The Periodic Table

The **periodic table** of elements is one of the most familiar symbols in science. One can be found hanging in virtually every chemistry laboratory and classroom in the world. In fact, some predict that it will be the one document we will have in common with any intelligent form of life we encounter in the universe.

So what is this remarkable **table**? It is a list of all the known *elements*—pure chemicals that cannot be separated into simpler substances. Of these elements, 92 occur naturally on Earth. In their pure or mixed forms, they make up all known substances, human-made as well as naturally occurring.

But the **periodic table** is much more than a simple list. It is also a powerful tool for understanding the elements. The term "**periodic**" refers to a repeating pattern, and the **periodic table** arranges the elements according to a repeating pattern of shared chemical properties.

As a result, chemistry students and working scientists do not have to memorize the properties of every known element. Instead, they can look at the **periodic table** and quickly see to what "family" a given element belongs. Knowing the general characteristics of these families, the chemist can predict the physical and chemical qualities of their individual members.

To understand the **periodic table** as well as possible, it helps to trace its development back over the past 200 years.

History

The 1800s were an exciting time in chemistry, with more and more elements being discovered every year. As each element was discovered, its properties were noted. Does it react with water? Does it conduct electricity? Is it shiny, dull, hard, or crumbly? And so on.

By this time, chemists had also found ways to figure out the atomic masses of the different elements. That is, chemists were able to devise methods to calculate how much elements weighed in comparison to each other.

As understanding of the elements grew, it became clear that many shared similar traits. Chemists began trying to organize their growing list of elements in a meaningful way.

One of the first to notice a repeating pattern, or *periodicity*, to the elements, was the English chemist John Newlands. In 1864, Newlands drew up a list of the known elements in order of increasing atomic mass. He then noted that each element showed properties similar to the element eight places ahead of it as well as to the element eight places behind it.

Newlands called this phenomenon the "law of octaves." But it was not well received. In fact, at a meeting of the Chemical Society of London in 1866, chemists ridiculed Newlands, asking whether he had tried listing the elements in alphabetical order, because surely any list would have some kind of coincidental pattern. But Newlands' critics were wrong. He had stumbled onto something important.

Then, three years later, in 1869, Dmitri Mendeleyev, a Russian chemistry professor, completed the first of several successful **periodic** tables. Like Newlands, Mendeleyev arranged the known elements (64 at that time) in order of increasing atomic mass. But he did so from left to right in horizontal rows. More important, Mendeleyev began a new row each time he found an element that shared the qualities of one before it. As a result, each vertical column contained elements with the same number of valence electrons, and therefore with similar chemical properties.

For example, all of the elements in the **periodic table's** first column—hydrogen, lithium, sodium, potassium, rubidium, cesium, francium—react strongly with water. Even more interesting, water'**s** reaction with each of these elements grows stronger as one moves down the column from hydrogen, growing explosive by the time one reaches sodium. Each of Mendeleyev'**s** columns became known as a "family."

So confident was Mendeleyev in the pattern revealed by his **table** that he left blank spaces in positions where he thought an element was missing, or yet to be discovered. He even predicted in detail what the physical and chemical properties of these unknown elements would be. The following years proved him right repeatedly, as each of the predicted elements was discovered.

The discovery of those three elements—gallium, scandium, and germanium—not only gained acceptance for Mendeleyev'**s table**, but it was also a vindication for Newlands. It confirmed that certain physical and chemical properties of the elements recur every eighth element. We now understand this to be a result of *valence*, the number of electrons an atom has available for chemical reactions. But 19th-century chemists had yet to discover the electron—or, for that matter, any subatomic particle.

Another chemist, Lothar Meyer of Germany, published a very similar **periodic table** at about the same time as Mendeleyev'**s**. But his was neither as complete nor as accurate, and it never came into wide use.

Mendeleyev'**s periodic table** continued to expand with the discovery of more elements. By the mid-20th century, it had assumed the basic form we know today.

Table Arrangement

As mentioned, the usefulness of the **periodic table** lies in its ingenious arrangement. Mendeleyev and other chemists of his day had no concept of subatomic structure. But remarkably, Mendeleyev'**s table** is organized in a way that gives us clear information about each element'**s** number of electrons and the size of its nucleus. We now know this is because an element'**s** atomic structure determines its physical and chemical properties.

Several forms of the **periodic table** exist. The most familiar is called the medium-period, or "modern," **periodic table**. Each of its seven horizontal rows is called a *period*, and the elements are numbered across each period from left to right. This order gives each element its *atomic* *number*. We now know that each element'**s** atomic number tells us the positive charge of its atomic nucleus. In other words, it tells us the number of protons that occur in its atomic nucleus. The number of neutrons in the nucleus is usually, but not always, equal to the number of protons.

In general, arranging the elements in order of atomic number places them in order of increasing atomic mass. One of the two known exceptions to this is cobalt, which comes before nickel despite having a slightly larger atomic mass. This is because the most common form of cobalt has two more neutrons in its atomic nucleus than does the most common form of nickel. In fact, subtracting any element'**s** atomic number from its atomic mass (rounded to a whole number) always tells us its number of neutrons.

Most useful of all, perhaps, is the way the **periodic table** is arranged so as to organize similar elements in vertical rows called groups, or *families*. Some of the most important families include that of the noble gases, the six elements in the far-right column. (Chemists use the term *noble* to describe an element that is inert, or does not react easily with other elements.) The far-left column comprises the alkali metals.

The periods, or rows, of the **table** are of varying lengths. The first period consists of only two elements—hydrogen and helium—separated on either side of the **table** in order to place them in their designated families. Similarly, a large gap separates the first two and last six elements of periods two and three. The fourth and fifth periods have 18 elements each and span the complete width of the modern **periodic table**.

The sixth and seventh rows are called the "long" periods. Each contains or can contain 32 elements. To maintain the useful arrangement of the **periodic table**, portions of these two periods are spliced out and traditionally placed below the rest of the **table**.

The first of these two "extra" strips is called the lanthanide series. All the elements in it share nearly identical properties with the element lanthanum, which comes immediately before them in the sixth period of the **table**. All the lanthanides can be thought of as belonging to the same group as lanthanum. The same applies to the second "extra" strip, called the actinide series. All the actinide elements share the properties of actinide in the seventh period and can be thought of as belonging to its group.

In addition to arranging elements in vertical groups and horizontal periods, the **periodic table** arranges them in three general categories. Spreading across the left and center of the **table** are the metals, recognized by their hardness and luster and defined by their tendency to conduct electricity and heat. On the right of the **table** are the nonmetals. These elements tend to be soft and crumbly, and conduct rather poorly.

The metals and nonmetals are separated by a stair-step dividing line made up of eight "metalloids," elements with intermediate properties. Hydrogen, sitting by itself at the top of group one, is a unique element that can be considered both metal and nonmetal or neither.

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