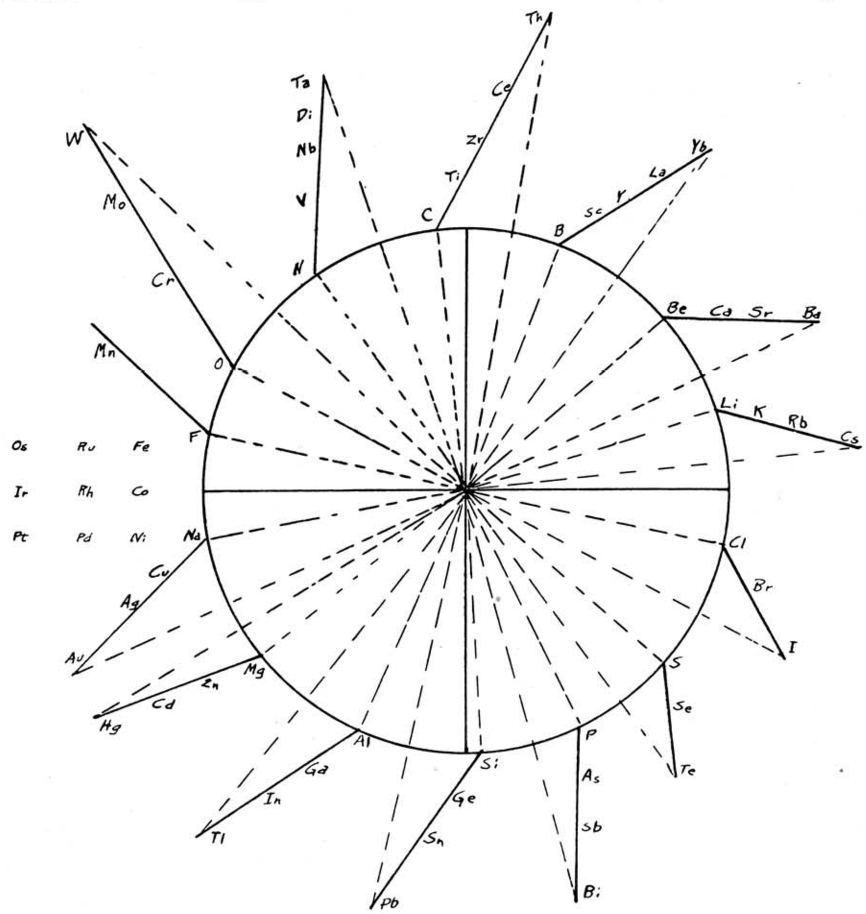


FIGURE 27.—FLAVITZKY'S ARRANGEMENT

on the horizontal, in the lower half. A modification of the table brought up to date appeared in 1929 (*106*).

| | 4 | 5A | 6A | 7A | | 0 | | 1A | 2A | 3A | 4 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Vb | Pb | Bi | Po | 85 | | Nt | | 87 | Ra | Ac | Th | VIa |
| IVb | Sn | Sb | Te | I | | Xe | | Cs | Ba | La | Ce | Va |
| IIIb | Ge | As | Se | Br | | Kr | | Rb | Sr | Y | Zr | IVa |
| IIb | Si | P | S | Cl | | Ar | | K | Ca | Sc | Ti | IIIa |
| Ib | C | N | O | F | | Ne | | Na | Mg | Al | Si | IIa |
| | | | | H | | He | | Li | Be | B | C | Ia |
| III′ | Ti | V | Cr | Mn | Fe | Co | Ni | Cu | Zn | Ga | Ge | III′ |
| IV′ | Zr | Cb | Mo | 43 | Ru | Rh | Pd | Ag | Cd | In | Sn | IV′ |
| V″ | Ce Pr Nd 61 Eu Gd Tb Dy Ho Er Ad Cp Yb Lu | | | | | | | | | | | V″ |
| V′ | La | Ta | W | 75 | Os | Ir | Pt | Au | Hg | Tl | Pb | V′ |
| VI | Th | Bv | U | | | | | | | | | |
| | 4 | 5B | 6B | 7B | | 8 | | 1B | 2B | 3B | 4 | |

FIGURE 28.—HACKH'S CLASSIFICATION OF THE ELEMENTS

FRIEND—1925 (*107*): In an attempt to include the rare earths without unduly destroying symmetry,

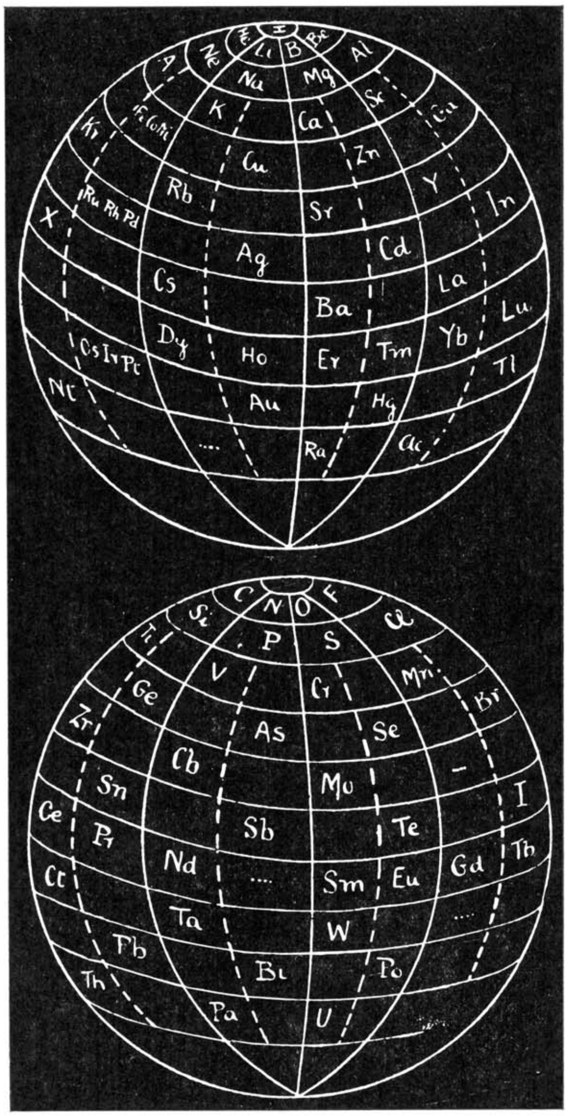

FIGURE 29.—FRIEND'S PERIODIC SYSTEM

Friend arranged the elements around the surface of a sphere (Figure 29). The periods are arranged much like those in a Mendeléeff chart. The rare-earth elements are closely packed into a belt in the lower "torrid zone." Below the equatorial belt, the elements tend to show greater instability. The order of B and Be is obviously an error in copy.

STEPHENSON—1929 (*108*): The elements are here arranged in order of their atomic numbers and the "percentage increase of atomic weight of each element over its predecessor" is calculated. Negative values for A − K, Co − Ni, and Te − I are accepted and used in the statistical series. H is left out, as it has no predecessor. When arranged in columns of six (Figure 30) some chemical relationships are shown. The author states that "each column begins and ends with related elements," and "contains two sets of triads."

| | I | II | III | IV | V | VI |
|---|---|---|---|---|---|---|
| H ⟶ | He | Li | Be | B | C | N |
| | O | F | Ne | Na | Mg | Al |
| | Si | P | S | Cl | A | K |
| | Ca | Se | Ti | V | Cr | Mn |
| | Fe | Co | Ni | Cu | Zn | Ga |
| | Ge | As | Se | Br | Kr | Rb |
| | Sr | Yt | Zr | Nb | Mo | (43) |
| | Ru | Rh | Pd | Ag | Cd | In |
| | Sn | Sb | Te | I | Xe | Cs |
| | Ba | La | Ce | Pr | Nd | (61) |
| | Sm | Eu | Gd | Tb | Dy | Ho |
| | Er | Tm | Yb | Lu | Hf | Ta |
| | W | (75) | Os | Ir | Pt | Au |
| | Hg | Tl | Pb | Bi | (84) | (85) |
| | Rn | (87) | Ra | (89) | Th | (91) ⟶ U |

FIGURE 30.—STEPHENSON'S STATISTICAL PERIODIC TABLE

## CONCLUSIONS

The contributions by Gibbes, Spring, Reynolds, and Crookes, cited in this section may be considered the forerunners of the modern helical arrangements. The other tables included seem to hold unique places among systems of classification and apparently have not been subjected to numerous modifications as is true of the tables by Bayley, Thomsen, Werner, and others which have appeared in textbooks in grossly modified forms without being so designated.

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