WESTERN OREGON UNIVERSITY

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A BRIEF HISTORY OF THE DEVELOPMENT OF THE PERIODIC TABLE

Although Dmitri Mendeleev is often considered the "father" of the periodic table, the work of many scientists contributed to its present form.

In the Beginning

A necessary prerequisite to the construction of the periodic table was the discovery of the individual elements. Although elements such as gold, silver, tin, copper, lead and mercury have been known since antiquity, the first scientific discovery of an element occurred in 1649 when Hennig Brand discovered phosphorous. During the next 200 years, a vast body of knowledge concerning the properties of elements and their compounds was acquired by chemists (view a 1790 article on the elements). By 1869, a total of 63 elements had been discovered. As the number of known elements grew, scientists began to recognize patterns in properties and began to develop classification schemes.

Law of Triads

In 1817 Johann Dobereiner noticed that the atomic weight of strontium fell midway between the weights of calcium and barium, elements possessing similar chemical properties. In 1829, after discovering the halogen triad composed of chlorine, bromine, and iodine and the alkali metal triad of lithium, sodium and potassium he proposed that nature contained triads of elements the middle element had properties that were an average of the other two members when ordered by the atomic weight (the Law of Triads).

This new idea of triads became a popular area of study. Between 1829 and 1858 a number of scientists (Jean Baptiste Dumas, Leopold Gmelin, Ernst Lenssen, Max von Pettenkofer, and J.P. Cooke) found that these types of chemical relationships extended beyond the triad. During this time fluorine was added to the halogen group; oxygen, sulfur,selenium and tellurium were grouped into a family while nitrogen, phosphorus, arsenic, antimony, and bismuth were classified as another. Unfortunately, research in this area was hampered by the fact that accurate values of were not always available.

First Attempts At Designing a Periodic Table

If a periodic table is regarded as an ordering of the chemical elements demonstrating the periodicity of chemical and physical properties, credit for the first periodic table (published in 1862) probably should be given to a French geologist, A.E.Beguyer de Chancourtois. De Chancourtois transcribed a list of the elements positioned on a cylinder in terms of increasing atomic weight. When the cylinder was constructed so that 16 mass units could be written on the cylinder per turn, closely related elements were lined up vertically. This led de Chancourtois to propose that "the properties of the elements are the properties of numbers." De Chancourtois was first to recognize that elemental properties reoccur every seven elements, and using this chart, he was able to predict the the stoichiometry of several metallic oxides. Unfortunately, his chart included some ions and compounds in addition to elements.

Law of Octaves

John Newlands, an English chemist, wrote a paper in 1863 which classified the 56 established elements into 11 groups based on similar physical properties, noting that many pairs of similar elements existed which differed by some multiple of eight in atomic weight. In 1864 Newlands published his version of the periodic table and proposed the Law of Octaves (by analogy with the seven intervals of the musical scale). This law stated that any given element will exhibit analogous behavior to the eighth element following it in the table.

Who Is The Father of the Periodic Table?

There has been some disagreement about who deserves credit for being the "father" of the periodic table, the German Lothar Meyer (see a picture) or the Russian Dmitri Mendeleev. Both chemists produced remarkably similar results at the same time working independently of one another. Meyer's 1864 textbook included a rather abbreviated version of a periodic table used to classify the elements. This consisted of about half of the known elements listed in order of their atomic weight and demonstrated periodic valence chages as a function of atomic weight. In 1868, Meyer constructed an extended table which he gave to a colleague for evaluation. Unfortunately for Meyer, Mendeleev's table became available to the scientific community via publication (1869) before Meyer's appeared (1870).

Dmitri Ivanovich Mendeleev (1834-1907), the youngest of 17 children was born in the Siberian town of Tobol'sk where his father was a teacher of Russian literature and philosophy (see a picture). Mendeleev was not considered an outstanding student in his early education partly due to his dislike of the classical languages that were an important educational requirement at the time even though he showed prowess in mathematics and science. After his father's death, he and his mother moved to St. Petersburg to pursue a university education. After being denied admission to both the University of Moscow and St. Petersburg University because of his provincial background and unexceptional academic background, he finally earned a place at the Main Pedagogical Institute (St. Petersburg Institute). Upon graduation, Mendeleev took a position teaching science in a gymnasium. After a time as a teacher, he was admitted to graduate work at St. Petersburg University where he earned a Master's degree in 1856. Mendeleev so impressed his instructors that he was retained to lecture in chemistry. After spending 1859 and 1860 in Germany furthering his chemical studies, he secured a position as professor of chemistry at St. Petersburg University, a position he retained until 1890. While writing a textbook on systematic inorganic chemistry, *Principles of Chemistry*, which appeared in thirteen editions the last being in 1947, Mendeleev organized his material in terms of the families of the known elements which displayed similar properties. The first part of the text was devoted to the well known chemistry of the halogens. Next, he chose to cover the chemistry of the metallic elements in order of combining power -- alkali metals first (combining power of one), alkaline earths (two), etc. However, it was difficult to classify metals such as copper and mercury which had multiple combining powers, sometimes one and other times two. While trying to sort out this dilema, Mendeleev noticed patterns in the properties and atomic weights of halogens, alkali metals and alkaline metals. He observed similarities between the series Cl-K-Ca , Br-/Rb-Sr and I-Cs-Ba. In an effort to extend this pattern to other elements, he created a card for each of the 63 known elements. Each card contained the element's symbol, atomic weight and its characteristic chemical and physical properties. When Mendeleev arranged the cards on a table in order of ascending atomic weight grouping elements of similar properties together in a manner not unlike the card arrangement in his favorite solitare card game, patience, the periodic table was formed. From this table, Mendeleev developed his statement of the periodic law and published his work *On the Relationship of the Properties of the Elements to their Atomic Weights* in 1869 (view a copy of Mendeleev's table as published in *Annalen* suppl. VIII, 133 (1871). The advantage of Mendeleev's table over previous attempts was that it exhibited similarities not only in small units such as the triads, but showed similarities in an entire network of vertical, horizontal, and diagonal relationships. In 1906, Mendeleev came within one vote of being awarded the Nobel Prize for his work.

At the time that Mendeleev developed his periodic table since the experimentally determined atomic masses were not always accurate, he reordered elements despite their accepted masses. For example, he changed the weight of beryllium from 14 to 9. This placed beryllium into Group 2 above magnesium whose properties it more closely resembled than where it had been located above nitrogen. In all Mendeleev found that 17 elements had to be moved to new positions from those indicated strictly by atomic weight for their properties to correlate with other elements. These changes indicated that there were errors in the accepted atomic weights of some elements (atomic weights were calculated from combining weights, the weight of an element that combines with a given weight of a standard.) However, even after corrections were made by redetermining atomic weights, some elements still needed to be placed out of order of their atomic weights. From the gaps present in his table, Mendeleev predicted the existence and properties of unknown elements which he called eka-aluminum, eka-boron, and eka-silicon. The elements gallium, scandium and germanium were found later to fit his predictions quite well. In addition to the fact that Mendeleev's table was published before Meyers', his work was more extensive predicting new or missing elements. In all Mendeleev predicted the existence of 10 new elements, of which seven were eventually discovered -- the other three, atomic weights 45, 146 and 175 do not exist. He also was incorrect in suggesting that the element pairs of argon-potassium, cobalt-nickel and tellurium-iodine should be interchanged in position due to inaccurate atomic weights. Although these elements did need to be interchanged, it was because of a flaw in the reasoning that periodicity is a function of atomic weight.

Discovery of the Noble Gases

In 1895 Lord Rayleigh reported the discovery of a new gaseous element named argon which proved to be chemically inert. This element did not fit any of the known periodic groups. In 1898, William Ramsey suggested that argon be placed into the periodic table between chlorine and potassium in a family with helium, despite the fact that argon's atomic weight was greater than that of potassium. This group was termed the "zero" group due to the zero valency of the elements. Ramsey accurately predicted the future discovery and properties neon.

Atomic Structure and the Periodic Table

Although Mendeleev's table demonstrated the periodic nature of the elements, it remained for the discoveries of scientists of the 20th Century to explain why the properties of the elements recur periodically.

In 1911 Ernest Rutherford (see a picture) published studies of the scattering of alpha particles by heavy atom nuclei which led to the determination of nuclear charge (view the paper here). He demonstrated that the nuclear charge on a nucleus was proportional to the atomic weight of the element. Also in 1911, A. van den Broek in a series of two papers (1, 2)proposed that the atomic weight of an element was approximately equal to the charge on an atom. This charge, later termed the atomic number, could be used to number the elements within the periodic table. In 1913, Henry Moseley (see a picture) published the results of his measurements of the wavelengths of the x-ray spectral lines of a number of elements which showed that the ordering of the wavelengths of the x-ray emissions of the elements coincided with the ordering of the elements by atomic number. With the discovery of isotopes of the elements, it became apparent that atomic weight was not the significant player in the periodic law as Mendeleev, Meyers and others had proposed, but rather, the properties of the elements varied periodically with atomic number.

The question of why the periodic law exists was answered as scientists developed an understanding of the electronic structure of the elements beginning with Niels Bohr's studies of the organization of electrons into shells through G.N. Lewis' (see a picture) discoveries of bonding electron pairs.

The Modern Periodic Table

The last major changes to the periodic table resulted from Glenn Seaborg's work in the middle of the 20th Century. Starting with his discovery of plutonium in 1940, he discovered all the transuranic elements from 94 to 102. He reconfigured the periodic table by placing the actinide series below the lanthanide series. In 1951, Seaborg was awarded the Nobel Prize in chemistry for his work. Element 106 has been named seaborgium (Sg) in his honor.