TYPES *of* GRAPHIC CLASSIFICATIONS *of the* ELEMENTS

II. Long Charts

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LONG CHARTS (WERNER TYPE)

THE CHARTS of this division are essentially those in which short charts have been elongated in such manner that the elements of each period are arranged in single series.

MENDELÉEFF—1869 (*36*): Mendeléeff's first table was a vertical arrangement in which the elements could be read in order of increasing atomic weight from the top down and in successive series from left to right. The first column consisted of H and Li; the second, of Be to Na; the third started with Mg. An improved form of this table appeared in 1872 (*37*) (Figure 5).

			K	Rb	Cs	...	...
			Ca	Sr	Ba	...	...
			...	? Yt	? Di	Er	...
			Ti	Zr	Ce	? La	Th
			V	Nb	...	Ta	...
			Cr	Mo	...	W	U
			Mn	...	...	...	...
Typical Elements			Fe	Ru	...	Os	...
			Co	Rh	...	Ir	...
			Ni	Pd	...	Pt	...
H	Li	Na	Cu	Ag	...	Au	...
	Be	Mg	Zn	Cd	...	Hg	...
	B	Al	...	In	...	Tl	...
	C	Si	...	Sn	...	Pb	...
	N	P	As	Sb	...	Bi	...
	O	S	Se	Te	...	...	...
	F	Cl	Br	J	...	...	...

FIGURE 5.—MENDELÉEFF'S VERTICAL TABLE

H occupied the first position separately; the vertical series in order were Li to F, Na to Cl, K to Br, etc., causing the halogens to appear in the same bottom series, while H, Li, Na, Cu, Ag, and Au constituted a midway series, and K, Rb, and Cs formed the topmost series.

WALKER—1891 (*38*): Walker's is similar to the Mendeléeff vertical table (*37*). He pointed to the objection to placing Li and Na in line with Cu, Ag, and Au, and to the unique position of the non-metals in the lower left triangular area. His use of the terms "odd and even series" seems reminiscent of the "short chart" type.

BASSETT—1892 (*39*): This table (Figure 6) also resembles Mendeléeff's later vertical arrangement (*37*). The Cs period, however, starts far above the horizontal line of K and Rb, thereby giving space to the known and predicted elements of that period. The alkali metals appear in three horizontal lines. Co and Ni are arranged in order of their atomic weights. Bassett suggested cutting out the table and rolling it onto a cylinder of such circumference that similar elements would fall in line, forming what are now known as groups and families. For instance, Li, Na, K, Rb, and Cs would then fall on a line parallel to the axis of the cylinder.

				Cs	?
				Ba	?
				La	?
				Ce	Th
				Nd	?
				Pd	U
				?	?
				Sm	?
				?	?
				?	?
				?	?
				?	?
				Tb	?
				Ho	?
				?	?
				Er	?
				?	?
				Tm	
				?	
				Yb	
		K	Rb	?	
		Ca	Sr	?	
		Sc	Y	?	
		Ti	Zr	?	
		V	Nb	Ta	
		Cr	Mo	W	
		Mn	?	?	
		Fe	Ru	Os	
		Ni	Rh	Ir	
		Co	Pd	Pt	
Li	Na	Cu	Ag	Au	
Be	Mg	Zn	Cd	Hg	
B	Al	Ga	In	Tl	
C	Si	Ge	Sn	Pb	
N	P	As	Sb	Bi	
O	S	Se	Te	?	
F	Cl	Br	I	?	

FIGURE 6.—VERTICAL ARRANGEMENT BY BASSETT

RANG—1893 (*40*): The table (Figure 7) is arranged so that closely related elements are in the same vertical row. The four groups, A, B, C, D, classify elements of common properties; "A" contains the most electropositive elements, "D" the most electronegative. The position of H over Ga, In, and Tl is most unusual.

Valence	I	II	III	IV	V	VI	VII	VIII			I	II	III	IV	V	VI	VII
Series																	
1	"	"	"	"	"	"	"	"	"	"	"	"	H	"	"	"	"
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	Ni	Co	Cu	Zn	Ga	Ge	As	Se	Br
5	Rb	Sr	Y	Zr	Nb	Mo	"	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I
6	Cs	Ba	Di	"	Ta	W	"	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	"	"
7	"	Ms	"	Th	"	U	"	"	"	"	"	"	"	"	"	"	"
Group	1	2	3				4						5			6	7
		A					B						C			D	

"Di here represents all the triads that are between Ba and Ta. H may not be exactly in its true place, still it cannot be very far from it."

FIGURE 7.—RANG'S PERIODIC TABLE

The order of Co and Ni is the same as in the Bassett table (*39*).

HORSLEY—1900 (*41*): Horsley's chart appears in Rudorf's book (*41*) as one of four modifications of Mendeléeff's arrangement (*37*). This horizontal chart shows the usual families, including the zero group elements, which occupy the central position. The elements read from left to right, beginning with He and Li as the first series; Be to Na (Na under Li), as the second; Mg to Co (K under Na), third; Cu to Pd (Zn under Mg), fourth; Ag to Pt, etc. Horsley's chart appears to be the forerunner of the types in which the helium family occupies a central position adjacent to the halogen family on the left and the alkali family on the right.

STAIGMÜLLER—1901 (*42*): In this chart the arrangement by Rang (*40*) is modified to include the He family before the alkali metals. H is placed to the left of He, thus being the first member of the first period. Ru and Os appear in their respective periods under Mn, Rh and Ir under Fe, Pd and Pt under Ni, Au under Co, and Hg under Ag. The Cs period consists of two series, but the rare-earth elements receive little consideration. The author called attention to the location of the non-metals in an upper right enclosure, as did Walker (*38*).

WERNER—1905 (*43*): Werner avoided periods of two or more series by allowing the Cs period to determine the width of the table (Figure 8). Among the irregularities in order of atomic weights, he cited the case of Nd and Pr which are no longer so placed. The "inert elements" complete each period, and the distribution is made to show family relationships. Be and Mg are definitely classed with Zn and Cd.

SCHMIDT—1911 (*44*): Schmidt attempted to show by means of his table that elements form systems and sub-systems which stand in genetic relation to each other. In form it appears to be a modification of the charts of Staigmüller (*42*) and Werner (*43*), divided into several vertical areas consisting of from one to four families. A table similar to that of Schmidt would result if Staigmüller's chart were cut on a line between the N and Ge families, and the right segment fitted to the left, causing the elements to join in the usual order of atomic weight increase. This arrangement opened between the columns consisting of C-Si-Ti-Zr-Ce-Th and V-Nb-Ta, respectively, to allow space for the Werner rare-earth series, completes a Schmidt arrangement. Schmidt placed Pr before Nd, but did not leave spaces for missing rare-earth elements. The positions of the "eighth group" elements correspond to Werner's arrangement.

STACKELBERG—1911 (*45*): Stackelberg's first table is patterned after Staigmüller's (*42*) with slight modifications. H is placed in the Li family instead of in the Li period. C and Si are transferred to the right, over Ge. The "zero group" elements appear at the right edge as well as at the left in the table. The

...																														...	...
H																														...	He
Li																									Be	B	C	N	O	F	Ne
Na																									Mg	Al	Si	P	S	Cl	A
K	Ca															Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr															Y	Zr	Nb	Mo	...	Ru	Rh	Pd	Ag	Cd	Jn	Sn	Sb	Te	J	Xn
Cs	Ba	La	Ce	Nd	Pr	...	...	Sa	Eu	Gd	Tb	Ho	Er	Tu	Y	...	...	Ta	W	...	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	...	...	...
...	Ra	Laα	Th	...	...	...	...	...	U	...	...	...	...	Ac	...	...	...	...	...	...	...	...	...	...	...	...	Pbα	Biα	Teα	...	...

FIGURE 8.—WERNER'S PERIODIC TABLE

"platinum elements," Au and Hg, are restored to their logical places in the arrangement, as shown by Werner (*43*) and Schmidt (*44*), but the order of Ni and Co is according to their atomic weights. A second table was designed by cutting the first on a line between Co and Cu and fitting the segments together, causing the "zero group" elements to assume the central position as in the Horsley chart (*41*). The author described the formation of a cylindrical chart from the second arrangement, as an additional aid in the study of relationships between elements.

CÁCERES—1911 (*46*): The author claimed that his vertical table was not essentially different from Werner's (*43*). By starting the first period with H and He, he reduced the number of periods to six. Unlike Werner, he placed Be and Mg in line with the alkaline-earth elements, and made the Cs period of the same length as the K and Rb series by arranging that portion containing the rare-earth elements in four series, two descending and two ascending. Although the author regarded this irregular arrangement as an aid in classification, it is rather unusual to find Sm in the Mn family, and Nd, Eu, and Tm in the Cr family.

MEYER—1918 (*47*): The second of the author's two tables is a modification of the first, a Bayley type. Meyer's table differs from Schmidt's (*44*) in that Ni, Pd, and Pt constitute the right ends of their respective periods. The rare earths are arranged in order of increasing atomic number after Ba, and H is placed above Li, thereby occupying a central position. Valence numbers are placed at the tops of the groups, which are numbered at the bottom with Roman numerals.

CHAUVIERRE—1919 (*48*): Chauvierre's table probably resembles Stackelberg's (*45*) in form more than any other long chart of the "Werner Type." The first two periods are divided on a line between Gl and B; the "zero group" elements appear on the left side only; the additional rare-earth elements are extended across the table, causing Tb to appear in the Al family, "Tu" in the C family, and Yb in the P family. The middle section of the table is arranged to show the "famille du fer," which includes V and Cr also, the "famille du palladium," which includes Nb and Mo also, the "famille du didyme" (Pr and Sm), the "famille du platine," and the "metaux radioactifs" (Th and U). Seventeen empty spaces are shown representing places for missing elements, including one noble gas, but the chart as printed shows Cu and Hg in positions apparently not meant for them by the author, which may account for the excessive number of blank spaces.

STEINMETZ—1918 (*49*): The chart is a modification of the one by Staigmüller (*42*) in which H is placed over F, Co precedes Ni, many elements are added, and the "platinum metals" are treated in a more orderly manner.

PFEIFFER—1920 (*50*): Pfeiffer shortened the Werner chart (*43*) by indicating the position of the rare-earth elements following Ce and placing them below the last period in a single line.

ODDO—1920 (*51*): Oddo's arrangement appears to be a modification of Staigmüller's (*42*). H is placed over Li and the non-metals of the Staigmüller table are transferred as a unit to the left side, thus allowing the two major headings, "Metalloidi" and "Metalli." The rare earths are arranged in two series which, with Sc and Yt, are enclosed by a dotted line. An attempt has been made to place the isotopic forms of the radioactive elements. In a revision (*52*), Oddo placed Sb with the non-metals and B with the metals, and elaborated his treatment of the radioactive elements.

BURY—1921 (*53*): Bury's is a Werner table (*43*) brought up to date in connection with an extensive treatment of the atomic structure of the elements. The structures of the so-called transition elements and the rare earths are given especially detailed consideration.

NORRISH—1922 (*54*): This table, patterned after Stackelberg's arrangement (*45*), is derived from a consideration of colored ions, valency, and atomic structure. Many physical data are presented below each symbol.

LORING—1922 (*55*): The author claimed that his "Wedge Periodic Table" indicated where missing elements were of low concentration, if existent at all. In design, it appears to be a mirror image of a Bassett table (*39*) in which the periods are moved to place the alkali elements in line, rather than the halogens. The "zero group" and many other new elements are included. The sketch is designed to justify the unique title.

COURTINES—1925 (*56*): The unfolded tower arrangement (Figure 9) appears much like a modernized Chauvierre chart (*48*) cut on a line between Ni and Cu, with the right part fitted to the left in order of increasing atomic numbers. The rare-earth elements, however, are placed on a novel accordion-like folded strip with ends made secure just below Yt and between Ba and Hf. The author describes in detail the method of folding the chart into a tower-like cylindrical model. H is folded back to show its lack of relationship to other groups of elements. In the space for each symbol, electron arrangements and isotopes are also enumerated.

RODEBUSH—1925 (*57*): Rodebush has taken the Rang arrangement (*40*) and brought it up-to-date from the standpoint of Bohr's conception of the grouping of electron orbits, which are indicated by the shell structure of the inert gases at the end of each period. H is placed above F, and the list of rare-earth elements is shown occupying a position following La and preceding Hf.

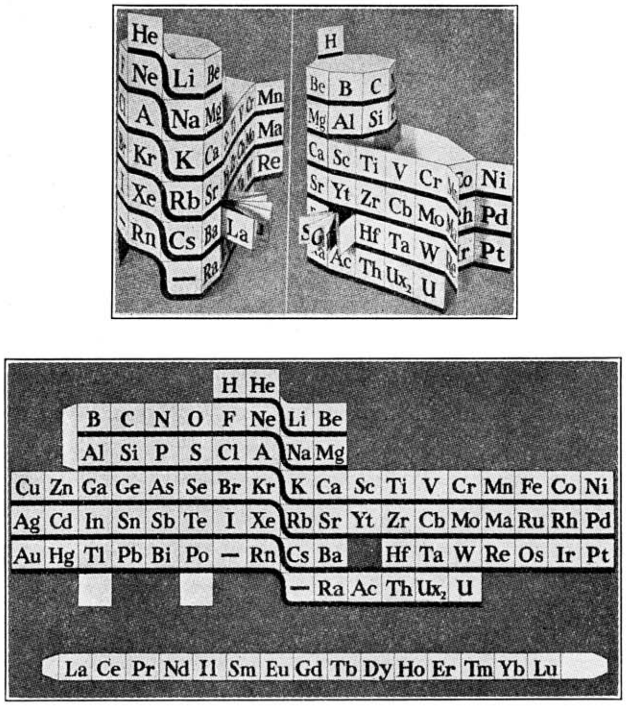

FIGURE 9.—COURTINES' PERIODIC CLASSIFICATION

LEROY—1931 (*58*): Although LeRoy referred to his chart as being a modification of Deming's periodic table (*69*), it seems more reasonable to consider it a modification of Werner's table (*43*). To construct a chart similar to LeRoy's, move Sc and Y of Werner's table (Figure 8) to a position above La, cut the table on a vertical line to the left of Ti and join the outside edges, draw a line from H to both Li and F and add the new elements not listed in Figure 8. The positions of Pa and U in LeRoy's chart were dictated by geometric form, apparently, rather than chemical relationships.

CONCLUSIONS

The majority of the charts of this division are arranged, like Werner's, with the most electropositive elements at one edge, and the most electronegative at the other. The arrangements of Schmidt, Meyer, Oddo, Courtines, and LeRoy appear to be efforts to bring the most active elements to a central position. With the exception of Schmidt's table, the "inert elements" divide the electronegative from the electropositive elements. The charts of Mendeléeff, Walker, Bassett and Loring fail to show the family relationships consistently because of their insistence on unbroken short periods. That there is great difference of opinion as to where the intermediate elements of the short periods should be placed is very apparent. The division between C and N is favored by Rang, Staigmüller, Schmidt, Meyer, Steinmetz, and Rodebush; between B and C, by Stackelberg and Norrish; between Be and B, by Cáceres, Chauvierre, Oddo, and Courtines; and between Li and Be, by Werner, Pfeiffer, Bury, and LeRoy. The placing of the rare-earth elements has also been treated in a diversified manner.

LONG CHARTS (BAYLEY TYPE)

The arrangements in this division include those long charts which show the relationships within the short-chart groups without destroying the advantage of simplicity of the Werner type. By solid and dotted lines and shading, the authors have attempted to show family distinctions.

BAYLEY—1882 (*59*): The elements are arranged (Figure 10) in order of increasing atomic weight, and divided into cycles and series. Bayley observed the recurrence of the same groups of properties in sets of seven and emphasized, graphically, family relationships.

CARNELLEY—1886 (*60*): Carnelley's diagram is similar to Bayley's table (*59*). The Cs period is kept in line with those of K and Rb by dividing it into two series.

THOMSEN—1895 (*61*): This table, similar to Bayley's (*59*), was arranged to show genetic relationships of elements. The elements of the five periods of one series each, are arranged from electropositive to electronegative. H forms the head of the table, while the remaining elements are divided into two periods of 7 elements each, two of 17 each, and one of 31. Al-

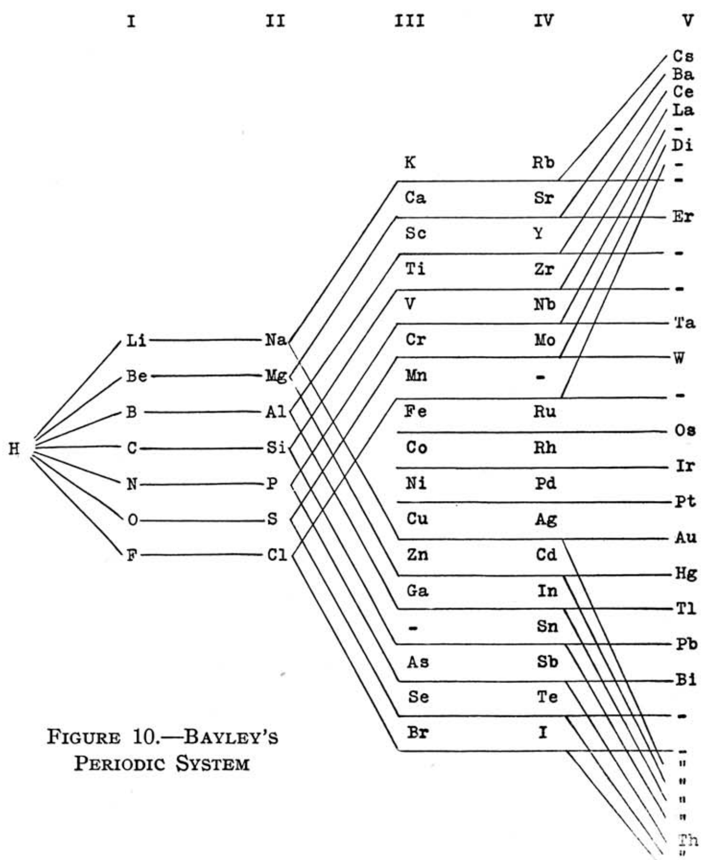

FIGURE 10.—BAYLEY'S PERIODIC SYSTEM

though the rare-earth elements are listed in the Cs period, the family relationships are maintained by connecting lines. Numerous modifications of Thomsen's table have appeared from time to time, notable among which should be mentioned the Thomsen-Bohr Table (*62*).

RICHARDS—1898 (*63*): Richards stated that his table was a modified form of the Thomsen arrangement (*61*). His modification appears to be a Thomsen chart in which the last period is arranged in a manner similar to Carnelley's plan (*60*). Many blank spaces are introduced and the author listed as unclassified He, A, Pr, Ne, Sa, Gd, Tb, Er, Th, and Yt.

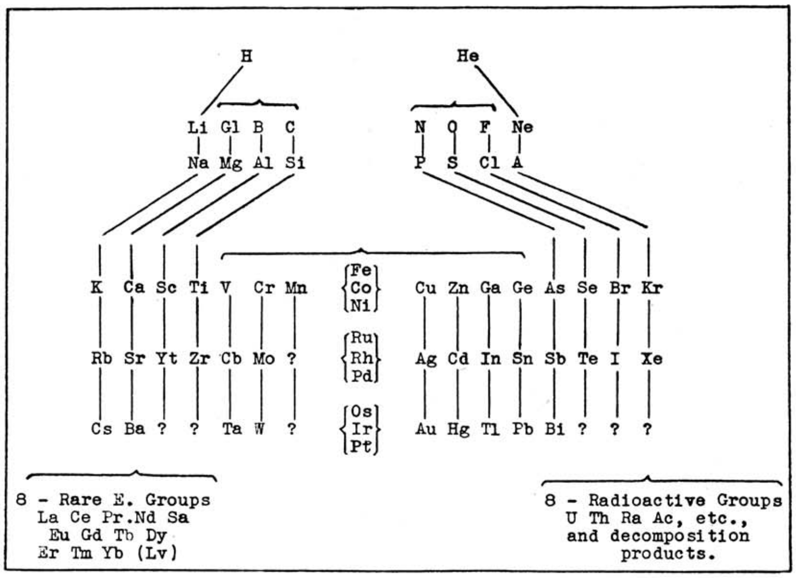

FIGURE 11.—ADAMS' PERIODIC TABLE

ADAMS—1911 (*64*): The table (Figure 11) is virtually a mirror image of Thomsen's chart (*61*), arranged in a horizontal position. He with H brings the number of periods up to six. The rare-earth elements are arranged in a compact group following Ba, thereby reducing the length of the Cs period. Adams attempted to remedy what he considered the principal defect of the Mendeléeff table (*11*), namely, the placing of dissimilar elements in the same family.

HOPKINS—1911 (*65*): In describing his arrangement, Hopkins stated "that Richards' table (*63*) is in all essentials identical with the one now proposed." Hopkins' chart, however, is a mirror image of Richards' chart, turned through ninety degrees in the clockwise direction, omitting H and He, and placing the "zero group" elements, Ne to Xe, on the right side. Ra and several rare-earth elements are added. In place of showing the family relationships by lines as proposed by Carnelley (*60*) and Richards, Hopkins has attempted to show by figures at the heads of the columns, approximate specific gravities and position numbers; the latter are considered the fundamental properties of elements.

MEYER—1918 (*47*): The form of the first of two tables is practically identical with the Adams' chart (*64*). The "Mendeléeff" group numbers are used to identify the columns of both short and long periods. The Cs period is completed with U, but the rare-earth elements are indicated between Ba and Ta, and are enumerated in a horizontal row at the bottom of the table.

SCHALTENBRAND—1921 (*66*): This skeleton arrangement which appears like an expanding family tree, is an attempt to show the derivation of the periods of elements by an "extension" of the first, H-He, period. In the second period, Li, C, F, and He, only, are enumerated. The expansion for the rare earths appears to be in anticipation of Antropoff's arrangement (*68*) and Bohr's modification of Thomsen's chart (*62*).

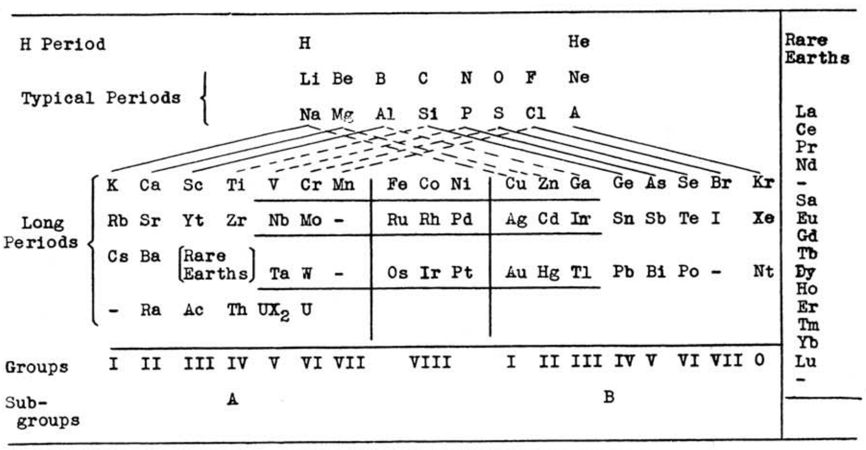

FIGURE 12.—MARGARY'S PERIODIC TABLE

MARGARY—1921 (*67*): Margary's table (Figure 12) was designed to show each period in an orderly complete form and all family relationships of the short-type chart. The "subgroups" are clearly indicated and the rare-earth elements are placed between Ba and Ta by giving the inclusive atomic numbers and enumerating the elements at the right side of the chart in a vertical column.

ANTROPOFF—1926 (*68*): Antropoff's chart in its final form is virtually a Margary table (*67*) in which the elements of the short periods are given enough

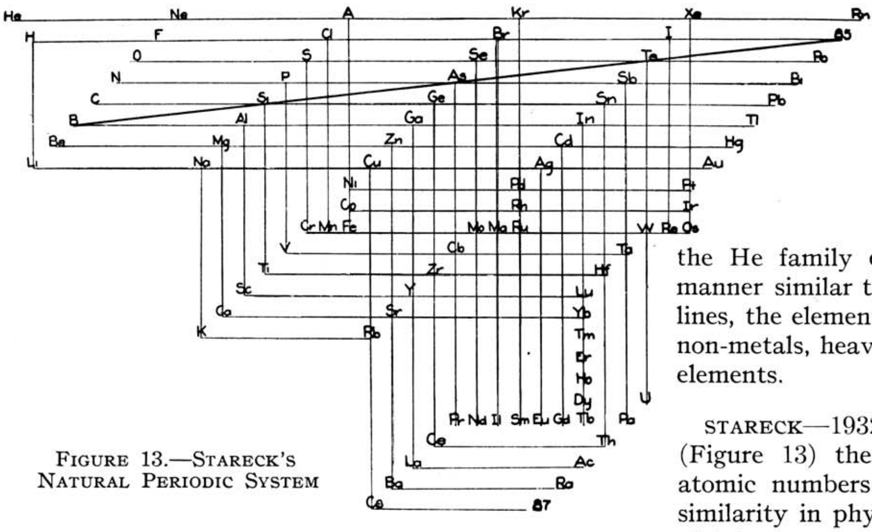

FIGURE 13.—STARECK'S NATURAL PERIODIC SYSTEM

horizontal space to extend them in line with the long periods. In place of using lines, the columns are variously shaded. The He family appears at both sides of the chart, while in a central position above C, H appears as the element from which all others are derived. The rare-earth elements are enumerated in a horizontal arrangement at the lower edge instead of at the right side, as in Margary's table.

DEMING—1927 (*69*): In its general make-up, Deming's chart embodies many of the good features of the charts of Norrish (*54*), Margary (*67*), Antropoff (*68*), Rodebush (*57*), and others. It appears to be a Norrish chart with the He family on the left side only; the relation of the short periods to the long periods is shown by lines much as in the Margary table; the rare-earth elements are treated as in the latter's table, except that the vertical column is replaced by a rectangular area in the lower central part; H is given an important central position as in Antropoff's arrangement. The electron orbits of the He family elements are effectively shown in a manner similar to that of Rodebush. By heavy black lines, the elements are clearly classified as inert gases, non-metals, heavy metals, light metals, and rare-earth elements.

STARECK—1932 (*70*): In Stareck's periodic table (Figure 13) the elements are grouped according to atomic numbers and arranged to indicate degree of similarity in physical properties. The non-metals are plainly segregated. The straight horizontal and zigzag lines show relationships of groups and families. The rare-earth elements fit into a large V-shaped arrangement. The typical eighth-group elements develop a similar, but smaller, arrangement.

CONCLUSIONS

In the early tables of the "Bayley Type," the relationships of the subgroups were not indicated; the charts of Margary, Antropoff, and Deming, however, suggest the relations of families within a "Mendeleéff group" by full and broken lines, or by shaded areas. The rare-earth elements have received varied treatment.

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