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

I. Introduction and Short Tables

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A bibliography of periodic tables, beginning with the work of Mendeléeff and Meyer, is presented. The tables are classified into five definite types and each type is treated chronologically with illustrations and descriptions.

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INTRODUCTION

THE average student of chemistry does not obtain a comprehensive view of the various systems of classification of the elements from his reading of textbooks and books of reference. Even a perusal of the literature may not result in an orderly picture of the developments of types of classifications. Since the publication of the excellent treatise on the periodic law by Venable (*1*) a number of books (*2*, *3*, *4*, *5*, *6*, *7*, *8*) with similar titles have appeared. Among textbooks, the one by Caven and Lander (*9*) no doubt is still unique in its thorough treatment of "Systematic Inorganic Chemistry from the Standpoint of the Periodic Law."

The authors of this paper do not pretend to supply a need for an up-to-date comprehensive treatment; they believe, however, that the classification of systems as to type is unique and will prove to be a means to a better understanding of systems of classification of the elements. No claim is made that such a classification is the only, or even the best method of approach. The attempts to classify the elements up to the time of the pronouncement of the periodic law seem to lend themselves readily only to the chronological treatment.

Every text or reference book devoting one or more chapters to the classification of elements makes the student familiar with the notable contributions of Dalton (Table of Atomic Weights—1803), Prout (Hypothesis—1815), Döbereiner (Triads—1829), and Newland (Law of Octaves—1865). Among the less familiar may be mentioned Cooke for his unique table of classification (1854); Odling for his extension of the work on triads resulting in a "Natural Grouping of the Elements" (1857); Williamson for a "Classification of the Elements in Relation to their Atomicities" (1864), which made application of the excellent contribution by

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Series.	Group I R_2O	Group II. RO	Group III. R_2O_3.	Group IV. RH_4. RO_2.	Group V. RH_3. R_2O_5.	Group VI. RH_2. RO_3.	Group VII. RH. R_2O_7.	Group VIII. RO_4.
1	H=1							
2	Li=7	Be=9.4	B=11	C=12	N=14	O=16	F=19	
3	Na=23	Mg=24	Al=27.3	Si=28	P=31	S=32	Cl=35.5	
4	K=39	Ca=40	—=44	Ti=48	V=51	Cr=52	Mn=55	Fe=56, Co=59 Ni=59, Cu=63
5	(Cu=63)	Zn=65	—=68	—=72	As=75	Se=78	Br=80	
6	Rb=85	Sr=87	? Y=88	Zr=90	Nb=94	Mo=96	—=100	Ru=104, Rh=104 Pd=106, Ag=108
7	(Ag=108)	Cd=112	In=113	Sn=118	Sb=122	Te=125	I=127	
8	Cs=133	Ba=137	? Di=138	? Ce=140	....	....	....	....
9	....	....	....	....	....	....	....	....
10	....	....	? Er=178	? La=180	Ta=182	W=184	....	Os=195, Ir=197 Pt=198, Au=199
11	(Au=199)	Hg=200	Tl=204	Pb=207	Bi=208	....	....	
12	....	....	....	Th=231	....	U=240	....	....

FIGURE 1.—MENDELÉEFF'S TABLE

Cannizzaro; and lastly, Hinrichs, whose "Chart of the Elements" (1867) may very well be considered the first of the spiral systems of classification in much the same way that we think of the telluric screw of de Chancourtois as the first of the helical systems. Although Hinrichs was a devoted proponent of the Proutian hypothesis and a vigorous critic of the periodic law, he concluded his "Programm der Atomechanik, oder die Chemie eine Mechanik der Panatome" (*10*) with the remarkable statement, "The properties of the chemical elements are functions of their atomic weights."

CLASSIFICATIONS BASED ON THE PERIODIC LAW

Since the announcement of the periodic law by Mendeléeff (1869), a larger and more varied array of systems of classification has appeared. Each new effort has arisen from the author's attempt to overcome objectionable features of systems then in the literature, and to produce a more useful instrument. The average student of chemistry cannot hope to acquire a mental picture of each individual system in its chronological order, but through an orderly arrangement of types, a fairly comprehensive view can be obtained. It was with the hope of attaining this latter objective that the authors entered upon this study. Through the study of books, articles, and photostatic copies or tracings of the various types of classifications, five or six distinct types of systems, based on graphic arrangement primarily, have been discovered. Only those systems for which copies of tables could be obtained are included in the bibliography. Each type of classification is indicated by naming one notable example; thus, I, Short Chart (Mendeléeff type); II, Long Chart (Werner type); III, Long Chart (Bayley type); IV, Spiral Arrangement (Baumhauer type); V, Helical Arrangement (Harkins type); VI, Miscellaneous (distinctly individual classifications).

I. SHORT CHARTS (MENDELÉEFF TYPE)

Although short charts had been presented at earlier dates, those of Mendeléeff and Meyer are the first systematic classifications based on the periodic law. Charts of this division are all arranged in columns (groups), not to exceed nine, and the long periods consist of two or more series.

MENDELÉEFF—1872 (*11*): His first scheme, 1869, commonly called the vertical table, can best be classified with the long charts. The chart announced in 1872 (Figure 1) is the model commonly associated with the name of the great Russian chemist. The boldness and success of his classic work in prophesying the properties of missing elements are familiar to every student of chemistry.

MEYER—1870 (*12*): Although vertical, Meyer's table, produced independently and practically simultaneously, bears a marked resemblance to the horizontal short table of Mendeléeff. A mirror image of the latter's table, cut between the second and third groups, and the left strip placed along the right edge, would make a fairly accurate reproduction of Meyer's table. In his "Modern Theories of Chemistry" (*13*) he produced a much improved table of the "Mendeléeff type," and suggested the possibility of rolling it on a vertical cylinder in such a way that Ni is joined to Cu, Pd to Ag, and Pt to Au, thus showing the continuity of a spiral. His atomic volumes curve, which demonstrates graphically the periodic law, is, however, the contribution with which we associate the name of Lothar Meyer most generally.

GRETSCHEL and BORNEMANN—1883 (*14*): An arrangement based on the horizontal tables by Meyer and Mendeléeff is described. Cu, Ag, and Au are not listed in group VIII. The groups are called families, and the subgroups are listed as groups "A" and "B." The eighth group elements are all listed in "group B." The few rare-earth elements then known are consolidated in their "family III, group A."

DEELEY—1893 (*15*): This author claimed to have arranged the elements more in accord with their properties than preceding investigators had done. There are nine columns or groups. The Li and Na periods read from right to left; Na, however, is shifted to the left end of its period. All other periods read from left to right, and then right to left, ending with the halogens in the third column from the left side. The so-called alkali, alkaline earth, halogen, sulfur, phosphorus, carbon, aluminum, magnesium, and copper (headed by Li) families appear in order from left to right. Fe, Ru, and Os form family A in the seventh column; Mn, Rh, Ir, in the eighth; and Ni, Co, Pd, Pt, in the ninth (each in order of atomic weight in its respective series).

VENABLE—1895 (*16*): Venable suggested that "the idea of periodicity be subordinated at least until it can be fully proved" (*1*). The table presented is similar to the Mendeléeff short table except that Cu, Ag, and Au are definitely placed in group I. The seven "bridge elements" of the first period, are centered at the top of each column, and directly under them are placed those of the second period, "typical elements." The elements of each long period are in one series, thus those in the two families of the same period are on the same horizontal line and form a double column at each side of the "bridge" and "typical" elements. Venable observed that "from the typical element of each group diverge two subgroups, generally triads" (*1*). The emphasis appears to be placed on the regularity of increments in atomic weights and properties.

Reihe	Gruppe 0	Gruppe I	Gruppe II	Gruppe III	Gruppe IV	Gruppe V	Gruppe VI	Gruppe VII	Gruppe VIII
	—	—	—	—	RH_4	RH_3	RH_2	RH	—
	R	R_2O	RO	R_2O_3	RO_2	R_2O_5	RO_3	R_2O_7	RO_4
1		1 H							
2	He 4	Li 7	Be 9	B 11	C 12	N 14	O 16	F 19	
3	20 Ne	23 Na	24 Mg	27 Al	28 Si	31 P	32 S	35.5 Cl	
4	A 40	K 39	Ca 40	Sc 44	Ti 48	V 51	Cr 52	Mn 55	Fe 56 Co 59 Ni 59 Cu 63
5		63 Cu	65 Zn	70 Ga	72 Ge	75 As	79 Se	80 Br	
6	Kr 82	Rb 85	Sr 87	Y 89	Zr 90	Nb 94	Mo 96	– 100	Ru 102 Rh 103 Pd 106 Ag 108
7		108 Ag	112 Cd	114 In	119 Sn	120 Sb	128 Te	127 J	
8	Xe 128	Cs 133	Ba 137	La 139	Ce 140 Pr 141 Nd 144 – 145				
					– 147 Sm 148 Eu 151 – 152				
					– 155 Gd 156 – 159 – 160				
					Tb 163 Ho 165 Er 166 – 167				
					Tm 171 Yb 173 – 176				
					– 178	Ta 182	W 184	– 190	Os 191 Ir 193 Pt 195 Au 197
9		197 Au	200 Hg	204 Tl	207 Pb	209 Bi	212 –	214 –	
10	– 218	– 220	Rd 225?	– 230	Th 233	– 235	U 239		

FIGURE 2.—BRAUNER'S TABLE

ARMSTRONG—1902 (*17*): This table consists of sixteen columns, and the elements are arranged in series from left to right beginning with H in the first column and first series, and ending with U in the sixteenth column and last series. Each element is given a whole number regardless of its exact atomic weight. The author regarded argon and similar elements as polyatomic, like nitrogen. Since the elements of the argon family are considered diatomic, their positions are unusual. The first complete horizontal series is: 1 H, 2 He, 3, 4, 5, 6, 7 Li, 8, 9 Be, 10 Ne, 11 B, 12 C, 13, 14 N, 15, 16 O. The "dominant principle on which the arrangement is based is that of maintaining elements which belong to the same family in the appropriate column."

BRAUNER—1902 (*18*): This table (Figure 2) is practically identical with the Mendeléeff short table, except that new elements, atomic numbers, group zero, and more exact atomic weights are introduced. Through a thorough study of the rare-earth elements, Brauner concluded that all should be placed in a miniature table following La and preceding the space now occupied by Hf.

BILTZ—1902 (*19*): To simplify the classification, the author eliminated the eighth group and the detailed list of rare earths, and represented each of these aggregations of elements by the symbol of a representative preceded by a summation sign. The eighth group elements are indicated as family A of group VII.

ZENGHELIS—1906 (*20*): This attempt to improve the table resembles that of Biltz, except that Zenghelis gave in brackets the complete list of elements in place of abbreviating with a summation sign.

BAUER—1911 (*21*): The eighth group is reinstated, giving place to the groups of elements consolidated in the seventh group by Biltz and Zenghelis. Bauer separated the complete table on a line between the fourth and fifth groups, permitting a rectangular space between Sn and Ce on the left, and Sb and Ta on the right for the remainder of the rare-earth elements.

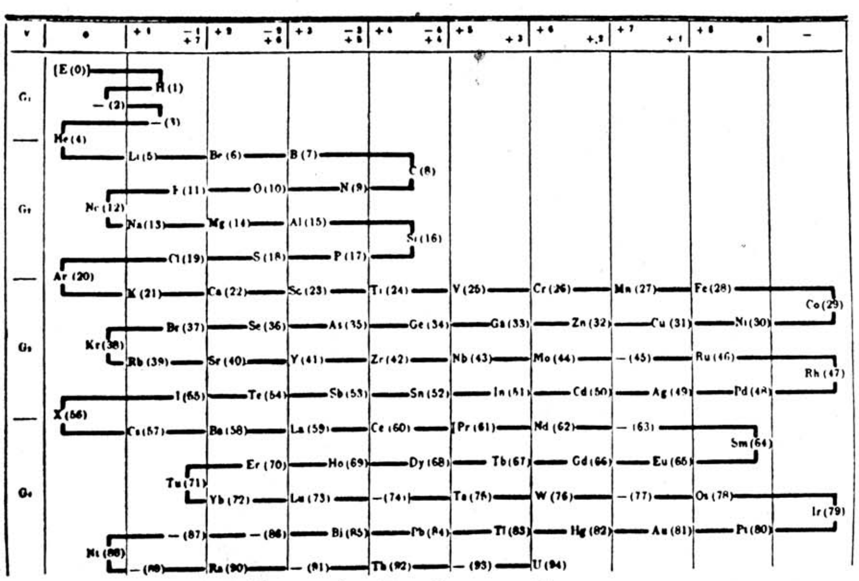

FIGURE 3.—THE RYDBERG TABLE

RYDBERG—1913 (*22*): A chart (Figure 3) is developed from a consideration of the theories of atomic structure and valence. The first period starts with He and extends to the right to C, and then doubles back, causing F to fall in the same column with Li; likewise, Cl falls in line with Na in the next period. The first long period establishes the extreme right column with Co, thus placing Br under K. The rare earths cause their period to occupy four lines across the chart, two to the right and two to the left. The most electropositive and electronegative elements appear in group I. On the basis of atomic structure, the arrangement shows elements other than H preceding He, as well as beyond U.

DUSHMAN—1915 (*23*): The Mendeléeff table is brought up-to-date to include the zero group elements at the left, the body of rare-earth elements as an enlargement of the position we could expect to be occupied by a single element in group III, and the isotopes of the radioactive elements.

DAUVILLIER—1922 (*24*): A new table is proposed in which modern theories of atomic structure determine the positions of the elements. It differs from the ordinary table mainly in the sixth group, which contains in the potassium series, Mn, Fe, Co, Ni, in addition to Cr, as members of family A, and the corresponding elements of the rubidium and cesium series hold analogous positions; the sulfur family elements constitute family B, as usual. Group VII contains the halogen family only, and group VIII, the helium family. The remainder of the rare-earth elements are indicated with Ce in group IV; these fourteen elements which follow cerium, are listed below the table in two horizontal lines.

RENZ—1922 (*25*): A suggested improvement in Mendeléeff's table, by vertical elongation, gives space to a single vertical column of all the rare-earth elements in group III, family A.

SEARS—1924 (*26*): This table has been constructed to emphasize, by lines, the distinctions between families. An attempt has been made to show the relationships of the elements of the lithium and sodium periods to those of the long periods. A second table (*27*) has been designed to show group and family relationships by a third dimension, and by arrows, to indicate the order of increasing activity and basicity.

GEAUQUE—1925 (*28*): Geauque has retained the eight groups of the Mendeléeff table and has utilized the Rydberg arrangement. Group VIII is usual, but the elements from La to Hf, inclusive, form a miniature Rydberg table within the limits of groups I and IV. These latter elements and Sc and Y are inclosed by a heavy line.

ROLLA—1928 (*29*): A typical Mendeléeff table is presented, but H is placed before He without group designation. Although families "a" and "b" are indicated in the group headings, the elements are arranged in straight vertical lines. The rare-earth elements are

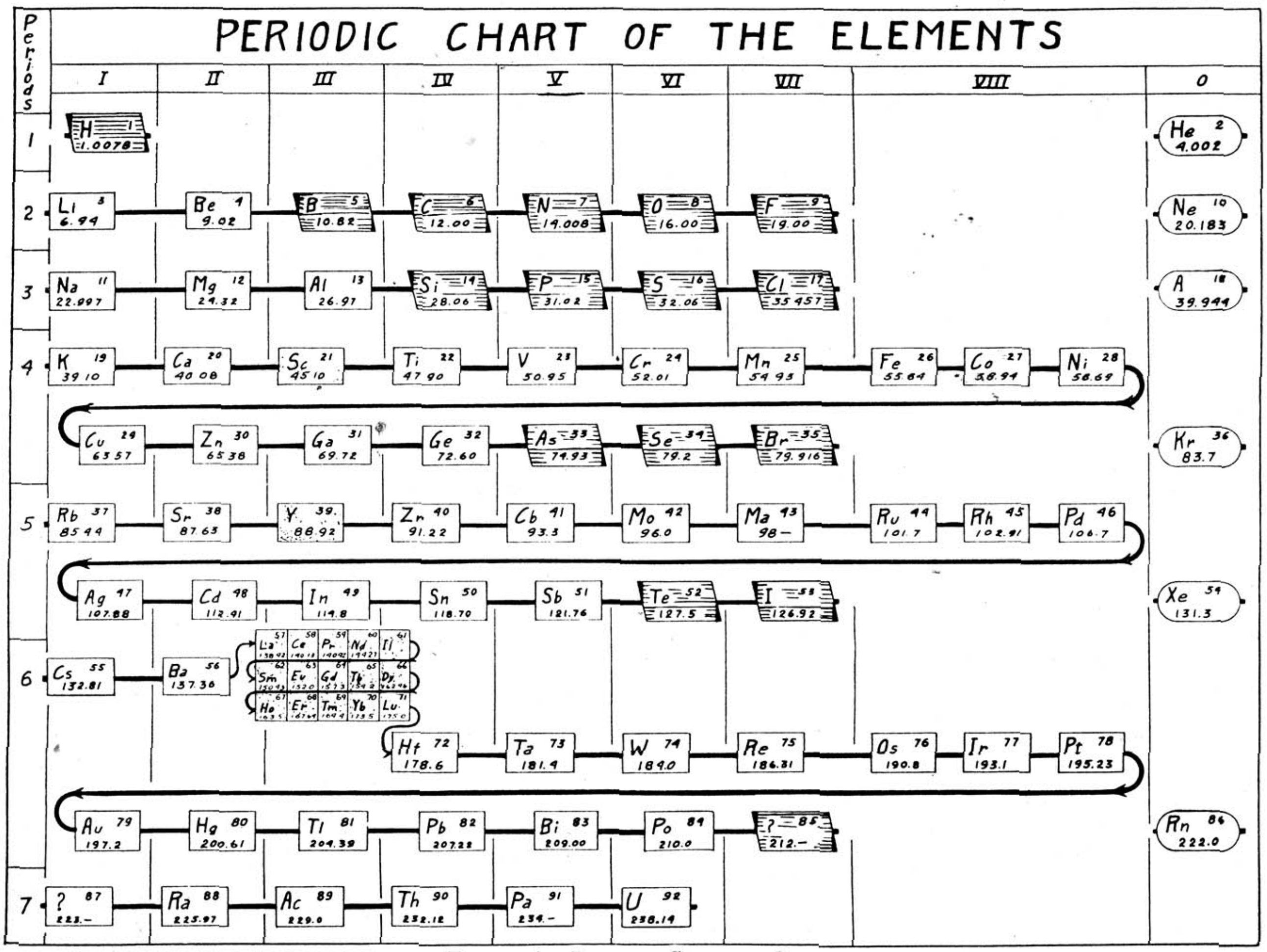

FIGURE 4.—PERIODIC CHART BY QUAM

listed in two horizontal rows, from Ce to Tb, and Dy to Hf. The enclosure may lead the student to think that the rare-earth elements are Ce to Hf, or atomic numbers 58 to 72, inclusive.

SILVERMAN—1928 (*30*): This table is, as the compiler states, "Mendeléeff's Periodic System of the Elements." In modernizing the table, group 0, atomic numbers, periods, and many new elements have been added. The rare-earth elements are enumerated at the bottom of the table and blank spaces are indicated as in the original. The period containing the rare-earth elements is numbered 5 and 6.

HUBBARD—1928 (*31*): This is a typical short table in which the helium family appears both in group zero and in group eight; the rare-earth elements are indicated by inclusive atomic numbers in group III, and are named at the bottom of the table in two horizontal lines. The table is crowded with much physical data usually sought in handbooks.

CENTRAL SCIENTIFIC COMPANY—1930 (*32*): This table appears to be a slightly modified Brauner table (Figure 2) brought up to date. The elements Pr to Hf, inclusive, are listed as the rare-earth elements in an enclosure in groups III and IV under La and Ce, and preceding Ta.

MITRA—1931 (*33*): The author claims to have combined the periodic chemical chart and the electron configuration chart. The groups read horizontally from left to right; group I starts at the top with H and Li, while VIII, at the bottom, includes the helium family, in addition to the usual group VIII elements. The table is designed to show electron levels and quantum values of orbits. The elements Ce to Lu are placed in an enclosed series extending from group III to group VII, inclusive.

SHEMYAKIN—1932 (*34*): The helium family is placed in group VIII in this typical "Mendeléeff" table. The rare-earth elements, however, are distributed across the table in three series from group III to VIII, inclusive. The author has very definitely placed the elements of the lithium and sodium periods in families; Li and Na are in family A, and all others, including the inert elements, in B families.

QUAM—1933 (*35*): The chart (Figure 4) is a modification of the Brauner table. The heavy black lines maintain the continuity of each period. An effort has been made to indicate families by alignment in each group. Thus the positions of Be and Mg indicate a closer relation to Zn and Cd than to the alkaline-earth elements. The non-metals, other than the zero group elements, are indicated by shading, and the rare-earth elements by the dotted rectangles in group III. The so-called inert elements are placed in group 0 at the right to show the completion of the stable atomic arrangement, and also to show the transition from the extreme electronegative elements of one period to the extreme electropositive of the next.

CONCLUSION

Several of the short tables cited may appear to be unlike the Mendeléeff table in minor details as to form, but the authors in all cases have been guided by the principles of the periodic law.

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