12.3 The Periodic Table of the Elements

How many elements make up the universe? The only way to tell if a substance is an element is to try and chemically break it down into other substances by any possible means. A substance that can be chemically broken apart cannot be an element. As of this writing, scientists have identified 117 confirmed elements. Only about 90 of these elements occur naturally. The others are made in laboratories.

VOCABULARY

periodic table - a chart that organizes the elements by their chemical properties and increasing atomic number.

period - a row of the periodic table.

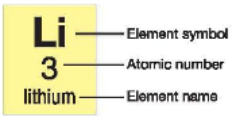
group - a column of the periodic table.

The periodic table

The modern periodic table

As chemists worked on identifying the true elements, they noticed that some elements acted like other elements. For example, the soft metals lithium, sodium, and potassium always combine with oxygen in a ratio of two atoms of metal to one atom of oxygen (Figure 12.17). By keeping track of how each element combined with other elements, scientists began to recognize repeating patterns. From this data, they developed the first periodic table of the elements. The **periodic table** organizes the elements according to how they combine with other elements due to their chemical properties.

Organization of the periodic table



The periodic table is organized in order of increasing atomic number. The lightest element (hydrogen) is at the upper left. The heaviest is on the lower right. Each element corresponds to one box in the periodic table, identified with the element symbol.

The periodic table is further divided into periods and groups. Each horizontal row is called a **period**. Across any period, the properties of the elements gradually change. Each vertical column is called a **group**. Groups of elements have similar properties. The *main group elements* are Groups 1 and 2 and Groups 13 through 18 (the tall columns of the periodic table). Elements in Groups 3 through 12 are called the *transition elements*. The inner transition elements, called *lanthanides* and *actinides*, are often shown below the bottom row of the chart in order for the chart to fit on a page.

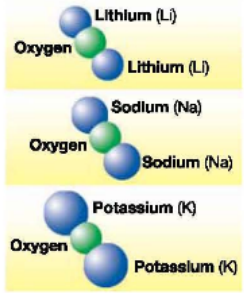


Figure 12.17: *The metals lithium, sodium, and potassium all form compounds with a ratio of two atoms of the metal to one atom of oxygen. All the elements in Group 1 of the periodic table form similar compounds.*

Reading the periodic table

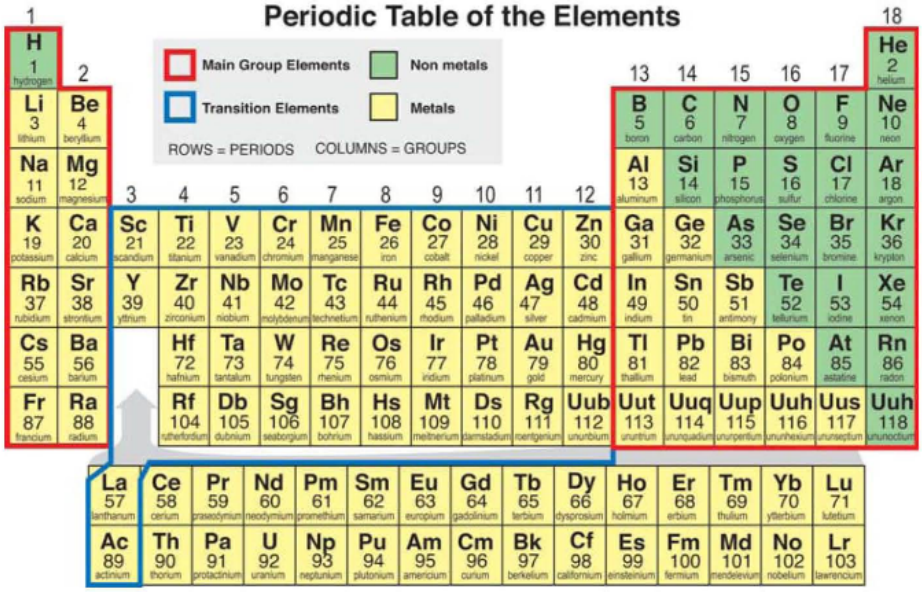
Metals, nonmetals, and metalloids

Most of the elements are **metals**. A metal is typically shiny, opaque, and a good conductor of heat and electricity as a pure element. Metals are also ductile, which means they can be bent into different shapes without breaking. **Nonmetals** are poor conductors of heat and electricity. Solid nonmetals are brittle and appear dull. With the exception of hydrogen, the nonmetals are on the right side of the periodic table. The elements on the border between metals and nonmetals are called *metalloids*. Silicon is an example of a metalloid element with properties in between those of metals and nonmetals.

VOCABULARY

metals - elements that are typically shiny and good conductors of heat and electricity.

nonmetals - elements that are poor conductors of heat and electricity.



Atomic mass

Atomic mass units The mass of individual atoms is so small that the numbers are difficult to work with. To make calculations easier, scientists came up with the **atomic mass unit** (amu). One atomic mass unit is about the mass of a single proton (or neutron). In laboratory units, 1 amu is 1.66×10^{-24} gram. That's 0.00000000000000000000000166 gram!

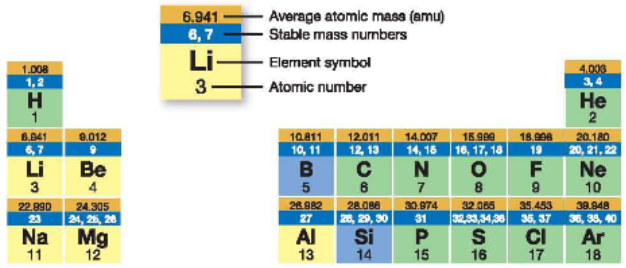
Atomic mass and isotopes The **atomic mass** is the *average* mass (in amu) of an atom of each element. Atomic masses differ from mass numbers because most elements in nature contain more than one isotope (see chart below). For example, the atomic mass of lithium is 6.94 amu. That does NOT mean there are 3 protons and 3.94 neutrons in a lithium atom! On average, out of every 100 atoms of lithium, 6 atoms are Li-6 and 94 atoms are Li-7 (Figure 12.18). The *average* atomic mass of lithium is 6.94 because of the mixture of isotopes.

Atomic number review As you learned earlier, 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.

VOCABULARY

atomic mass unit - a unit of mass equal to 1.66×10^{-24} grams.

atomic mass - the average mass of all the known isotopes of an element, expressed in amu.



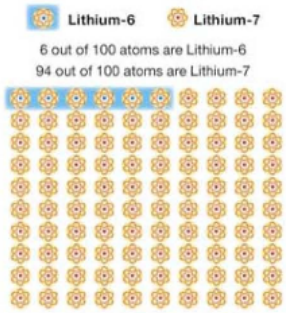


Figure 12.18: *Naturally occurring elements have a mixture of isotopes.*

Groups of the periodic table

Alkali metals

All of the elements in the different groups of the periodic table have similar chemical properties. The first group is known as the **alkali metals**. Some examples of this group are the elements lithium (Li), sodium (Na), and potassium (K). The alkali metals are soft and silvery in their pure form and are highly reactive. Each of them combines in a ratio of two to one with oxygen. For example, lithium oxide has two atoms of lithium per atom of oxygen.

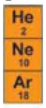
Group 2 metals

Some examples of Group 2 metals are beryllium (Be), magnesium (Mg), and calcium (Ca). These metals also form oxides, however, they combine one-to-one with oxygen. For example, beryllium oxide has one beryllium atom per each oxygen atom.

Halogens

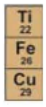
The **halogens** are on the right-hand side of the periodic table. These elements tend to be toxic in their pure form. Some examples are fluorine (F), chlorine (Cl), and bromine (Br). The halogens are also very reactive and are rarely found in pure form. When combined with alkali metals, they form salts, such as sodium chloride (NaCl) and potassium chloride (KCl).

Noble gases



On the far right of the periodic table are the **noble gases**. Some examples of this group are the elements helium (He), neon (Ne), and argon (Ar). These elements do not naturally form chemical bonds with other atoms and are almost always found in their pure state. They are sometimes called *inert gases* for this reason.

Transition metals



In the middle of the periodic table are the transition metals, including titanium (Ti), iron (Fe), and copper (Cu). These elements are usually good conductors of heat and electricity. For example, the wires that carry electricity in your school are made of copper. Figure 12.19 shows the location of the groups of elements on the periodic table.

VOCABULARY

alkali metals - elements in the first group of the periodic table.

halogens - elements in the group containing fluorine, chlorine, and bromine, among others.

noble gases - elements in the group containing helium, neon, and argon, among others.

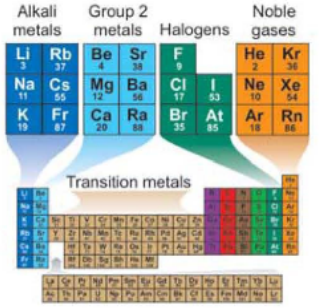


Figure 12.19: *Groups of the periodic table.*

Energy levels and the periodic table

Period 1 is the first energy level

The periods (rows) of the periodic table correspond to the energy levels in the Bohr model of the atom (Figure 12.20). The first energy level can accept up to two electrons. Hydrogen (H) has one electron and helium (He) has two. These two elements complete the first period.

Period 2 is the second energy level

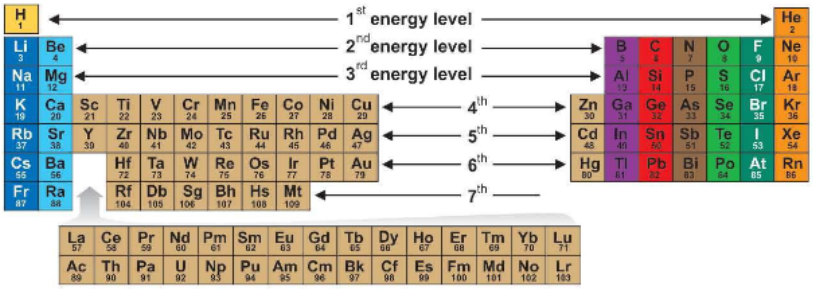
The next element, lithium (Li), has three electrons. Lithium begins the second period because the third electron goes into the second energy level. The second energy level can hold eight electrons, so there are eight elements in the second row of the periodic table, ending with neon (Ne). Neon has 10 electrons, which completely fill the second energy level.

Period 3 is the third energy level

Sodium (Na) has 11 electrons, and starts the third period because the eleventh electron goes into the third energy level. We know of elements with up to 118 electrons. These elements have their outermost electrons in the seventh energy level.

Outer electrons

As we will see in the next chapter, the outermost electrons in an atom are the ones that interact with other atoms. The outer electrons are the ones in the highest energy level. Electrons in the completely filled inner energy levels do not participate in forming chemical bonds.



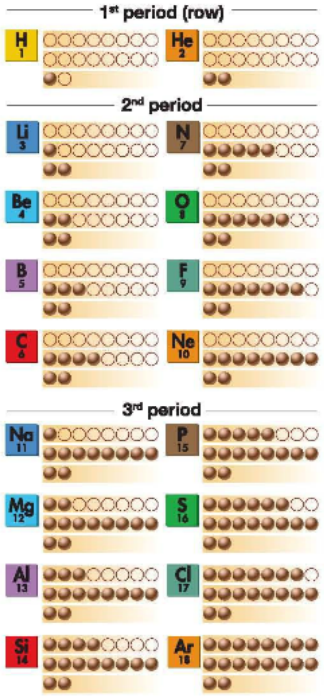


Figure 12.20: *The rows (periods) of the periodic table correspond to the energy levels for the electrons in an atom.*

Section 12.3 Review

1. Groups of the periodic table correspond to elements with:
   a. the same mass number
   b. the same atomic number
   c. similar chemical properties
   d. similar numbers of neutrons
2. Which element is the atom shown in Figure 12.21?
3. Name three elements that have similar chemical properties to oxygen.
4. The atomic mass unit (amu) is:
   a. the mass of a single atom of carbon
   b. one-millionth of a gram
   c. approximately the mass of a proton
   d. approximately the mass of an electron
5. Which element belongs in the empty space in Figure 12.22?
6. The outermost electrons of the element vanadium (atomic #23) are in which energy level of the atom? How do you know?
7. The elements fluorine, chlorine, and bromine are in which group of the periodic table?
   a. the alkali metals
   b. the oxygen-like elements
   c. the halogens
   d. the noble gases
8. Which three metals are in the third period (row) of the periodic table?

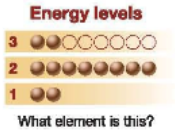


Figure 12.21: *Question 2.*

			He 2
N 7	O 8	F 9	Ne 10
P 15	S 16	?	Ar 18
As 33	Se 34	Br 35	Kr 36
Sb 51	Te 52	I 53	Xe 54

Figure 12.22: *Question 5.*