**Development of the Periodic Table**

元素周期表的演进

The periodic table is a chart that reflects the periodic recurrence of chemical and physical properties of the elements when the elements are arranged in order of increasing atomic number (the number of protons in the nucleus). It is a monumental scientific achievement, and its development illustrates the essential interplay between observation, prediction, and testing required for scientific progress. In the 1800's scientists were searching for new elements. By the late 1860's more than 60 chemical elements had been identified, and much was known about their descriptive chemistry. Various proposals were put forth to arrange the elements into groups based on similarities in chemical and physical properties. The next step was to recognize a connection between group properties (physical or chemical similarities) and atomic mass (the measured mass of an individual atom of an element). When the elements known at the time were ordered by increasing atomic mass, it was found that successive elements belonged to different chemical groups and that the order of the groups in this sequence was fixed and repeated itself at regular intervals. Thus when the series of elements was written so as to begin a new horizontal row with each alkali metal, elements of the same groups were automatically assembled in vertical columns in a periodic table of the elements. This table was the forerunner of the modern table.

元素周期表是按原子序数(元素原子核中质子的数量)由小到大依次排列，反映化学周期性和元素的物理特征的图表。这一科学发现具有里程碑的意义，它进一步证明了科学探索过程中观察、预测和实证之间的根本联系。19世纪一开始，科学家们不断探索新的元素。到19世纪60年代后期，已经发现了60种以上的化学元素，而许多描述性化学被认知。人们提出各种建议，认为该基于化学和物理特征的相似性将化学元素排列成组。他们接下来又证实了元素的族群特性(物理或是化学相似性)和原子质量(一种元素的单个原子的测量质量)之间存在联系。当时元素还是按照原子质量从小到大排列，人们发现，一些具备连续性的元素却分属不同的化学组，并且发现在这种排列方式下，元素群组的顺序是固定的且定期重复。因此，当每一新行都以碱性金属元素开始并逐步将这一系列的元素排列出来时，元素周期表中同一组中的元素就会自动归入一个垂直纵列中。这个表格就是现代元素周期表的雏形。

When the German chemist Lothar Meyer and (independently) the Russian Dmitry Mendeleyev first introduced the periodic table in 1869-70, one-third of the naturally occurring chemical elements had not yet been discovered. Yet both chemists were sufficiently farsighted to leave gaps where their analyses of periodic physical and chemical properties indicated that new elements should be located. Mendeleyev was bolder than Meyer and even assumed that if a measured atomic mass put an element in the wrong place in the table, the atomic mass was wrong. In some cases this was true. Indium, for example, had previously been assigned an atomic mass between those of arsenic and selenium. Because there is no space in the periodic table between these two elements, Mendeleyev suggested that the atomic mass of indium be changed to a completely different value, where it would fill an empty space between cadmium and tin. In fact, subsequent work has shown that in a periodic table, elements should not be ordered strictly by atomic mass. For example, tellurium comes before iodine in the periodic table, even though its atomic mass is slightly greater. Such anomalies are due to the relative abundance of the "isotopes" or varieties of each element. All the isotopes of a given element have the same number of protons, but differ in their number of neutrons, and hence in their atomic mass. The isotopes of a given element have the same chemical properties but slightly different physical properties. We now know that atomic number (the number of protons in the nucleus), not atomic mass number (the number of protons and neutrons), determines chemical behavior.

当德国化学家迈耶(Lother Meyer)和(彼此独立的)俄国化学家门捷列夫在1869年到1870年间首次发布元素周期表时，有三分之一的天然化学元素还没被发现。然而这两位化学家都极富远见，他们在周期表上留白，对元素物理性和化学性的分析空白处还有新的元素有待发现。门捷列夫比迈耶更为大胆，他甚至做出假设，如果周期表按原子质量排列，但元素位置不对的话，那么原子质量也是错的。在某些情况下，这个设想是正确的。以铟为例，先前测量出铟的原子质量在砷和硒之间。但是因为在周期表中这两个元素之间没有缝隙，由此门捷列夫提出铟的原子质量变为截然不同的一个值，这样就可以将其置于镉和锡之间的空位。事实上，接下来的研究表明，元素周期表中元素不能严格按照原子质量排列。例如，尽管碲的原子质量比碘略大，但在元素周期表中，它却排在碘前面。出现这种反常现象，主要是因为相对丰富的“同位素”或者各种元素的多样性。同一元素的所有同位素具有相同的质子数，但中子数不同，因此它们的原子质量也不一样。一个特定元素的同位素具有相同的化学特征，但在物理性质上有一些细微差异。现在我们知道，是原子数目(原子核中质子的数量)而非原子质量(质子和中子的数量)决定着元素的化学性质。

Mendeleyev went further than Meyer in another respect: he predicted the properties of six elements yet to be discovered. For example, a gap just below aluminum suggested a new element would be found with properties analogous to those of aluminum. Mendeleyev designated this element "eka-aluminum" (eka is the Sanskrit word for "next") and predicted its properties. Just five years later an element with the proper atomic mass was isolated and named gallium by its discoverer. The close correspondence between the observed properties of gallium and Mendeleyev’s predictions for eka-aluminum lent strong support to the periodic law. Additional support came in 1885 when eka-silicon, which had also been described in advance by Mendeleyev, was discovered and named germanium.

门捷列夫在另一个研究上也比迈耶更为深入：他预测还有六种元素的性质待被发现。例如，就在铝下面有一个空位，这表明还有一个性质和铝类似的新元素存在。门捷列夫将该元素定义为“铝下元素”(eka是梵语词，意思是“下一个”)并且还预测了其性质。仅仅5年之后，原子质量相吻合的元素就被分离出来，发现者将其命名为“镓”。镓所表现出的特性和门捷列夫对“铝下元素”的预测一一对应，这为元素法则提供了一个强有力的依据。还有一个例证，1885年发现“硅下元素”，同样为门捷列夫所预测，后来命名为锗。

The structure of the periodic table appeared to limit the number of possible elements. It was therefore quite surprising when John William Strutt, Lord Rayleigh, discovered a gaseous element in 1894 that did not fit into the previous classification scheme. A century earlier, Henry Cavendish had noted the existence of a residual gas when oxygen and nitrogen are removed from air, but its importance had not been realized. Together with William Ramsay, Rayleigh isolated the gas (separating it from other substances into its pure state) and named it argon. Ramsay then studied a gas that was present in natural gas deposits and discovered that it was helium, an element whose presence in the Sun had been noted earlier in the spectrum of sunlight but that had not previously been known on Earth. Rayleigh and Ramsay postulated the existence of a new group of elements, and in 1898 other members of the series (neon, krypton, and xenon) were isolated.

元素周期表的框架似乎限制了可能存在的元素数量。因此，当约翰•威廉姆•斯特拉特(瑞利男爵)，在1894年发现一种气态元素不能适应之前的元素表时会非常惊讶。一个世纪以前，亨利•卡文迪许就注意到，当氧气和氮气从空气中被移除后仍然有残余气体存在，但当时没人意识到其中的重要性。瑞利和威廉•拉姆齐一道，共同分离出一种气体(将之与其他物质隔离并存于一个真空环境)并将其命名为氩。拉姆齐经过研究又发现了另一种存在于自然界中的气体元素——氦，该元素在太阳中存在，并且很早就被发现存在于太阳光谱中，但是之前并没有在地球上找到过。瑞利和拉姆齐做出假设，认为存在一组新元素，1898年，这一系列元素中的其他元素(氖，氪，氙)也被成功分离出来。