

1.3

KEY CONCEPT

The periodic table is a map of the elements.



BEFORE, you learned

- The periodic table is organized into groups of elements with similar characteristics
- The periodic table organizes elements according to their properties



NOW, you will learn

- How elements are classified as metals, nonmetals, and metalloids
- About different groups of elements
- About radioactive elements

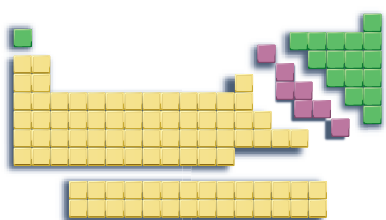
VOCABULARY

reactive p. 26
 metal p. 27
 nonmetal p. 29
 metalloid p. 30
 radioactivity p. 30
 half-life p. 32

THINK ABOUT

How are elements different?

The photograph shows common uses of the elements copper, aluminum, and argon: copper in a penny, aluminum in a pie plate, and argon in a light bulb. The atoms of each element is located in a different part of the periodic table, and each has a very different use. Find these elements on the periodic table. What other elements are near these?



■ metal ■ metalloid ■ nonmetal

The periodic table has distinct regions.

The periodic table is a kind of map of the elements. Just as a country's location on the globe gives you information about its climate, an atom's position on the periodic table indicates the properties of its element. The periodic table has three main regions—metals on the left, nonmetals (except hydrogen) on the right, and metalloids in between. The periodic table on pages 20 and 21 indicates these regions with different colors. A yellow box indicates a metal; green, a nonmetal; and purple, a metalloid.

Its position in the table also indicates how reactive an element is. The term **reactive** indicates how likely an element is to undergo a chemical change. Most elements are somewhat reactive and combine with other materials. The atoms of the elements in Groups 1 and 17 are the most reactive. The elements of Group 18 are the least reactive of all the elements.

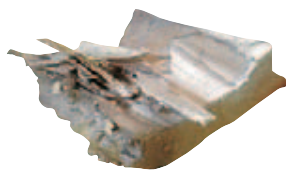


CHECK YOUR READING

How does the periodic table resemble a map?

Most elements are metals.

When you look at the periodic table, it is obvious from the color that most of the elements are metals. In general, **metals** are elements that conduct electricity and heat well and have a shiny appearance. Metals can be shaped easily by pounding, bending, or being drawn into a long wire. Except for mercury, which is a liquid, metals are solids at room temperature.



Sodium is a metal that is so soft it can be cut with a knife at room temperature.



You probably can name many uses for the metal **copper**.

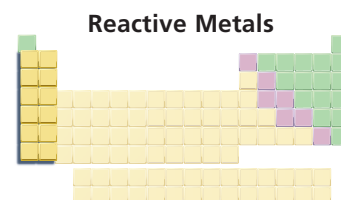


Aluminum is often used for devices that must be strong and light.

Reactive Metals

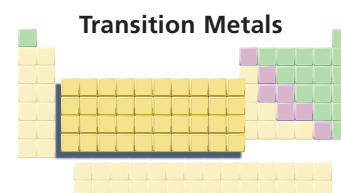
The metals in Group 1 of the periodic table, the alkali metals, are very reactive. Sodium and potassium are often stored in oil to keep them away from air. When exposed to air, these elements react rapidly with oxygen and water vapor. The ions of these metals, Na^+ and K^+ , are important for life, and play an essential role in the functioning of living cells.

The metals in Group 2, the alkaline earth metals, are less reactive than the alkali metals. They are still more reactive than most other metals, however. Calcium ions are an essential part of your diet. Your bones and teeth contain calcium ions. Magnesium is a light, inexpensive metal that is often combined with other metals when a lightweight material is needed, such as for airplane frames.



Transition Metals

The elements in Groups 3–12 are called the transition metals. Among these metals are some of the earliest known elements, such as copper, gold, silver, and iron. Transition metals are generally less reactive than most other metals. Because gold and silver are easily shaped and do not react easily, they have been used for thousands of years to make jewelry and coins. Ancient artifacts made from transition metals can be found in many museums and remain relatively unchanged since the time they were made. Today, dimes and quarters are made of copper and nickel, and pennies are made of zinc with a coating of copper. Transition metal ions even are found in the foods you eat.

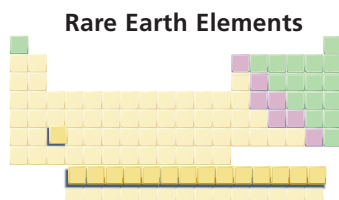


The properties of the transition metals make them particularly important to industry. Iron is the main part of steel, a material used for bridges and buildings. Most electric wires and many other electrical devices are made of copper. Copper is also used to make water pipes. Indeed, it would be hard to think of an industry that doesn't make use of transition metals.

Although other transition metals may be less familiar, many of them are important for modern technology. The tiny coil of wire inside incandescent light bulbs is made of tungsten. Platinum is in the catalytic converters that reduce pollution from automobile engines.

For many applications, two or more metals are combined to form an alloy. Alloys can be stronger, less likely to corrode, or easier to shape than pure metals. Steel, which is stronger than the pure iron it contains, often includes other transition metals, such as nickel, chromium, or manganese. Brass, an alloy of copper and zinc, is stronger than either metal alone. Jewelry is often made of an alloy of silver and copper, which is stronger than pure silver.

Rare Earth Elements



The rare earth elements are the elements in the top row of the two rows of metals that are usually shown outside the main body of the periodic table. Taking these elements out of the main body of the table makes the table more compact. The rare earth elements are often referred to as lanthanides because they follow the element lanthanum (La) on the table. They are called rare earth elements because scientists once thought that these elements were available only in tiny amounts in Earth's crust. As mining methods improved, scientists learned that the rare earths were actually not so rare at all—only hard to isolate in pure form.

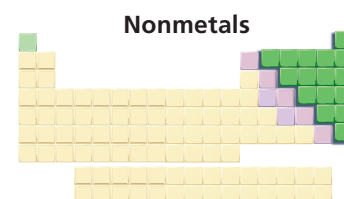
More and more uses are being found for the rare earth elements. Europium (Eu), for example, is used as a coating for some television tubes. Praseodymium (Pr) provides a protective coating against harmful radiation in the welder's helmet in the photograph on the right.



Nonmetals and metalloids have a wide range of properties.

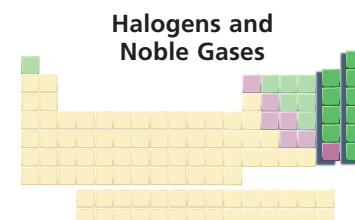
The elements to the right side of the periodic table are called **nonmetals**. As the name implies, the properties of nonmetals tend to be the opposite of those of metals. The properties of nonmetals also tend to vary more from element to element than the properties of the metals do. Many of them are gases at room temperature, and one—bromine—is a liquid. The solid nonmetals often have dull surfaces and cannot be shaped by hammering or drawing into wires. Nonmetals are generally poor conductors of heat and electric current.

The main components of the air that you breathe are the nonmetal elements nitrogen and oxygen. Nitrogen is a fairly unreactive element, but oxygen reacts easily to form compounds with many other elements. Burning and rusting are two familiar types of reactions involving oxygen. Compounds containing carbon are essential to living things. Two forms of the element carbon are graphite, which is a soft, slippery black material, and diamond, a hard crystal. Sulfur is a bright yellow powder that can be mined from deposits of the pure element.



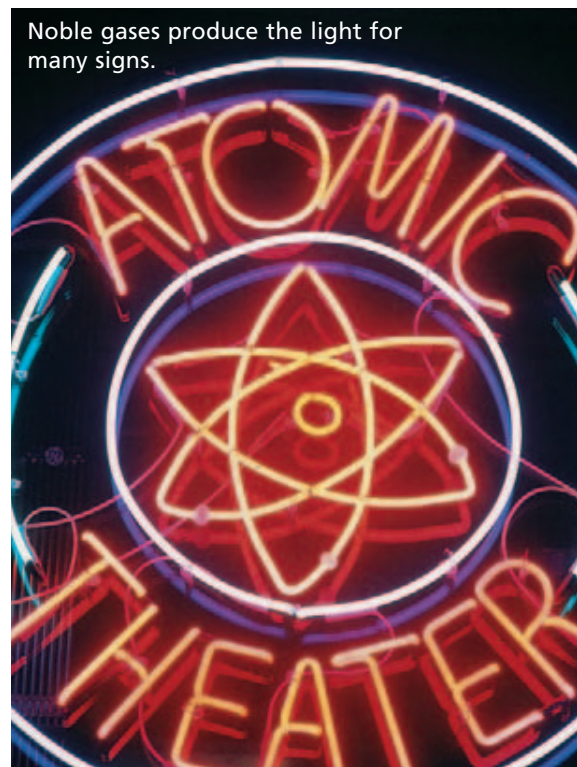
Halogens

The elements in Group 17 are commonly known as halogens, from Greek words meaning “forming salts.” Halogens are very reactive nonmetals that easily form compounds called salts with many metals. Because they are so reactive, halogens are often used to kill harmful microorganisms. For example, the halogen chlorine is used to clean drinking water and to prevent the growth of algae in swimming pools. Solutions containing iodine are often used in hospitals and doctors’ offices to kill germs on skin.



Noble Gases

Group 18 elements are called the noble, or inert, gases because they almost never react with other elements. Argon gas makes up about one percent of the atmosphere. The other noble gases are found in the atmosphere in smaller amounts. Colorful lights, such as those in the photograph on the right, are made by passing an electric current through tubes filled with neon, krypton, xenon, or argon gas. Argon gas also is placed in tungsten filament light bulbs, because it will not react with the hot filament.

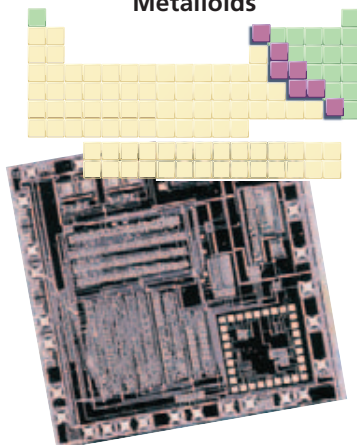


CHECK YOUR
READING

Where on Earth can you find noble gases?

Metalloids

Metalloids



The metalloid silicon is found in sand and in computer microchips.

Metalloids are elements that have properties of both metals and nonmetals. In the periodic table, they lie on either side of a zigzag line separating metals from nonmetals. The most common metalloid is silicon. Silicon atoms are the second most common atoms in Earth's crust.

Metalloids often make up the semiconductors found in electronic devices. Semiconductors are special materials that conduct electricity under some conditions and not under others. Silicon, gallium, and germanium are three semiconductors used in computer chips.

Some atoms can change their identity.

The identity of an element is determined by the number of protons in its nucleus. Chemical changes do not affect the nucleus, so chemical changes don't change one type of atom into another. There are, however, conditions under which the number of protons in a nucleus can change and so change the identity of an atom.

Recall that the nucleus of an atom contains protons and neutrons. Attractive forces between protons and neutrons hold the nucleus together even though protons repel one another. We say an atomic nucleus is stable when these attractive forces keep it together.

Each element has isotopes with different numbers of neutrons. The stability of a nucleus depends on the right balance of protons and neutrons. If there are too few or too many neutrons, the nucleus may become unstable. When this happens, particles are produced from the nucleus of the atom to restore the balance. This change is accompanied by a release of energy.

If the production of particles changes the number of protons, the atom is transformed into an atom of a different element. In the early 1900s, the Polish physicist Marie Curie named the process by which atoms produce energy and particles **radioactivity**. Curie was the first person to isolate polonium and radium, two radioactive elements.

An isotope is radioactive if the nucleus has too many or too few neutrons. Most elements have radioactive isotopes, although these isotopes are rare for small atoms. For the heaviest of elements—those beyond bismuth (Bi)—all of the isotopes are radioactive.

Scientists study radioactivity with a device called a Geiger counter. The Geiger counter detects the particles from the breakup of the atomic nucleus with audible clicks. More clicks indicate that more particles are being produced.



CHECK YOUR
READING

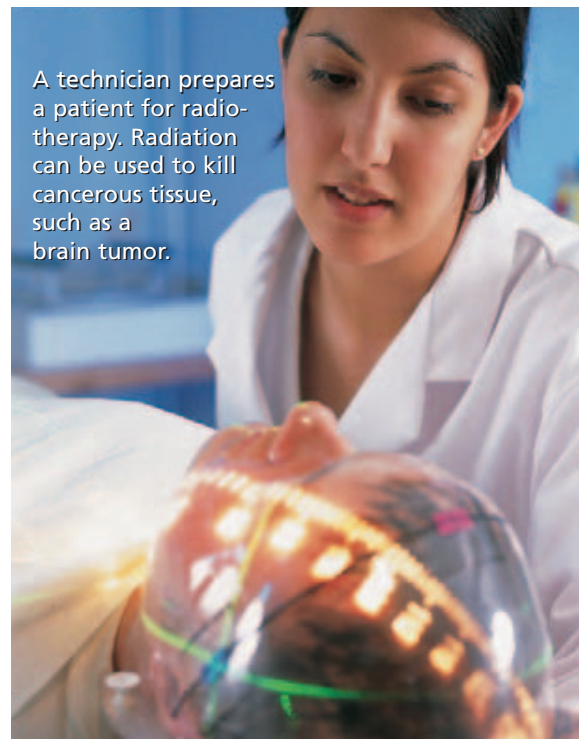
How can an atom of one element change into an atom of a different element?

Uses of Radioactivity in Medicine

The radiation produced from unstable nuclei is used in hospitals to diagnose and treat patients. Some forms of radiation from nuclei are used to destroy harmful tumors inside a person's body without performing an operation. Another medical use of radiation is to monitor the activity of certain organs in the body. A patient is injected with a solution containing a radioactive isotope. Isotopes of a given atom move through the body in the same way whether or not they are radioactive. Doctors detect the particles produced by the radioactive isotopes to determine where and how the body is using the substance.

Although radiation has its benefits, in large doses it is harmful to living things and should be avoided. Radiation can damage or kill cells, and the energy from its particles can burn the skin. Prolonged exposure to radiation has been linked to cancer and other health problems.

A technician prepares a patient for radiotherapy. Radiation can be used to kill cancerous tissue, such as a brain tumor.



INVESTIGATE Radioactivity

How quickly can atoms change?

PROCEDURE

- 1 Put 50 pennies in a bag. The pennies represent 50 atoms.
- 2 Pour out the pennies.
- 3 Count the number of pennies that landed head side up. These represent atoms whose nuclei changed.
- 4 Refill the bag with only the pennies that landed tail side up.
- 5 Repeat steps 2–4 until all of the pennies have landed head side up. Each time you pour out the pennies counts as one turn.
- 6 Construct a graph with the number of atoms that changed on the y-axis and the number of turns on the x-axis.

WHAT DO YOU THINK?

- After one turn, how many atoms had changed? had not changed?
- In how many turns did all the atoms change?
- From looking at your graph, what can you conclude about the rate of radioactive change?

CHALLENGE If you used a different number of pennies, would your results be different? In what way?

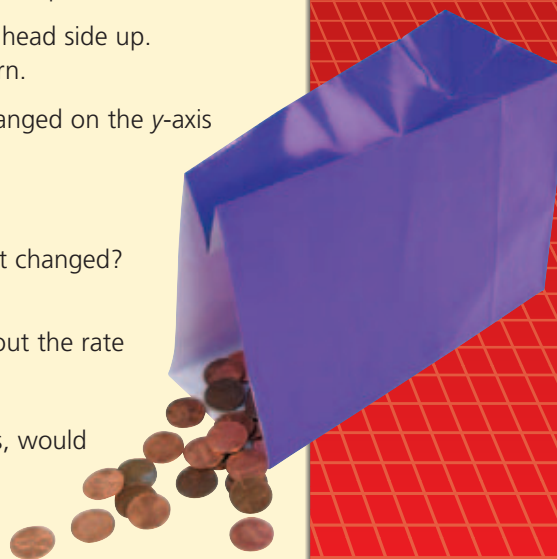
SKILL FOCUS

Modeling

MATERIALS

- 50 pennies
- bag
- graph paper

TIME
30 minutes





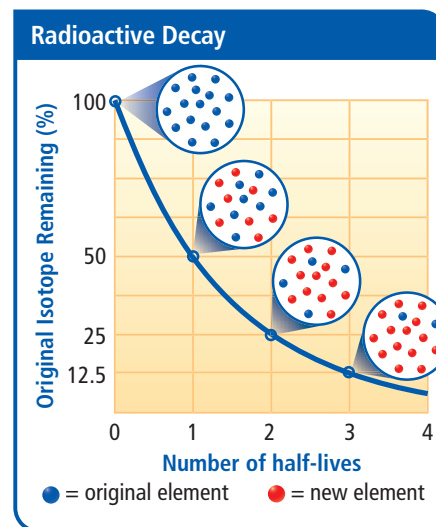
Watch how a radioactive element decays over time.

Radioactive Decay

Radioactive atoms produce energy and particles from their nuclei. The identity of these atoms changes because the number of protons changes. This process is known as radioactive decay. Over time, all of the atoms of a radioactive isotope will change into atoms of another element.

Radioactive decay occurs at a steady rate that is characteristic of the particular isotope. The amount of time that it takes for one-half of the atoms in a particular sample to decay is called the **half-life** of the isotope. For example, if you had 1000 atoms of a radioactive isotope with a half-life of 1 year, 500 of the atoms would change into another element over the course of a year. In the next year, 250 more atoms would decay. The illustration to the right shows how the amount of the original isotope would decrease over time.

The half-life is a characteristic of each isotope and is independent of the amount of material. A half-life is also not affected by conditions such as temperature or pressure. Half-lives of isotopes can range from a small fraction of a second to many billions of years.



Half-Lives of Selected Elements

Isotope	Half-Life
Uranium-238	4,510,000,000 years
Carbon-14	5,730 years
Radon-222	3.82 days
Lead-214	27 minutes
Polonium-214	.00016 seconds

1.3 Review

KEY CONCEPTS

1. What are the three main classes of elements in the periodic table?
2. What are the major characteristics of metals?
3. How can an atom of one element change to an atom of another element?

CRITICAL THINKING

4. **Compare** Use the periodic table to determine whether a carbon or a fluorine atom would be more reactive.
5. **Calculate** What fraction of a radioactive sample remains after three half-lives?

CHALLENGE

6. **Analyze** Why do you think the noble gases were among the last of the naturally occurring elements to be discovered?