



Lewis Reeve Gibbs and the Classification of the Elements

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LEWIS Reeve Gibbs, Professor of Chemistry at the College of Charleston from 1839 to 1892, stands alone among American chemists of his generation by virtue of his valuable and original speculations on the classification of the chemical elements. The present paper pays belated tribute to a man who, though handicapped by isolation in a small southern college and experiencing the privations which followed the Civil War, nevertheless arrived independently at many of the conclusions reached a few years earlier by the founders of the Periodic System.

At no time since Gibbs' first presentation of his ideas has justice been done him, and mischance and neglect have combined to render his work practically unknown. Between 1870 and 1874 Gibbs worked out the first version of his "Synoptical Table of the Chemical Elements" and in October, 1875, discussed an improved form of it at a meeting of the Elliott Society of Charleston, in whose *Proceedings* the paper (1) was duly scheduled to appear. But within a month the difficulties of the reconstruction period had obliged the Elliott Society to suspend all activities and for more than ten years Gibbs' contribution lay unpublished. Only in 1886 did the "Synoptical Table" and its explanation reach a public which had long since ceased to need it. Since that day little attention has been paid to Gibbs' scheme. The single previous account of it is that given by Venable (2) who presents it

briefly and somewhat in the light of a curiosity, without much attempt to assess its virtues and defects. Venable's reproduction of the table contains several errors and is open to criticism. The present account seeks greater fairness to Gibbs by presenting his classification against the background of those which it was intended to supplant; for if the "Synoptical Table" is to be compared at all with the generalizations of Lothar Meyer and Mendeleeff, it must be with their original schemes (3) of 1868 and 1869, respectively. These relatively crude arrangements—and not the Periodic Table as we know it today—were their authors' first answers to the question which Gibbs asked independently in America: What is the "natural" grouping of the chemical elements?

Since the speculations of Prout and Döbereiner in 1815-17, chemists had sought an underlying connection between mass and the other properties of atoms. While certain family relationships soon became clear, any comprehensive attempt at ordering the elements in a natural system based on mass was, until 1860, doomed to failure because of the inconsistent values of atomic weights current before that time. Only after the new chemistry of Gerhardt, Cannizzaro, and Stastto — to name but a few—had provided a revised table of atomic weights did the way stand open to the discovery of the Periodic Law. Gibbs, writing in

1874-75, was aware of the important revisions of atomic weights for these had soon found their way across the Atlantic, but of classifications he knew only the early and imperfect ones of Gladstone (4), Cooke (5), Odling (6), and Dumas (7).

The extent of Gibbs' knowledge of other contemporary workers may now be considered. Venable refers to the "presumptive" evidence of Gibbs' complete ignorance of the Periodic Law and the work which led up to it. This evidence, consisting of Gibbs' apparently full citation of such published work as was known to him and the unlikelihood of his bringing forward his own imperfect classification had he known of the advances made in Europe, is much strengthened by the following considerations. In 1860 Gibbs already foresaw (8) the difficulties which scholars would experience in the approaching Civil War, especially in the matter of access to scientific journals. He may not have foreseen the disruption of academic life during the War itself, which involved the temporary dispersal of students, faculty, and library (9), and rendered scholarly work impossible for several years. Even on the resumption of normal activities in 1866, financial problems remained to harass the college and its faculty, and

this is reflected in a letter written much later by Gibbs to his Board of Trustees (10). Though the college had never supplied scientific periodicals, he says, he had in former years bought many himself which "in later times" he had found himself unable to do. Thus the entire decade during which the Periodic Law was gradually emerging from the work of New-lands, Lothar Meyer, and Mendeleeff was for Gibbs one of chaos and deprivation. We cannot be surprised, therefore, that of the twelve literature references cited by Gibbs in his paper of 1875, only three are to publications of later date than 1860, and of these two are to the 1863 and 1868 editions of Watts' "Dictionary of Chemistry." It may be noted that only in the second supplement to this (1875) did its first account of Mendeleeff's work appear, while Gibbs' principal periodical source of information, the *Chemical News*, first carried a brief account of the Periodic Law in the issue of December 24, 1875. Needless to say, no such account had yet found its way into any of the standard texts, so that the originality of Gibbs' paper can hardly be doubted.

Figure 1 is a photograph of Gibbs' table as it appeared when finally published.

TABLE OF CHEMICAL ELEMENTS.											
a	S E R I E S .								GROUPS.		
	A	B	C	D	E	F	G	H, I		K	
-4		C=12	Si=28	Ti=50			Sn=118			Silicon Gr.	
-3		N=14	P=31	V=51.3	As=75	Cb=94	Sb=122	Ta=182	Au=196.6	Phosphorus Gr.	
-2		O=16	S=32	Cr=52.5	Se=79	Mo=96	Te=128	W=184	Os=199	Sulphur Gr.	
-1		F=19	Cl=35.5		Br=80		I=127			Chlorine Gr.	
0											
+1	Li=7	Na=23	K=39		Rb=85	Ag=108	Cs=133		Tl=204	Kalium Gr.	
+2	Gf=9.3	Mg=24	Ca=40	Zn=65	Sr=87.5	Cd=112	Ba=137		Pb=207	Calcium Gr.	
+3	-B=11								Bi=210		
Al=27.5—Cr=52.5 ; Mn=55 ; Fe=56 ; Co=59 ; Ni=59 ; Cu=63.5—U=120										Iron Gr.	
Y=61.7										Zr=89.5; Ce=92 ; La=92 ; D=96 Er=112 ; Th=115.7	
In=74										Ru=104; Ro=104; Pd=106—Pt=197 ; Ir=197	Platinum Gr.
H=1					Hg=200						

FIGURE 1.—GIBBES' SYNOPTICAL TABLE (1875)

How great an improvement it was upon the disconnected tables of atomic weights, electrochemical affinities, and valencies, which alone served to correlate the properties of the elements in American texts of 1870-74 can best be appreciated by following Gibbs' own account of his intentions and procedure in drawing it up. The name, "Synoptical Table," which he gave to his new scheme indicated his primary intention to display in a single chart as many as possible of the several types of relationships existing among the elements. He was well aware that, to obtain the advantages of a single table, some of those inherent in the customary separate tables must be lost, chief among these sacrifices being the abandonment of the linear form of the electrochemical series. But this was a minor disadvantage in the classification which should depict in one and the same table : "1. The Groups of Elements, as at present recognized. 2. The Atomic Weights of each Element, as now adopted. 3. The Character of each, as Perissad or Artiad.¹

3. Their Atomic equivalence or Atomicity, as Monad, Dyad, Triad, etc. 5. Their Electro-chemical character, as Electro-positive or Electronegative." In departing from the customary mode of presentation, Gibbs was wise enough to take his data from a single source, ". . . to avoid undue bias as to numbers, groups, etc." This source was Barker's textbook (11) which he was then using with his class.

Gibbs' approach to the problem of classifying the elements was thus the reverse of that followed by Gladstone, Newlands, Lothar Meyer, and Mendeleeff. All of these workers, seeking for a "natural" system, had arranged the elements in order of increasing atomic weight and the last three men had observed the periodic repetition of properties which led to the detection of the Periodic Law.

¹ Of odd or even valency, respectively. In Gibbs' day much importance was attached to these characteristics, which were wrongly thought to be invariable.

Gibbs' immediate aim was "to construct a Table to exhibit in the lecture-room a synoptical view of the Elements and their relations as developed in modern Chemistry"

To do this, he assembled the well-known families of elements, one below another, on parallel lines numbered from minus four through zero² to plus three, to correspond with the principal valence of each group. In each of these horizontal lines the elements were written in order of their atomic weights, increasing from left to right. Thus they also fell into vertical columns, or series, in which Gibbs observed ". . . a remarkable regularity . . . in the succession of the numbers . . . yet with gaps unfilled by numbers in several of the groups." Here, in other words, was the regular succession of atomic weights emerging from a system based upon stepwise change in the chemical property, valence.

We must now consider in greater detail Gibbs' arrangement of the elements, and the conclusions which he found it possible to draw. Guided by the order of succession which he had observed, Gibbs made several changes in the arrangement which would have been the consequence of following Barker's tables slavishly. With considerable chemical insight, Gibbs utilized his knowledge of isomorphism and other properties in placing vanadium, columbium, tantalum, chromium, and boron in the pigeon-holes now so familiar to chemists. In this way he placed in the main body of the chart, which corresponds closely with the skeleton of our present short form of the Periodic Table, forty-one of the sixty-three elements known in 1874. Of these, all but five—his Series K—were correctly located, and even where his fragmentary knowledge of some of the heavy elements misled him, Gibbs grasped the correct general outline. Thus:

² In order to bring as close together as possible those elements having the strongest affinity for each other, *e. g.*, the halogens and the alkali metals. It is impossible to suppose that Gibbs saw any significance, other than a mathematical one, in his line corresponding to zero valence.

"...this last series is marked K to indicate this large interval from G, and the intermediate column is marked H, I, to indicate uncertainty as to the number of intervening or missing series, and the probability that there would be at least two...."

The remaining twenty-one elements, all metals with the exception of hydrogen, and including the transition elements and the rare earths, offered greater difficulties, and the fact that in eight cases there were gross errors in the atomic weight values accepted at the time³ did not make it easier for Gibbes to arrive at a logical arrangement. The best that he could do was to lump all but hydrogen and mercury in a second part of his table, beneath the positive portion of the main part but distinct from it. Here he grouped the twenty recalcitrant metals⁴ along lines suggested by analytical and mineralogical similarities. Gibbes' failure to assign aluminum and manganese to suitable empty spaces in the upper portion of the table is striking, and must be explained by his secondary reliance upon atomic weight as a basis of classification. Chemical analogies between manganese and the halogens, and between aluminum and boron, were little recognized at the period in question, and Lothar Meyer's placing of aluminum and manganese in his first table was just as unsatisfactory. Gibbes recognized the inadequacies of the lower portion of his table and with a candor which also goes far to convince the reader of his perspicacity, he remarks concerning a particularly unsatisfactory corner:

"The other two, Er, Th, are written here for a reason, very unscientific indeed, but not without influence, I imagine, in other schemes than the present,—I know not where else to put

³ Namely for Ce, D, Er, In, La, Th, U, Y; although the equivalent weight had been determined fairly accurately in each case except that of the mixture didymium.

⁴As well as chromium which, though already located above, he wished to show in relation to aluminum, manganese, and iron.

Them. I am not sufficiently familiar with the elements on this line to make a better arrangement."

Hydrogen was given a position at the bottom of the table, incongruously associated with mercury. The latter element was tentatively assigned by Gibbes to its correct place in the calcium group, but owing to the novelty of the implied relationship, as well as the fact that gold (which he had wrongly placed in Series K) had a lower atomic weight, he did not so enter it in his final version of the table.

Despite obvious shortcomings, Gibbes' table succeeds to a remarkable degree in achieving the "synoptical" presentation of chemical relationships which was the objective of its author. It is important to remember that the development of a single relationship amongst all the elements was not uppermost in Gibbes' mind; to him the numerous attempts which had been made in previous years to work out algebraic equations relating all atomic weights seemed, at best, arithmetic or geometric exercises on which undue stress should not be laid. Having devoted much attention to such exercises in which, as an able mathematician, he was remarkably proficient, Gibbes finally remarked:

"The possibility of finding for the numerical series of atomic weights such expressions as above given is not to be overlooked, since these expressions may lead to the perception of new chemical relations, but they must hold a subordinate place until such relations have been brought out."

Similarly:

.. if chemical analogies or relations require large deviations such as the halving or doubling of some of these weights, our arithmetic and geometric structures will give way at once."

We can only regret that to the clarity, prudence, and lack of bias displayed by Gibbes throughout his argument, there

could not have been added the greater chemical experience which better facilities would have afforded him. We have finally to test the value of Gibbs' classification by inquiring what deductions he was able to draw from it. To what extent he was conscious of the periodic relationship implicit in his table is a question not easily decided. Certainly there are no words in his paper of 1875 which can fairly be considered an independent statement of the Periodic Law. Although Gibbs refers frequently to the "regularity" which he observed, the adjective "periodic" does not appear. Nevertheless, the diagram (Figure 2) which Gibbs offers as a graphic substitute for the main portion of his table, and still more the Archimedean spiral whose construction he minutely describes to demonstrate the continuity of his series, can leave little doubt that he was aware of a unifying relationship between the elements from lithium to barium, based upon recurrence of similar properties with increasing mass. His own words in this connection deserve quoting. They follow the details of the construction of the diagram:

"The points indicating the members of each Series will now be found to lie very approximately on a *right line*, these lines cutting the axis of ordinates at nearly the same angle. The 'parallelism' will now be not only arithmetic but geometric, presented to the eye, and will be most striking in the case of series A, B, C, less so in case of D, E, and F, G, K. Such a diagram may be found useful in instruction...."

Also:

"The remarkable continuity of the three series A, B, and C, permits the construction of another geometric design, less convenient than the last for reference, but allowing the *three* series to be exhibited in continuity as *one*, that is by the use of an Archimedean Spiral whose radius vector increases by 16 units in one revolution."

The construction of this having been detailed, Gibbs goes on to note, somewhat tersely :

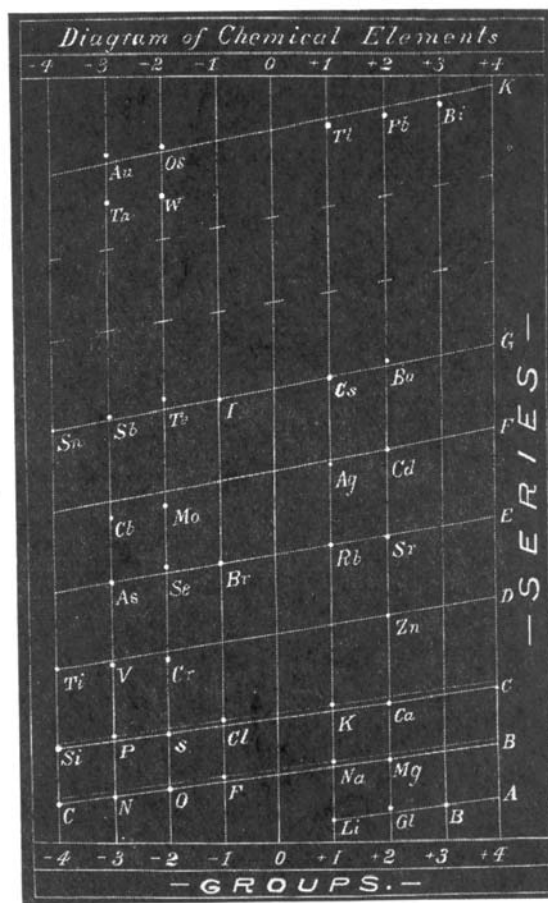


FIGURE 2.—GIBBES' DIAGRAM (1875)

"If the diagram of preceding section with rectangular coordinates were wrapped around a cylinder whose circumference equals interval in diagram from +4 to -4, the result just mentioned would be exhibited with the same accuracy, a helix being substituted for the spiral."

Gibbes' helix and spiral correspond to earlier suggestions of de Chancourtois and Mendeleeff, respectively; his diagram anticipates to a considerable extent those of several later authors, including Crookes' (12) of 1886.

The detailed prediction of undiscovered elements which was the most striking feature of Mendeleeff's long paper of 1871 (13) finds no parallel in the case of Gibbs, but the American chemist took particular note of the blank spaces in his table and, in considering the construction of curves which should correspond to the series of atomic weights, remarked: "...it may become worth our while to construct equations for such curves, especially if any of the gaps now existing were filled by the discovery of new elements." He also refers to certain of the blank spaces as corresponding to elements "missing at present." Gibbs' foresight thus contrasts very favorably with the arbitrary procedure of Newlands, whose Law of Octaves (14) failed to win the support it deserved largely because of its author's attempt to force all known elements into a rigid scheme in which some places were doubly filled and none left vacant.

Far more interesting is Gibbs' very astute differentiation between the two sub-groups of each family of elements. The existence of these, which had become clear to Meyer and Mendeleeff only with the development of the later forms of their respective tables, is pointed out by Gibbs in every case where his table afforded the necessary groups of elements. He refers to them as the "primary sub-group" (S, Se, Te; P, As, Sb; etc.) and the "secondary sub-group" (Cr, Mo, W; V, Cb, Ta; etc.). An equally compelling proof of Gibbs' chemical insight has never been commented upon. It is his recognition of what we know today as "typical" elements. Mendeleeff had so designated Li, Be, B, C, N, O, F in his paper of 1871, and the name, though often criticized, has been retained. Gibbs' clear ideas in the matter are best shown by his own words:

"Each of the negative members of series B, namely F, O, N, and C, though closely allied to the primary sub-group of their respective lines, is yet so distinctly marked by several characteristics that they may be regarded as forming in those lines each a *third* sub-group (consisting of a single member) for which it may be convenient to adopt some distinctive epithet."

It will be noted that Gibbs not only recognized the distinctive character of the later members of our first "short period"

but also appreciated the fact that each bears a closer relationship to what we should call the B sub-group of the family than it does to the A.

Perhaps enough has been said to justify the author's opinion that the obscure paper of Gibbs, despite its belated appearance, must rank as a classic of American chemistry. If little has been known of the "Synoptical Table," even less has been written about its author and his distinguished services to several branches of science. In view of the inaccessibility of biographical material pertaining to Gibbs, no apology is necessary for adding the following sketch of his career. In securing the material for it the author has had the kind assistance of Professor J. H. Easterby, Director of the Library, College of Charleston, and of Professor S. M. Christian of Agnes Scott College, to both of whom grateful acknowledgment is made (15).

Lewis Reeve Gibbs was born in Charleston, South Carolina, August 14, 1810, the son of Lewis Ladson Gibbs and Maria Henrietta Drayton. It is of interest that his mother enjoyed some reputation as a botanist. Young Gibbs was educated at the University of Pennsylvania Grammar School (1821-22), at Pendleton Academy, South Carolina, and at the South Carolina College, where he was graduated with first honors in 1829. Intending to qualify as a physician, Gibbs studied medicine at the Medical College of Charleston in 1830 and again in 1835-36, the four-year intermission having been devoted to the teaching of mathematics at his *alma mater*, first as tutor and later as acting professor. However, after taking his medical degree in 1836—he here gave early evidence of his versatility by submitting a prize-winning thesis in French!—Gibbes went to Paris to continue studies which were to become increasingly liberal. The young scientist's interest in natural history prompted him to take to France collections of South Carolina plants and of marine and fresh water shells of the South Atlantic states, which he exchanged with various naturalists abroad. During his stay of more than a year in Paris, Gibbs studied many subjects besides those usually pursued by medical men; he attended, among

others, the lectures of Gay-Lussac and Chevreul at the Jardin des Plantes and those of Dumas and Pouillet at the Sorbonne. Dulong was his teacher also, so that the young scholar who returned to Charleston in the autumn of 1837 and was soon appointed Professor of Mathematics and Natural Philosophy in the newly reorganized College of Charleston was well equipped for duties which were to expand into over half a century of devoted labor, on behalf of many causes.

During his long career, Gibbes taught, at one time or another, mathematics, astronomy, physics, chemistry, and mineralogy. He was for many years secretary of the college faculty, and to these academic responsibilities were added those of the presidency of the Elliott Society of Charleston from 1856-89, as well as an earlier post as secretary of the American Association for the Advancement of Science. Despite heavy demands on his time, Gibbes published numerous papers in many fields of science, mainly in the *Proceedings of the Elliott Society* and the *American Journal of Science*. Some of these were outstanding contributions to the science of the day, such as his comprehensive revision, in 1850, of the species of *Crustacea* in the various United States collections, to which he added valuable notes and descriptions of new species; also his comparison and discussion of all the observations made in the United States on the transit of Mercury of May, 1845. A

few other titles taken at random from a long list will serve to indicate the scope of Gibbes' interests, which were all the more remarkable for the thoroughness and scholarship with which this busy man cultivated them: "Solar and Lunar Eclipses"; "Tabular View of 13 Asteroids"; "On Some Points which have been overlooked in the Past and Present Condition of Niagara Falls"; "Determination of Longitude between Charleston and Washington"; "On a Convenient Form of Aspirator"; "Yucca Juice as an Indicator"; "The Ozonizing Powers of the Portulaca." The "Synoptical Table of the Chemical Elements" was Gibbes' principal essay in pure chemistry.

Gibbes' death occurred in Charleston on November 21, 1894, and was the occasion for comment on his work in leading scientific journals both here and abroad. In conclusion may fittingly be quoted the words of Henry E. Shepherd, President of the College of Charleston (1882-97), who in speaking of Dr. Gibbes said:

"Astronomy was his passion, but he cultivated nearly every phase of our complex modern science, and cultivated none that he did not dignify and adorn. As a teacher he was lucidity itself. He not only taught so that he might be understood by the pupil, but so that he could not be misunderstood. He ever manifested a spirit of absolute consecration to his ideal as a scientist, an insatiable quest of knowledge, undiminished even in the view of death, and respect and reverence for the eternal verities of the Christian faith."

LITERATURE CITED

- (1) GIBBES, "Synoptical table of the chemical elements," *Proceedings of the Elliott Society of Charleston*, 77-90 (Oct., 1875).
- (2) VENABLE, "The development of the periodic law," Chemical Publishing Co., Easton, Pa., 1896, pp. 126-32.
- (3) SEUBERT, "Das naturliche System der chemischen Elemente," (No. 68 of Ostwald's *Klassiker*), Engelmann, Leipzig, 1895, 134 pp.
- (4) GLADSTONE, "On the relation between the atomic weights of analogous elements," *Phil. Mag.*, (IV) 5, 313-20 (1853).
- (5) COOKE, "The numerical relation between the atomic weights, with some thoughts on the classification of the chemical elements," *Am. J. Sci.*, (II) 17, 387-407 (1854).
- (6) ODLING, "On the natural groupings of the elements," *Phil. Mag.*, (IV) 13, 423-39; 480-97 (1857).
- (7) DUMAS, "Memoire sur les equivalents des corps simples," *Ann. chim. phys.*, (3) 55, 129-210 (1859).

- (8) GIBBES, "Note on the intra-mercurial planets," Charleston (S. C.) *Courier*, July 31, 1860.
- (9) EASTERBY, "A history of the College of Charleston,"
College of Charleston, S. C., 1935, Chapter VII, pp. 145-55.
- (10) GIBBES, Letter to the Board of Trustees of the College of Charleston, Feb. 5, 1885.
- (11) BARKER, "A text book of elementary chemistry, theoretical and inorganic," 1st ed., J. P. Morton and Co., Louisville, Ky., 1870, 342 pp.
- (12) CROOKES, Address to the chemical section of the British Association, *Chem. News*, 54, 115-26 (1886).
- (13) MENDELEEFF, "Die periodische Gesetzmässigkeit der chemischen Elemente," *Ann.*, VIII Supplementband, 133-229 (1871).
- (14) NEWLANDS, "On the law of octaves," *Chem. News*, 12, 83 (1865).
- (15) In addition to the brief account given by EASTERBY, *op. cit.*, the following may be mentioned:
- (a) DAVIS, Outline sketch in Charleston (S. C.) *News-Courier*, Dec. 19, 1901.
 - (b) LABORDE, "History of the South Carolina College," Columbia, 1859.
 - (c) PINCKNEY, Obituary article in Charleston (S. C.) *News and Courier*, Jan. 26, 1895.