18.3 The Periodic Table of Elements

Before people understood the internal structure of the atom, they were able to identify elements by how they acted chemically. In this section, you learn how chemists summarize the properties of elements in the *periodic table of elements*, and how an element's chemistry and atomic structure are related.

Elements and compounds

In 1808, John Dalton published his theory that all materials were made up of atoms, and that atoms can bond together in different combinations. He supported his theory with experimental results. This work provoked two important questions. Which substances were *elements*, made up of only one kind of atom? Which substances were *compounds*, made up of combinations of atoms?

How many elements are there?

In the 18th through 20th centuries, new theories, technologies, and scientific discoveries motivated chemists to find and catalog all the elements that make up our universe. To do so, they had to carefully observe substances in order to identify them, and then try to break them apart by any possible means. If a substance could be broken apart, then they had even more work to do: They observed and tried to break apart each of those materials. If a substance could not be further broken apart, then it most probably was an element.

We now know of 111 different kinds of elements, and the search for new ones continues. Scientist try to build superheavy elements to determine the limits of the internal structure of the atom.

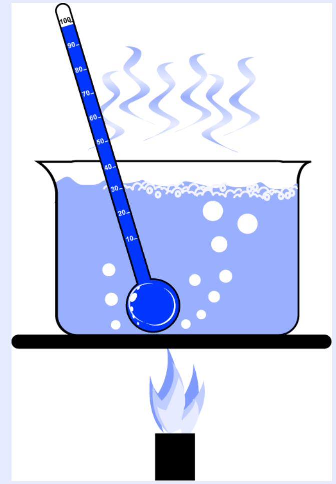
Groups of elements

Elements that are part of the same group act alike

As chemists worked on determining which substances were elements, they noticed that some elements acted very much like other elements. For example, one atom of some metals always reacts with two atoms of oxygen. Chemists called these similar elements a **group of elements**.

By keeping track of how each element reacted with other elements, chemists soon identified a number of groups. At the same time, they also began figuring out ways to determine the relative masses of different elements. Soon chemists were organizing this information into tables. The modern *periodic table of elements* is descended from the work of these early chemists.

Elements & alchemy



On a quest to make gold, the alchemist Hennig Brand (1630-1692) boiled urine and collected the vapor. The cooled vapor condensed and became a white waxy substance that glowed in the dark. Brand had isolated the element phosphorus, the first element discovered in modern times. Scientists know now that phosphorus, while poisonous in its elemental form, is an essential element in DNA, the molecule that carries our genetic makeup.

The periodic table of elements

If you read across the rows of the table, the elements are listed in order of increasing atomic number and weight. Each row indicates how many electrons are in each region of the electron cloud. As you remember, the electrons of an atom are found in an electron cloud around the nucleus. The electron cloud is divided into energy levels. By looking at the row number, you can figure out how many energy levels are filled and how many electrons are partially filling each region of the energy levels. For example, carbon, in row 2, has a filled energy level 1 and four electrons in energy level 2. You know that carbon has four electrons in energy level 2 because it is the fourth element in row 2. Recall that higher energy levels overlap, so this system becomes more complex the higher you go up on the periodic table. The outermost region of the electron cloud contains the valence electrons and is called the *valence shell*.

Partial Periodic Table

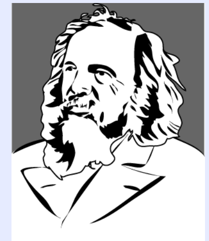
Number of valence electrons in parentheses

Transition metals - groups 3 - 12
(Variable number of valence electrons)

(1)	(2)											(3)	(4)	(5)	(6)	(7)	(8)
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**
H 1																	He 2
Li 3	Be 4											B 5	C 6	N 7	O 8	F 9	Ne 10
Na 11	Mg 12											Al 13	Si 14	P 15	S 16	Cl 17	Ar 18
K 19	Ca 20	Sc 21	Ti 22	V 23	Cr 24	Mn 25	Fe 26	Co 27	Ni 28	Cu 29	Zn 30	Ga 31	Ge 32	As 33	Se 34	Br 35	Kr 36
Rb 37	Sr 38	Y 39	Zr 40	Nb 41	Mo 42	Tc 43	Ru 44	Rh 45	Pd 46	Ag 47	Cd 48	In 49	Sn 50	Sb 51	Te 52	I 53	Xe 54

Because the most stable forms of atoms have either full or empty valence shells, the groups of elements relate to the way the valence shells of each element are filled. For example, the last column contains the group known as the noble gases. They don't react easily with any other elements, because this group has atoms with completely filled valence shells. We will study valence electrons in the next chapter.

The periodic table



In 1871, the Russian chemist Dimitri Mendeleev (1834-1907) organized information about all the known elements in a table that visually organized the similarities between them. It became known as the periodic table of elements.

Mendeleev placed each element on the table in a certain row and column based on its properties. Each column represents a group of elements with similar chemical behavior. For example, copper, silver, and gold are in the same column. How are these elements similar?

Reading the periodic table

As you just learned, the arrangement of each element in the periodic table conveys a lot of information about it. The individual listing can tell us even more about the element. A periodic table may show some, or, as in figure 18.17, all of the information for each element.

Chemical symbol

The **chemical symbol** is an abbreviation of the element's name. Unlike the abbreviations for a U.S. state, these symbol-abbreviations are not always obvious. Many are derived from the element's name in a language such as Latin or German.

In figure 18.17, Ag is the chemical symbol for the element silver. Its symbol comes from the Latin word for silver, *argentum*. Note that the first letter in the symbol is upper case and the second is lower case. Writing symbols this way allows us to represent all of the elements without getting confused. There is a big difference between the element cobalt, with its symbol Co, and the compound carbon monoxide, written as CO. What is the difference between Si and SI?

Atomic number

As you learned in the last section, the atomic number is the number of protons all atoms of that element have in their nuclei. If the atom is neutral, it will have the same number of electrons as well.

Mass numbers

The **mass number** of an element is the total number of protons and neutrons in the nucleus. In figure 18.17, you see that silver has two mass numbers, 107 and 109. This means that there are two types of silver atoms, one that has 47 protons and 60 neutrons, and one that has 47 protons and 62 neutrons. Forms of the same element with different mass numbers are called **isotopes**.

Atomic mass

Although the mass number of an isotope and the atomic number of an element are always whole numbers because they simply count numbers of particles, the **atomic mass** of an element is not. The atomic mass is the average mass of all the known isotopes of the element. It takes into consideration the relative abundance of the various isotopes. The atomic mass of an element is expressed in **atomic mass units**, or amu. *Each atomic mass unit is defined as the mass of 1/12 the mass of a carbon-12 atom* (6 protons and 6 neutrons in the nucleus, plus 6 electrons outside the nucleus). Since carbon consists of a mixture of naturally occurring isotopes, the atomic mass of carbon is not exactly 12 amu. You will learn more about how atomic mass is determined in the next chapter.

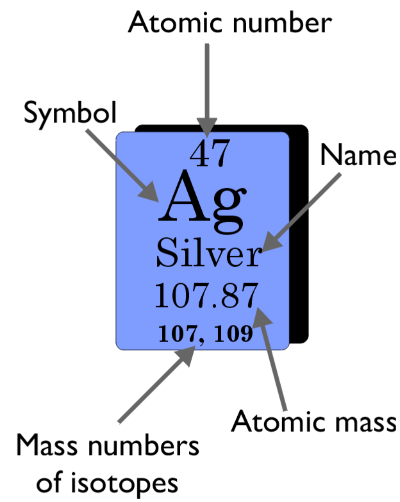


Figure 18.17: *The breadth of information the periodic table can provide.*

element	symbol	origin
copper	Cu	*cuprium*
gold	Au	*aurum*
iron	Fe	*ferrum*
lead	Pb	*plumbum*
potassium	K	*kalium*
silver	Ag	*argentum*
sodium	Na	*natrium*
tin	Sn	*stannum*

Figure 18.18: *The symbols for some elements don't always obviously match their names.*