CHAPTER 7

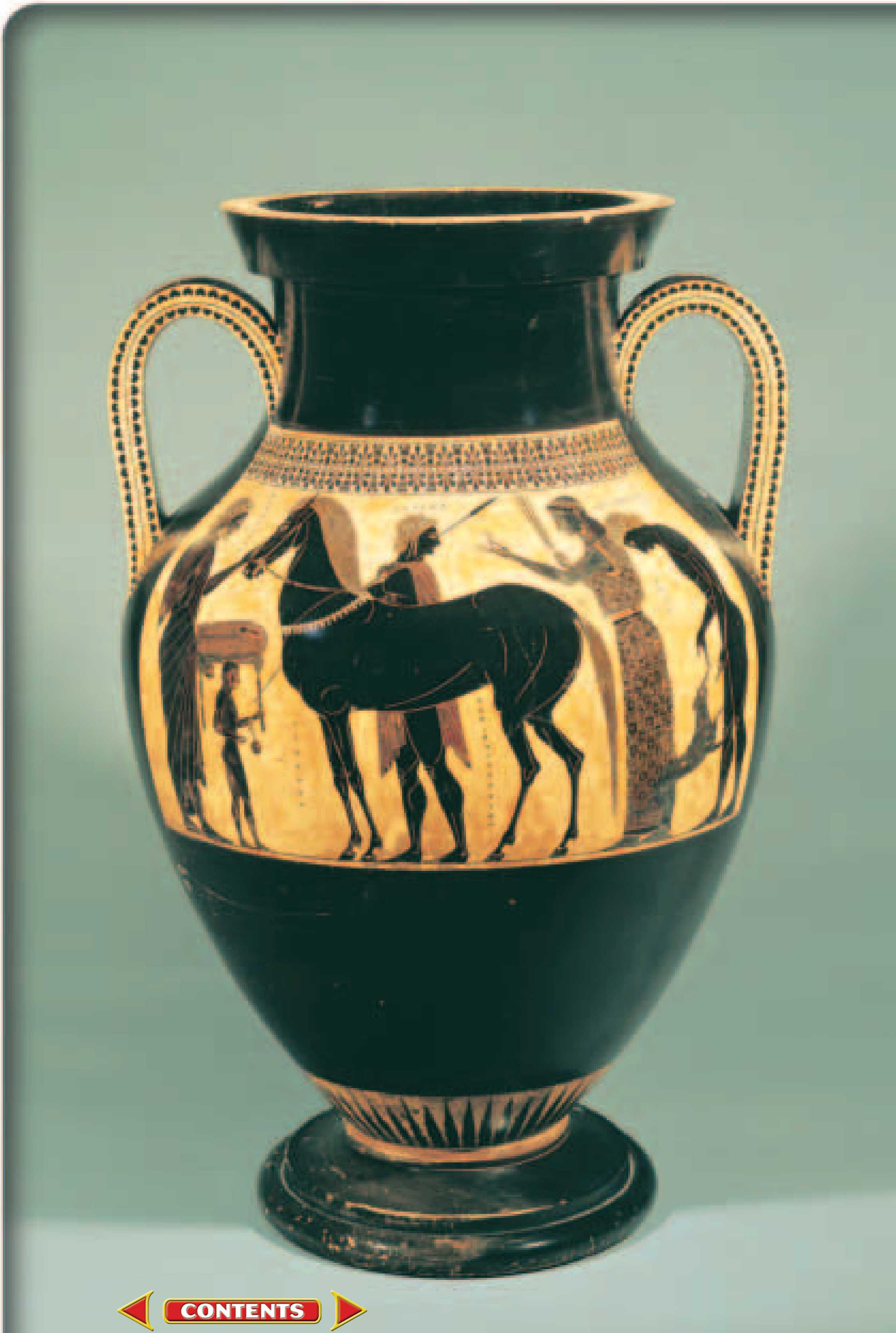
The Elements

What You'll Learn

- You will classify elements based on their electron configurations.
- You will relate electron configurations to the properties of elements.
- You will identify the sources and uses of selected elements.

Why It's Important

What you know about an element can affect the choices you make. Before all of its properties were known, toxic lead glazes were used to seal clay storage containers. Modern steel cans are lined with tin, which is a non-toxic element similar to lead.



Chemistry Online

Visit the Chemistry Web site at **chemistrymc.com** to find links about the elements.

Some historians think that drinking wine from lead-glazed vases contributed to the fall of the Roman Empire.

DISCOVERY LAB

Materials

- bar magnet
- aluminum foil
- paper clips
- coins
- hair pin
- soda cans
- empty soup cans
- variety of other items

Magnetic Materials

You know that magnets can attract some materials. In this lab, you will classify materials based on their interaction with a magnet and look for a pattern in your data.

Safety Precautions

Always wear your safety goggles during lab.

Procedure

1. Working with a partner, review the properties of magnets. Arrange the bar magnets so that they are attracted to one another. Then arrange them so that they repel one another.
2. Test each item with your magnet. Record your observations.
3. Test as many other items in the classroom as time allows. Predict the results before testing each item.

Analysis

Look at the group of items that were attracted to the magnet. What do these items have in common? In Section 7.3, you will learn more about what determines whether a material is magnetic.

Section 7.1

Properties of s-Block Elements

Objectives

- **Explain** how elements in a given group are both similar and different.
- **Discuss** the properties of hydrogen.
- **Describe** and **compare** the properties of alkali metals and alkaline earth metals.

Vocabulary

diagonal relationship

If you could travel through the universe to collect samples of matter, you would find 92 naturally occurring elements. The amount of each element would vary from location to location. Helium, which is the second most common element in the universe, is much less abundant here on Earth. Oxygen is the most abundant element on Earth. Per kilogram of Earth's crust, there are 4.64×10^5 mg of oxygen, but only 8×10^{-3} mg of helium. Elements with atomic numbers greater than 92 do not exist in nature. These synthetic elements must be created in laboratories or nuclear reactors.

Representative Elements

Recall from Chapter 6 that no one element can represent the properties of all elements. However, the elements in groups 1A through 8A are called representative elements because, as a group, they display a wide range of physical and chemical properties. For example, groups 1A through 8A include metals and nonmetals; highly reactive elements and some that hardly react at all; and elements that are solids, liquids, and gases at room temperature.

Elements in any given group on the periodic table have the same number of valence electrons. The number and location of valence electrons determine the chemistry of an element. Thus, elements within a group have similar physical and chemical properties. Representative elements display the range of possible valence electrons from one in group 1A to eight in group 8A. The valence electrons of representative elements are in s or p orbitals.

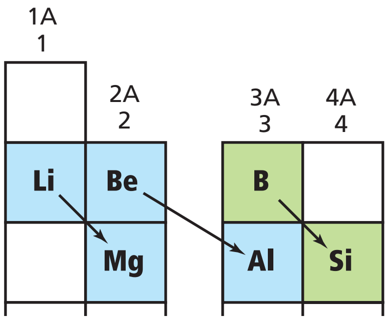


Figure 7-1

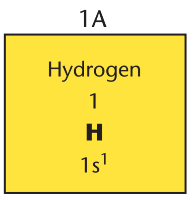
The diagonal arrows connect pairs of elements that have similar properties.

Why are the properties of elements within a group similar but not identical? Although elements within a group have the same number of valence electrons, they have different numbers of nonvalence electrons. Remember what happens as the atomic number increases within a group. As new levels of electrons are added, the atomic radius increases and the shielding effect increases. As a result, the ionization energy decreases. A lower ionization energy makes it easier for an element to lose electrons.

Recall that metals tend to lose electrons. Thus, the lower the ionization energy, the more reactive the metal. For a group of metals, reactivity *increases* as the atomic number increases. The opposite is true for nonmetals because nonmetals tend to gain electrons. The higher the ionization energy of a nonmetal, the more reactive the nonmetal. For a group of nonmetals, reactivity *decreases* as the atomic number increases. Of the representative elements, which is the most reactive metal? Which is the most reactive nonmetal? (Hint: What is the trend for ionization energy across a period?)

Diagonal relationships Some period 2 elements do not behave as predicted by their locations on the table. Often, the lightest element in a group is the least representative. These light elements have more in common with the period-3 element in the next group than with the period-3 element in their own group. These close relationships between elements in neighboring groups are called **diagonal relationships.** Three diagonal relationships that you will study later in this chapter are shown in **Figure 7-1.**

Hydrogen



Hydrogen is placed in group 1A because it has one valence electron. This placement does not mean that hydrogen has the same properties as the metals in group 1A. In fact, hydrogen shares many properties with the nonmetals in group 7A. Because hydrogen has both metallic and nonmetallic properties, it is not considered part of any group.

When Henry Cavendish discovered hydrogen in 1766, he called it "flammable air" because it burned when ignited in air. In 1783, Antoine Lavoisier named hydrogen for the water that forms when hydrogen and oxygen combine. Lavoisier used the Greek roots for water (*hydro*) and to form (*genes*). **Figure 7-2** shows the explosive reaction of hydrogen and oxygen that occurred when a passenger airship crashed in 1937. The airship was kept aloft by hydrogen, which is a colorless, odorless, lighter-than-air gas under normal conditions of temperature and pressure. As a part of water and most other compounds found in organisms, hydrogen is essential to life.

Figure 7-2

When the *Hindenburg* crashed in New Jersey, the hydrogen that kept the airship aloft came in contact with oxygen and exploded.

The universe contains more than 90% hydrogen by mass. There are three naturally occurring hydrogen isotopes: protium, deuterium, and tritium. The vast majority of hydrogen, 99.985%, is protium (hydrogen-1), which has no neutrons. Deuterium (hydrogen-2), which makes up 0.015% of hydrogen, has one neutron. Tritium (hydrogen-3), which has two neutrons, is a radioactive isotope. It is produced when cosmic rays bombard water in the atmosphere.

The physical properties of isotopes differ slightly because of differences in atomic mass. For example, water that contains deuterium is called heavy water because the neutrons in deuterium add mass to the water molecule. Some nuclear reactors use heavy water to help keep the chain reaction going. The heavy water slows down (or moderates) the neutrons produced during nuclear fission so that they can be absorbed by the uranium fuel. You will learn more about nuclear reactions in Chapter 25.

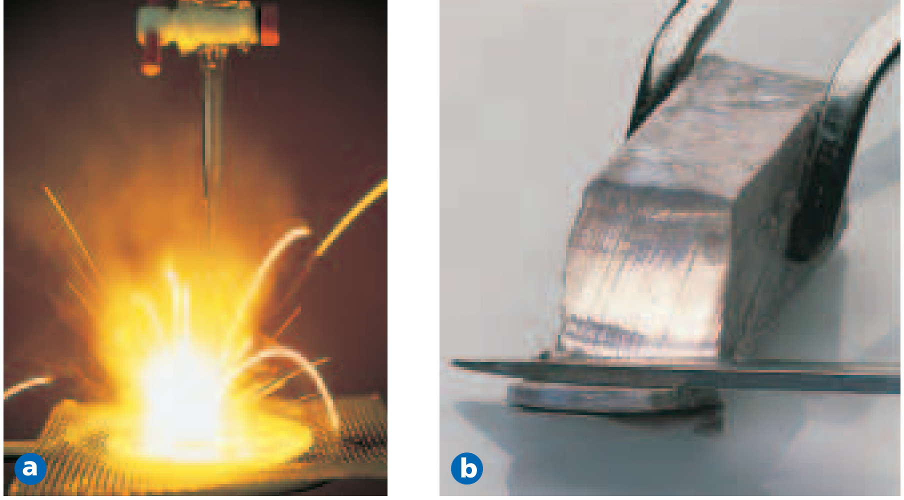


Figure 7-3

a The reaction of potassium and water produces hydrogen gas and an alkaline solution of potassium hydroxide. The heat produced by the reaction ignites the hydrogen.
b Sodium is as soft as cold butter. The shiny surface dulls as it reacts with oxygen.

Hydrogen's single valence electron explains its unusual set of metallic and nonmetallic properties. When a hydrogen atom acts like a nonmetal, it gains an electron and achieves the stable electron configuration of helium. When hydrogen reacts with a nonmetal such as oxygen, it acts like a metal. Hydrogen loses its single electron and forms a hydrogen ion (H^+). A hydrogen ion is a nucleus with a single proton. Does a hydrogen ion contain any neutrons? In Chapter 19, you will learn the role hydrogen ions play in the chemistry of acids and bases.

Hydrogen can be produced in the laboratory when a metal reacts with an acid or when electricity is used to separate water into hydrogen and oxygen. Large quantities of industrial hydrogen are produced when water reacts with methane, which is the main ingredient in natural gas. The major industrial use of hydrogen is in the production of ammonia from nitrogen and hydrogen gases. Hydrogen also is used to convert liquid vegetable oils into solid fats such as shortening. You will learn more about hydrogenation in Chapter 23, and fats and oils in Chapter 24.

Group 1A: Alkali Metals

People used to pour water over the ashes from a wood-burning fire to produce a compound of sodium called lye. They boiled the lye with animal fat to make soap. Lye, which is the active ingredient in drain cleansers, is an example of an alkaline solution. The term *alkali* comes from the Arabic *al-qili* meaning "ashes of the saltwort plant." Saltworts grow on beaches or near salt marshes. Because group 1A metals react with water to form alkaline solutions, as shown in **Figure 7-3a,** they are called alkali metals.

Alkali metals easily lose a valence electron and form an ion with a 1+ charge. They are soft enough to cut with a knife. Sodium, shown in **Figure 7-3b,** has the consistency of cold butter. Because alkali metals are highly reactive, they are found combined with other elements in nature. Lab samples are stored in oil to prevent a reaction with oxygen in the air. Alkali metals are good conductors of heat and electricity.

Lithium Trace amounts of lithium, the lightest alkali metal, are found in water, soil, and rocks. Lithium is the least reactive of the alkali metals. Its compounds are less likely to dissolve in water. In these and other properties, lithium is more closely related to magnesium than to the other alkali metals. Lithium has an atomic radius of 152 pm and an ionic radius of 76 pm. Magnesium has an atomic radius of 160 pm and an ionic radius of 72 pm. These similar physical properties lead to similar chemical properties, which is why lithium and magnesium have a diagonal relationship.

1A
Lithium 3 **Li** $[He]2s^1$
Sodium 11 **Na** $[Ne]3s^1$
Potassium 19 **K** $[Ar]4s^1$
Rubidium 37 **Rb** $[Kr]5s^1$
Cesium 55 **Cs** $[Xe]6s^1$
Francium 87 **Fr** $[Rn]7s^1$

Long-lasting lithium batteries may extend the range of electric automobiles. Compounds of lithium are used in dehumidifiers to absorb water. Lithium carbonate is used to strengthen glass and as a drug to treat bipolar disorders. Such disorders involve mood swings from mania to depression. Alloys of lithium, magnesium, and aluminum are used for items such as airplane parts because these parts must be strong, yet lightweight. Remember that an alloy is a solid solution. A chemist can fine-tune the properties of an alloy by varying the amount of each element.

Sodium and potassium The most abundant alkali metals are sodium and potassium. Sodium is used in sodium vapor lamps and as a heat exchanger in nuclear reactors. Because potassium is more reactive than sodium and more expensive to produce, elemental potassium has fewer industrial uses.

Humans and other vertebrates must have sodium and potassium in their diets because many biological functions are controlled by sodium and potassium ions. Potassium ions are the most common positive ions within cells. Sodium ions are the most common positive ions in the fluid that surrounds cells. When a nerve cell is stimulated, sodium ions flow into the cell and potassium ions flow out. This flow of ions across the cell membrane carries the nerve impulse along the cell. After the impulse passes, a compound attached to the cell membrane uses energy to move the ions back across the membrane so that they are in position for the next impulse.

Figure 7-4a shows a deposit of sodium chloride, or table salt—the most common sodium compound. Table salt occurs naturally in many foods. It is used to keep food from spoiling and to preserve foods for long-term storage, as shown in **Figure 7-4b.** These roles were especially important before the widespread use of refrigeration. Potassium chloride serves as a salt substitute for people whose intake of sodium must be limited. Potassium compounds are included in fertilizers because potassium is an important factor for plant growth and development. Potassium nitrate is used as an explosive for large-scale fireworks displays.

Other alkali metals The most reactive alkali metals—rubidium, cesium, and francium—have little commercial use. Rubidium, with a melting point of only 40°C, melts on a hot day. It will burst into flames if exposed to air. Francium, the most reactive alkali metal, is a rare radioactive element. For which SI base unit is cesium the atomic standard?

Careers Using Chemistry

Dietician

Would you like to help others improve their eating habits based on sound scientific principles? If so, consider a career as a dietician or nutritionist.

Dieticians work in public health clinics, hospitals, nursing homes, school systems, corporations, doctors' offices, and private practice. They often oversee meal planning and preparation. Dieticians also help people meet specific needs, such as planning meals for diabetic patients. They use diet to promote health and prevent disease.

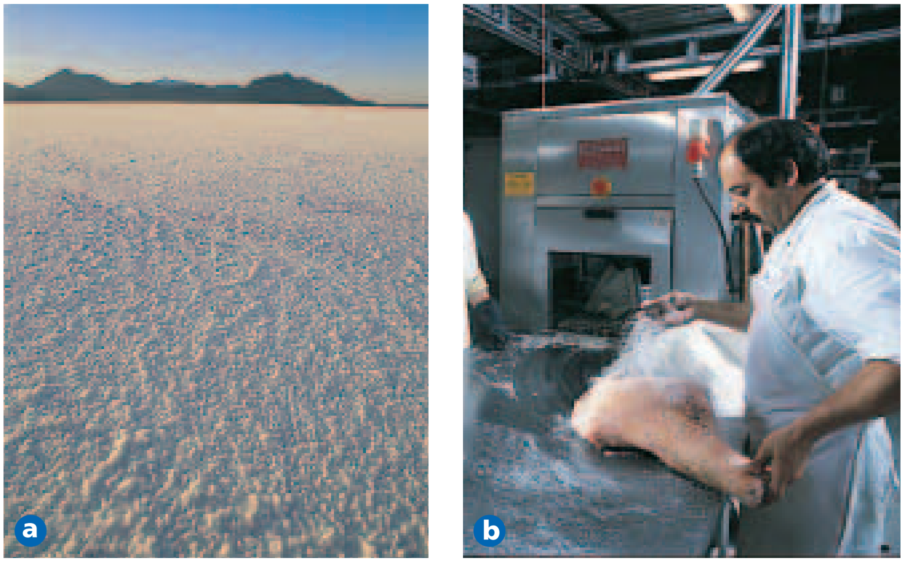


Figure 7-4

a The Bonneville Salt Flats in Utah formed when a vast landlocked salt lake evaporated. **b** People started to use salt as a preservative in the days when the only food to which people had access in winter was the food they had dried, cured, or canned.

Group 2A: Alkaline Earth Metals

Medieval alchemists classified solids that did not melt in their fires as "earths." Group 2A elements form compounds with oxygen, called oxides, that qualify as "earths" by this definition. Except for beryllium oxide, these oxides produce alkaline solutions when they react with water. The label alkaline earth reflects these two properties.

Alkaline earth metals are shiny solids that are harder than alkali metals. Although alkaline earth metals are less reactive than alkali metals, they are usually found combined with oxygen and other nonmetals in Earth's crust. Alkaline earth metals lose their two valence electrons to form ions with a 2+ charge. Reactions with water reveal the relative reactivity of the alkaline earth metals. Calcium, strontium, and barium react vigorously with room temperature water. Magnesium will react in hot water. Beryllium does not appear to react with water. When exposed to oxygen, alkaline earth metals form a thin oxide coating. Most compounds of alkaline earth metals do not dissolve easily in water. Do the **miniLAB** on the next page to observe some properties of an alkaline earth metal.

2A
Beryllium 4 **Be** $[He]2s^2$
Magnesium 12 **Mg** $[Ne]3s^2$
Calcium 20 **Ca** $[Ar]4s^2$
Strontium 38 **Sr** $[Kr]5s^2$
Barium 56 **Ba** $[Xe]6s^2$
Radium 88 **Ra** $[Rn]7s^2$

Beryllium The lightest member of group 2A, beryllium, is found combined with aluminum, silicon, and oxygen in a material called beryl. **Figure 7-5** shows two highly prized forms of beryl. Finding aluminum and beryllium together is not surprising because these elements have a diagonal relationship and, thus, similar chemical properties. Beryllium is used to moderate neutrons in nuclear reactors. Tools made from an alloy of beryllium and copper are used in situations where a spark from steel tools touching steel equipment could cause a fire or explosion. For example, beryllium–copper tools are used in petroleum refineries.

Calcium Calcium is an essential element for humans, especially in maintaining healthy bones and teeth. Calcium is found widely in nature, mainly combined with carbon and oxygen in calcium carbonate. This compound is the main ingredient in rocks such as limestone, chalk, and marble. Coral reefs build up from calcium carbonate exoskeletons that are created by marine animals called corals. Calcium carbonate is used in antacid tablets and as an abrasive in toothpaste. An abrasive is a hard material used to polish, smooth, or grind a softer material. Emery boards and sandpaper are examples of abrasive materials.

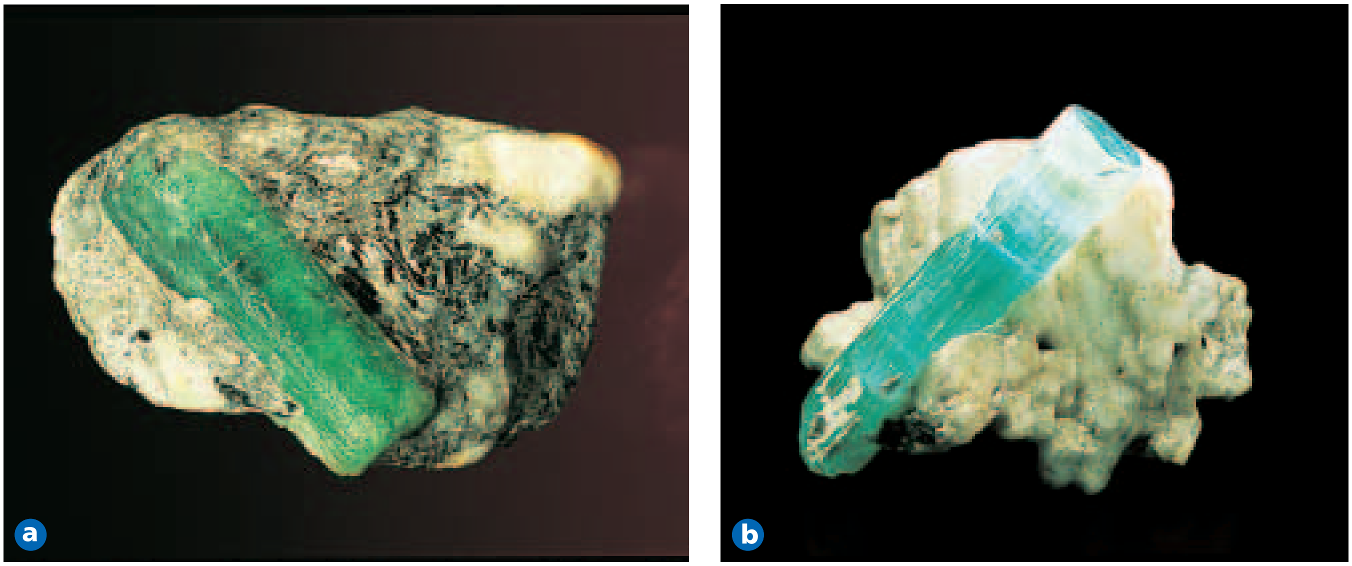


Figure 7-5
Beryllium-containing (a) emerald and (b) aquamarine get their brilliant colors from impurities—traces of chromium in emerald and traces of scandium in aquamarine.

Figure 7-6

Limestone is a relatively light building material that is easy to work with and durable.

Calcium carbonate as limestone was used to build the Roman aqueduct in **Figure 7-6**. When calcium carbonate decomposes, it forms an oxide of calcium called lime. Lime is one of the most important industrial compounds. For example, lime plays a role in the manufacture of steel, paper, and glass. Gardeners use lime to make soil less acidic. Wastewater treatment plants use lime, as do devices that remove pollutants from smokestacks. Lime is mixed with sand and water to form a paste called mortar.

Magnesium Magnesium is an abundant element that can be formed into almost any shape. Alloys of magnesium with aluminum and zinc are much lighter than steel but equally strong. The backpack frame in **Figure 7-7a** is made from a magnesium alloy, as are many bicycle frames and the "mag" wheels on the sports car in **Figure 7-7b**. The oxide of magnesium has such a high melting point that it is used to line furnaces. Plants cannot function

miniLAB

Properties of Magnesium

Observing and Inferring In this activity, you will mix magnesium with hydrochloric acid and observe the result.

Materials test tube, test tube rack, 10-mL graduated cylinder, hydrochloric acid, magnesium ribbon, sandpaper, cardboard, wood splint, safety matches

Procedure

Record all of your observations.

1. Place your test tube in a test tube rack. For safety, the test tube should remain in the rack throughout the lab.
2. Use a 10-mL graduated cylinder to measure out about 6 mL of hydrochloric acid. Pour the acid slowly into the test tube. CAUTION: *If acid gets on your skin, flush with cold running water. Use the eyewash station if acid gets in your eye.*
3. Use sandpaper to clean the surface of a 3-cm length of magnesium ribbon.
4. Drop the ribbon into the acid and immediately cover the test tube with a cardboard lid.
5. As the reaction appears to slow down, light a wood splint in preparation for step 6.
6. As soon as the reaction stops, uncover the test tube and drop the burning splint into it.
7. Pour the contents of the test tube into a container specified by your teacher. Then rinse the test tube with water. Do not place your fingers inside the unwashed tube.

Analysis

1. Compare the appearance of the magnesium ribbon before and after you used the sandpaper. What did the sandpaper remove?
2. What happened when you placed the ribbon in the acid? How did you decide when the reaction was over?
3. What did you observe when you placed the burning splint in the test tube?
4. What gas can ignite explosively when exposed to oxygen in the air? (Hint: The gas is lighter than air.)

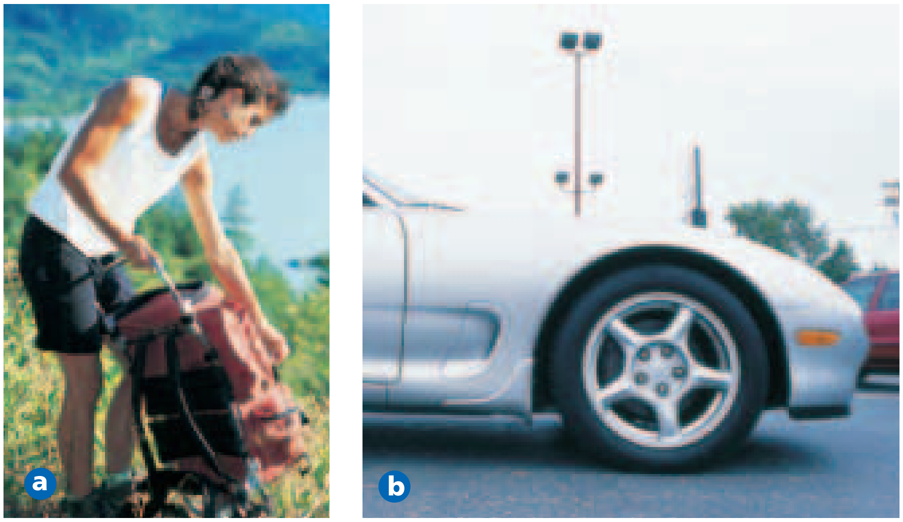


Figure 7-7

a The lighter the backpack frame, the more supplies a person can carry.
b Reducing a car's weight improves its engine performance, which is why sports cars were the first to use wheels made from a lightweight magnesium alloy.

without a supply of magnesium because each chlorophyll molecule contains a magnesium ion. Your body depends on magnesium ions, too; they play key roles in muscle function and metabolism.

When large quantities of calcium and magnesium ions are found in the water supply, the water is referred to as hard water. Hard water makes it difficult to wash oil from your hair or grease from your dishes because the ions interfere with the action of soaps and detergents. If there are large amounts of hydrogen carbonate ions in the water, they can combine with the calcium and magnesium ions to form deposits that can clog pipes, water heaters, and appliances such as steam irons. Devices called water softeners exchange sodium or hydrogen ions for the calcium and magnesium ions. Do the **CHEMLAB** at the end of the chapter to compare the cleaning ability of hard water and softened water.

Uses of other alkaline earth metals Strontium gives some fireworks their crimson color. Colorful barium compounds are used in paints and some types of glass. Barium also is used as a diagnostic tool for internal medicine. Radium is a highly radioactive element. Radium atoms emit alpha, beta, and gamma rays. Before people understood the danger, they used radium compounds to paint the hands on watches because paint containing radium glows in the dark.

Section 7.1 Assessment

1. Why are elements in groups 1A through 8A called representative elements?
2. What determines the chemical behavior of an element?
3. Why are alkali metals stored in oil?
4. What do group 1A and group 2A elements have in common? Give at least three examples.
5. What types of ions make water hard? What is the main problem with using hard water?
6. Name three factors that make magnesium a good choice for alloys.
7. **Thinking Critically** Lithium behaves more like magnesium than sodium. Use what you learned in Chapter 6 about trends in atomic sizes to explain this behavior.
8. **Applying Concepts** Hydrogen can gain one electron to reach a stable electron configuration. Why isn't hydrogen placed in group 7A with the other elements that share this behavior?

Section 7.2 Properties of p-Block Elements

Objectives

- **Describe** and **compare** properties of p-block elements.
- **Define** allotropes and provide examples.
- **Explain** the importance to organisms of selected p-block elements.

Vocabulary

mineral
ore
allotrope

3A
Boron 5 **B** $[He]2s^22p^1$
Aluminum 13 **Al** $[Ne]3s^23p^1$
Gallium 31 **Ga** $[Ar]4s^23d^{10}4p^1$
Indium 49 **In** $[Kr]5s^24d^{10}5p^1$
Thallium 81 **Tl** $[Xe]6s^24f^{14}5d^{10}6p^1$

Differences among the s-block metals are slight in comparison to the range of properties found among the p-block elements. Remember that some p-block elements are metals, some are metalloids, and some are nonmetals. Some are solids and some are gases at room temperature. Even individual p-block elements display a greater range of properties; for example, many form more than one type of ion. As you might expect, the explanation for this property lies with the electron configurations, especially those configurations that are not close to a stable, noble-gas electron configuration.

Group 3A: The Boron Group

Group 3A elements are always found combined with other elements in nature. They are most often found as oxides in Earth's crust. This group contains one metalloid (boron), one familiar and abundant metal (aluminum), and three rare metals (gallium, indium, and thallium). Based on the group number, you would expect group 3A elements to lose three valence electrons to form ions with a 3+ charge. Boron, aluminum, gallium, and indium form such ions. Thallium does not. Thallium is the most metallic member of the group with properties similar to those of alkali metals. Thallium loses only the p valence electron to form ions with a 1+ charge. Gallium and indium also can form ions with a 1+ charge.

Boron Although group 3A is named for the metalloid boron, as with other groups, the lightest member is the least representative. Boron has more in common with silicon in group 4A than with the metallic members of group 3A. Boron and silicon oxides combine to form borosilicate glass, which can withstand extreme differences in temperature without shattering. This property makes borosilicate glass ideal for the laboratory equipment and cookware shown in **Figure 7-8.**

The main source of boron is a complex compound of boron called borax. About half of the world supply of borax comes from a large deposit in California's Mojave Desert. Borax is used as a cleaning agent and as fireproof insulation. Another compound of boron, boric acid, is used as a disinfectant and as an eye wash. A form of boron nitride is the second hardest known material; only diamond is harder. These materials are classified as superabrasives. They are used in grinding wheels, which shape manufactured parts and tools.

Figure 7-8
a How might using borosilicate glassware contribute to lab safety?
b Cookware made from borosilicate glass is designed to go directly from the refrigerator to the oven.

Aluminum Aluminum is the most abundant metal and the third most abundant element in Earth's crust. It usually occurs combined with oxygen or silicon. Because removing aluminum from its ore, bauxite, requires a great deal of energy, it is cost effective to recycle the aluminum in products such as the cans shown in **Figure 7-9.** Aluminum oxide is the major compound in bauxite. It is used as an abrasive, to strengthen ceramics, and in heat-resistant fabrics. Many gems, including ruby and sapphires, are crystals of aluminum oxide with traces of other metals. Chromium gives ruby its red color; iron and titanium give sapphire its bright blue color. The compound aluminum sulfate, known as alum, is used in antiperspirants and to remove suspended particles during water purification.

Figure 7-9

The energy used to recycle aluminum is about 5% of the energy needed to extract aluminum from its ore.

Gallium Gallium can literally melt in your hand. It is used in some thermometers because it remains a liquid over a wide temperature range—from 30°C to 2403°C. A compound of gallium and arsenic called gallium arsenide produces an electric current when it absorbs light. This property makes gallium arsenide ideal for the semiconductor chips used in light-powered calculators and solar panels. These chips are ten times more efficient than silicon-based chips. Read **How It Works** at the end of the chapter to learn more about semiconductors.

Scientists are using a compound of gallium and nitrogen, gallium nitride, to develop lasers that emit blue rather than red light. Using the shorter wavelengths of blue light would triple the storage capacity of a DVD, making room for three two-hour movies. Blue lasers could increase the speed and resolution of laser printers. Medical devices for detecting cancer cells could be less expensive if they used low-cost, blue-light lasers.

Try at Home LAB

See page 955 in Appendix E for **Amazing Aluminum**

Group 4A: The Carbon Group

Based on the trends discussed in Chapter 6, the metallic properties of the elements in group 4A should increase as the atomic number increases. Carbon is a nonmetal; silicon and germanium are metalloids; tin and lead are metals. With such a wide range of properties, there are few rules that apply to all members of the group. One general trend does apply. The period-2 element, carbon, is not representative of the other elements within the group.

4A
Carbon 6 **C** [He]$2s^2 2p^2$
Silicon 14 **Si** [Ne]$3s^2 3p^2$
Germanium 32 **Ge** [Ar]$4s^2 3d^{10} 4p^2$
Tin 50 **Sn** [Kr]$5s^2 4d^{10} 5p^2$
Lead 82 **Pb** [Xe]$6s^2 4f^{14} 5d^{10} 6p^2$

Carbon Group 4A contains one of the most important elements on Earth: carbon. Except for water and ions such as sodium, most substances that control what happens in cells contain carbon. The branch of chemistry that studies these carbon compounds is called organic chemistry. Until 1828 when the first organic compound was synthesized in the laboratory, scientists thought that organic compounds could be created only in organisms. Chapter 9 will help you understand how carbon can form so many different compounds. Chapters 22 through 24 will provide more details about organic chemistry.

The branch of chemistry that deals with all other compounds is called inorganic chemistry, meaning "not organic." Carbonates, cyanides, carbides, sulfides, and oxides of carbon are classified as inorganic compounds. Geologists call these compounds minerals. A **mineral** is an element or inorganic compound that is found in nature as solid crystals. Minerals usually are found mixed with other materials in ores. An **ore** is a material from which a mineral can be removed at a reasonable cost. In other words, the cost of extraction cannot approach or exceed the economic value of the mineral.

Although both diamond and graphite contain only carbon atoms, they display different properties. Graphite is one of the softest known materials; diamond is one of the hardest. These different forms of the same element are

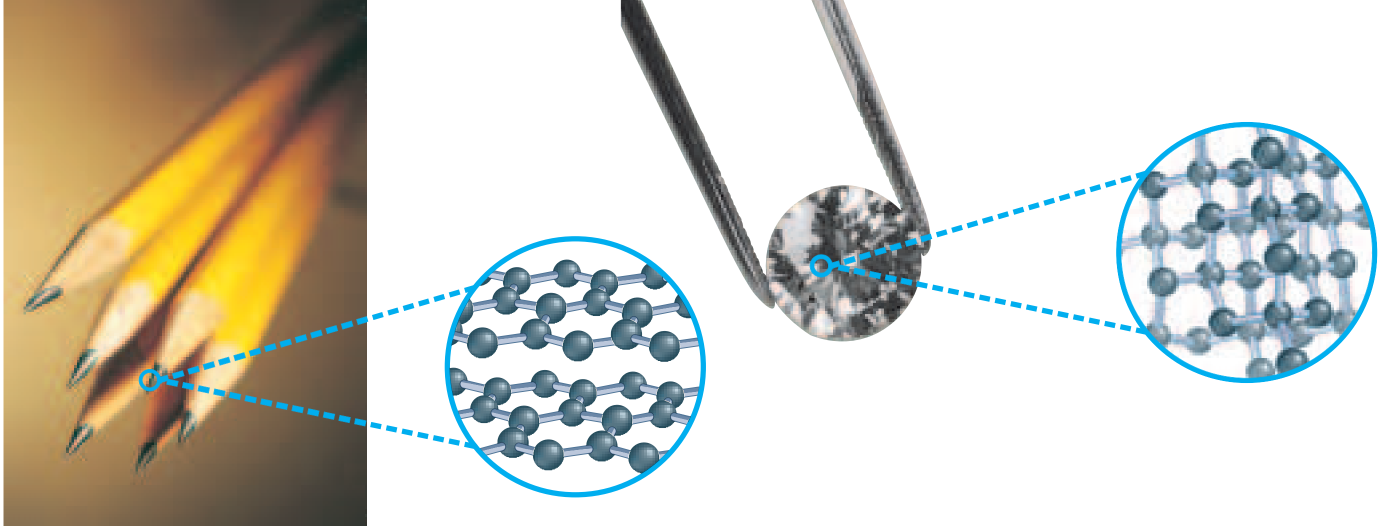


Figure 7-10

Comparing the diagrams to the photos should help explain why graphite and diamond have such different properties.

examples of allotropes. **Allotropes** are forms of an element in the same physical state—solid, liquid, or gas—that have different structures and properties. Because diamond and graphite are both solids made of carbon, they are allotropes. So is the amorphous form of carbon found in coal.

As shown in **Figure 7-10,** each carbon atom in graphite shares electrons with three other carbon atoms to form flat layers that can slide over one another. When you use a pencil, layers of carbon atoms slide onto your paper. This "slippery" property makes graphite a good lubricant. In diamond, each carbon atom shares electrons with four other carbon atoms to form a three-dimensional solid. Because of this arrangement, diamonds on grinding wheels are hard enough to sharpen tools and cut through granite or concrete.

Silicon Silicon, which is used in computer chips and solar cells, is the second most abundant element in Earth's crust after oxygen. Silicon occurs most often combined with oxygen in the compound silicon dioxide, which also is known as silica. Silica can be found in the quartz crystals, sand, and glass shown in **Figure 7-11.** When rocks containing quartz crystals weather, they produce white sand, which is the type of sand found on most beaches. If white sand is melted and allowed to cool rapidly, glass forms. A glass blower can shape glass into many different forms.

A compound of silicon and carbon, silicon carbide, is a major industrial abrasive. Its common name is carborundum. People who have a home workshop use silicon carbide sticks to sharpen their tools.

Figure 7-11

(a) Quartz crystals, (b) white sand, and (c) glass all contain silicon dioxide.

Figure 7-12

a The bronze used in this statue of a bull located in New York City's financial district is an alloy of tin and copper. **b** This pewter vase is lead free. About 8% antimony is mixed with tin to make the pewter harder.

Lead and tin Recall from the chapter opener that the metals tin and lead are similar with one key difference. Lead is toxic. The uses of pure tin are limited because tin is softer than most metals. For years, tin was used as a coating to keep steel cans from rusting, but aluminum cans are now more common. The decorative items in **Figure 7-12** are made from bronze and pewter. Bronze is an alloy of tin and copper with copper predominating. Some zinc is included to make the alloy harder. Pewter was made from about 40% lead and 60% tin until the toxic effects of lead became known.

Lead may have been the first pure metal obtained from its ores because of its low melting point. Analysis of ancient skeletons shows significant levels of lead. Until people realized the dangers of lead poisoning, lead was used for eating utensils, pipes for plumbing, as an additive in gasoline, and in paint. Paint at the hardware store no longer contains lead, but in older houses with layers of paint, lead may still be present. Lead is especially harmful for preschool children who may inhale it in dust or chew on scraps of peeling paint. In many states, a landlord cannot rent to a family with young children until the lead paint is removed. Currently, the major use of lead is in storage batteries for automobiles, which you will learn about in Chapter 21.

Group 5A: The Nitrogen Group

Although the nonmetals (N and P), metalloids (As and Sb), and metal (Bi) in group 5A each have five valence electrons, they display a wide variety of physical and chemical properties. Nitrogen, which you inhale with every breath, forms some of the most explosive compounds known. Phosphorus has three solid allotropes. Antimony and bismuth expand when they change from a liquid to a solid. Nitrogen can gain three electrons and form ions with a 3− charge; bismuth can lose three electrons and form ions with a 3+ charge.

Nitrogen Nitrogen gas is colorless, odorless, and relatively unreactive. About 78% of Earth's atmosphere is nitrogen. Proteins and other essential organic compounds contain nitrogen. However, most organisms cannot use the nitrogen in air to create these compounds. Bacteria in the soil and roots of plants such as clover convert, or "fix," molecular nitrogen into nitrogen compounds. These compounds are then used by plants and the animals that consume plants. Some essential organic compounds contain both nitrogen and phosphorus. In Chapter 24, you will learn how these compounds control the movement of energy and transfer of genetic information within cells.

5A
Nitrogen 7 **N** $[He]2s^2 2p^3$
Phosphorus 15 **P** $[Ne]3s^2 3p^3$
Arsenic 33 **As** $[Ar]4s^2 3d^{10} 4p^3$
Antimony 51 **Sb** $[Kr]5s^2 4d^{10} 5p^3$
Bismuth 83 **Bi** $[Xe]6s^2 4f^{14} 5d^{10} 6p^3$

History CONNECTION

The Swedish chemist Alfred Nobel (1833–1896) invented a safe way to use nitroglycerine. He mixed liquid nitroglycerine with sand to form a paste that could be shaped into rods. Nobel patented the mixture, which he called dynamite, and the blasting caps used to detonate the rods. The invention of dynamite greatly reduced the cost of drilling road and railway tunnels through rock. Nobel left most of his money to endow annual prizes in peace, chemistry, physics, medicine, and literature. These prizes are called Nobel Prizes.

As you learned in Section 7.1, the major industrial use of hydrogen is in the production of the nitrogen compound ammonia, which is a colorless gas with an irritating odor. Many cleaning products contain ammonia. Liquid ammonia can be used as a source of nitrogen for plants. It is stored under pressure and pumped directly into the soil. About 25% of ammonia is converted into nitric acid, which is used to produce explosives, dyes, and solid fertilizers. Artists use nitric acid to etch designs into metal plates. When ink is applied to the etched plate and then transferred to paper, a mirror image of the design appears. Some nitrogen compounds are extremely unstable. These include TNT (trinitrotoluene) and nitroglycerine.

Phosphorus Two of the three solid allotropes of phosphorus are shown in **Figure 7-13.** White phosphorus bursts into flames in air and must be stored in water. Red phosphorus is less reactive. It forms when white phosphorus is heated in the absence of air. Red phosphorus is used on the striking surface of matchboxes. The third allotrope, black phosphorus, is produced when either red or white phosphorus is heated under high pressure.

Most phosphorus is used to make phosphoric acid, which in turn is converted into phosphate compounds. These compounds have many uses. Some are found in processed cheese, laxatives, and baking powders. Others are used as a flame-retardant coating for fabrics and as a grease remover in cleaning products. Because phosphorus is essential for plant growth, fertilizers often contain phosphates. Do the **problem-solving LAB** on the next page to explore the role of fertilizers in the economics of farming.

The use of fertilizers containing phosphates can be harmful to the environment. In a lake, bacteria break down waste products and dead organisms into nutrients. Algae feed on these nutrients, which include phosphate ions. Small animals called zooplankton eat the algae; fish eat the zooplankton. If phosphate ions from fertilized fields reach the lake, they cause an increase in algae. Layers of algae form on the surface of the lake and keep light from reaching the algae below, which cannot survive if they do not have light for photosynthesis. Bacterial decay of dead algae uses large amounts of the dissolved oxygen in the water. There is not enough oxygen left to sustain other organisms. Over a long period of time, if algal growth is left unchecked, layers of waste can slowly build up on the lake bottom and the lake can evolve into a marsh or pond. Detergents that are sold in the United States no longer contain phosphate compounds because phosphate ions can be released into water by sewage treatment plants.

Figure 7-13

White phosphorus is toxic and flammable. Why must white phosphorus be stored in water? Red phosphorus is an amorphous solid, which means that there is no definite pattern to the arrangement of its atoms.

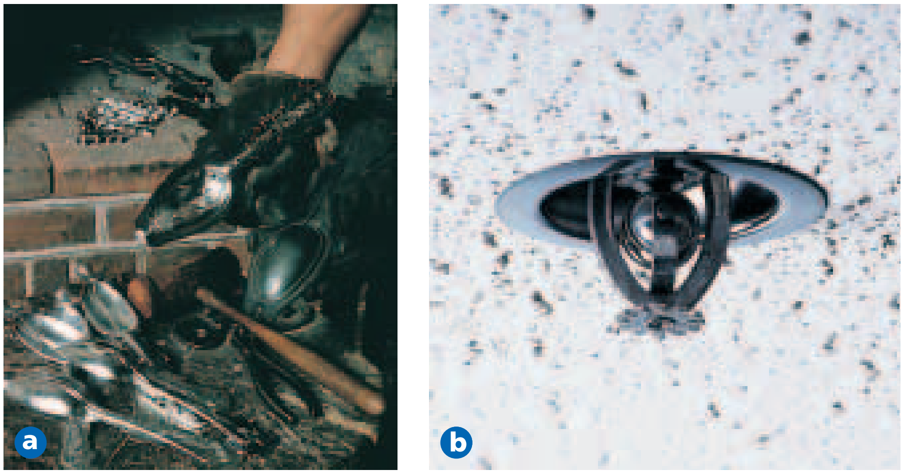


Figure 7-14

a Britannia metal is harder than pewter. This tin-antimony alloy's properties can be varied by the addition of zinc, copper, lead, or bismuth. **b** When heat from a fire melts the Wood's metal plug in a sprinkler head, water that was held back by the plug is freed.

Arsenic, antimony, and bismuth These group 5A elements are less abundant than nitrogen and phosphorus. However, they are among the oldest known elements. Although arsenic is toxic, for centuries physicians used small amounts of an arsenic and sulfur compound, arsenic sulfide, to treat some illnesses. A black compound of antimony and sulfur, antimony sulfide, was used as a cosmetic to darken eyebrows and make the eyes appear larger. Britannia metal, an alloy of tin and antimony, can be shaped by stamping or spinning, and cast in molds, as shown by the tableware in **Figure 7-14a.** Today, lead storage batteries contain 5% antimony. A compound of bismuth is the active ingredient in a popular, pink remedy for diarrhea and nausea. A low-melting alloy of bismuth, lead, tin, and cadmium called Wood's metal is used as a plug in automatic sprinkler systems, as shown in **Figure 7-14b.**

problem-solving LAB

Cost of Fertilizer

Interpreting Data Farmers deduct expenses from income to determine profit. The United States Department of Agriculture (USDA) collects annual data on production expenses from United States farmers, including data on fertilizer.

Analysis

1. What percent of the total expenses was spent on fertilizer and lime for each of the years shown? Round your answers to three significant figures.
2. What trend is revealed by your answers to question 1?

Thinking Critically

3. The table shows that farmers spent more money each year on fertilizer from 1993 to 1996. From this data, can you conclude that farmers increased their use of fertilizer at the same rate? Give a reason for your answer.

Production expenses (in millions)

Year	Total expenses ($)	Fertilizer* ($)
1993	160 548	8398
1994	167 547	9180
1995	174 161	10 033
1996	181 303	10 934

* This category includes money spent on lime, which is a soil conditioner.

4. Suppose the USDA data were altered to exclude farmers who raise livestock. Predict how this change would affect expenditures for fertilizer and lime as a percent of total expenses.
5. Use the Internet to find out if data since 1996 has confirmed the trend you identified in question 2.

Group 6A: The Oxygen Group

6A
Oxygen 8 **O** $[He]2s^2 2p^4$
Sulfur 16 **S** $[Ne]3s^2 3p^4$
Selenium 34 **Se** $[Ar]4s^2 3d^{10} 4p^4$
Tellurium 52 **Te** $[Kr]5s^2 4d^{10} 5p^4$
Polonium 84 **Po** $[Xe]6s^2 4f^{14} 5d^{10} 6p^4$

Polonium is the most metallic member of group 6A. But it is not a typical metal. It is rare, radioactive, and extremely toxic. Polonium is important historically because it was discovered by Marie and Pierre Curie in 1898 and named for Marie's native land, Poland. Selenium and tellurium are metalloids; oxygen and sulfur are nonmetals. There are some trends to note in group 6A. With six valence electrons, the elements act mainly as nonmetals. They tend to gain two electrons to form ions with a 2− charge; they also can share two electrons to achieve a stable electron configuration.

Oxygen Oxygen has two allotropes. You studied ozone (O_3) in Chapter 1. Remember that ozone is an unstable gas with a pungent odor and that it decomposes when exposed to heat or ultraviolet light. The odor of ozone is noticeable during electrical storms and near high-voltage motors such as those used in subway stations. Ozone produced in automobile emissions can irritate eyes, harm lung cells, and affect plant growth.

The allotrope that makes up about 21% of Earth's atmosphere is a colorless, odorless gas (O_2). Joseph Priestley (1733–1804) usually is credited with the discovery of oxygen. When he heated an oxide of mercury, the gas produced caused a candle to burn more brightly than it would in air. This experiment showed that air was a mixture and that one gas in air, not air as a whole, was responsible for combustion. When fuels burn, they release energy to heat homes, run automobiles, and operate machinery. The oxygen produced by plants during photosynthesis is used by both plants and animals during cellular respiration—the process that releases energy from carbohydrates. Like all organisms, the fish in **Figure 7-15a** needs a constant supply of oxygen.

Oxygen is separated from the other gases in air through a distillation process that is based on differences in boiling point among the gases. Oxygen is stored as a liquid under pressure in cylinders. These cylinders are too massive for all situations where oxygen may be needed, for example, on an airplane. Instead, a small canister is stored above each seat on the plane. The canister contains chemicals that can react to produce oxygen in an emergency.

Oxygen is the most abundant element in Earth's crust. It is found combined with metals in silicates and carbonates. Based on their names, what other elements are found in these compounds? Oxygen forms at least one oxide with every element except helium, neon, and argon. Oxygen combines with hydrogen to form two oxides—water and hydrogen peroxide, which is used as a bleach. **Figure 7-15b** shows another use of hydrogen peroxide. Oxygen also forms two oxides with carbon—carbon monoxide and carbon dioxide. Which oxide is essential to life and which is life-threatening?

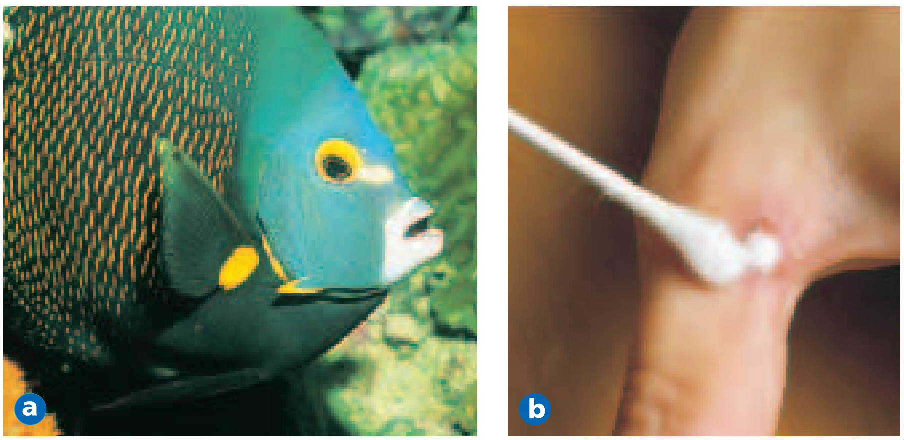


Figure 7-15

a Fish use their gills to remove oxygen from water.
b A 3% solution of hydrogen peroxide in water can help disinfect an open wound.

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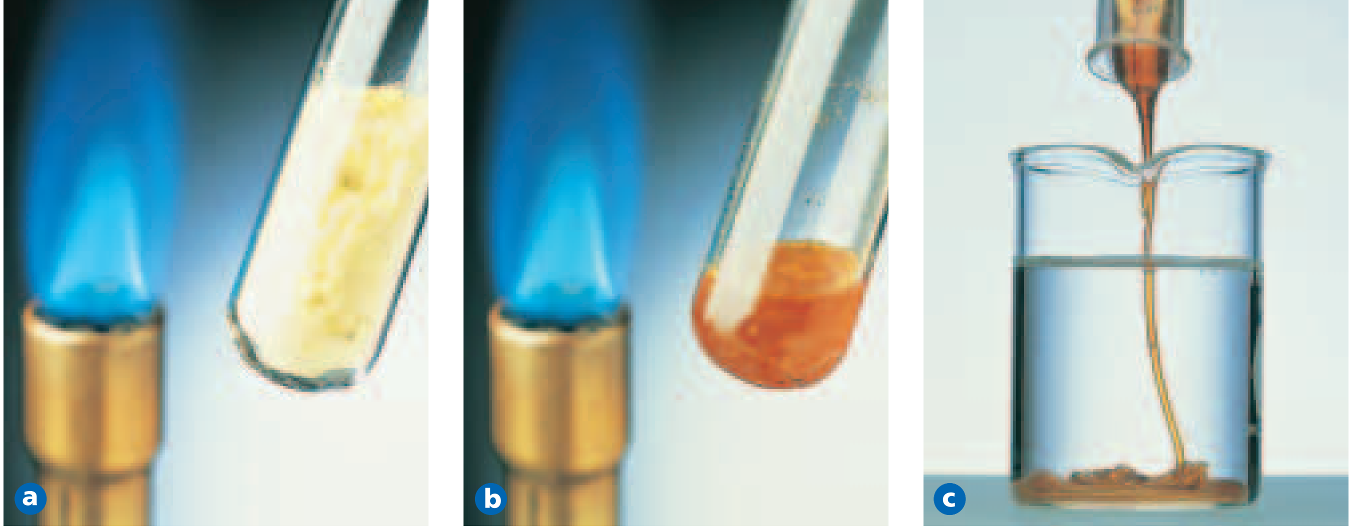

Figure 7-16

a When brittle, yellow sulfur is heated, b it melts at 112°C. c Further heating produces a thick, red-brown syrup. When the syrup is poured into cold water, an amorphous solid forms. This allotrope is called plastic sulfur because it stretches like a rubber band.

Sulfur Sulfur can be found combined with mercury in cinnabar or with lead in galena. It also is found uncombined in underground deposits. When water heated to 160°C and compressed air are pumped into a deposit, the yellow solid melts and is forced to the surface. Sulfur has ten allotropes, more than carbon and oxygen combined. **Figure 7-16** shows how a brittle allotrope that can be ground into a powder can be changed into one that is elastic.

When sulfur is burned in air, it reacts with oxygen to form sulfur dioxide, which is used to preserve fruit and as an antibacterial agent. Sulfur dioxide released into the atmosphere reacts with water vapor to form one of the acids in acid rain. More than 90% of the sulfur dioxide produced is used to make sulfuric acid. This inexpensive acid is used by so many industries that the amount of it produced can indicate the strength of an economy. About half the sulfuric acid produced is used to make fertilizers. Products ranging from steel to paper to paints also depend on this acid.

Scientists have discovered places in the deep ocean where heat from Earth's interior is released through vents, or openings, in Earth's crust. Because light does not reach the depth shown in **Figure 7-17,** the food chain cannot begin with photosynthesis. Instead, it begins with hydrogen sulfide, which also is released through the vents. (Hydrogen sulfide gives a rotten egg its vile odor.) Some unusual bacteria that live near these vents use hydrogen sulfide as an energy source. Other organisms feed on these bacteria. Volcanoes also release hydrogen sulfide from Earth's interior into the atmosphere. When silver dulls, this is a sign that it has reacted with atmospheric hydrogen sulfide to form silver sulfide, which is called tarnish.

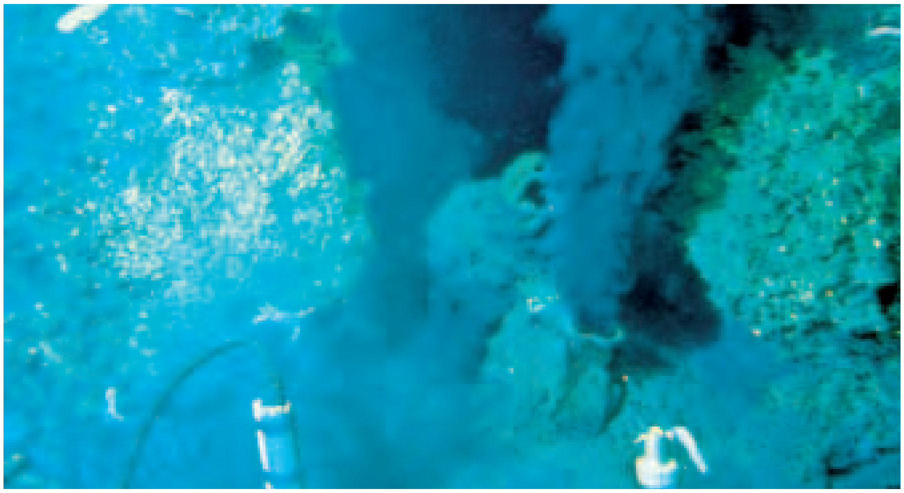

Figure 7-17

Heat and hydrogen sulfide released at deep ocean vents support many organisms.

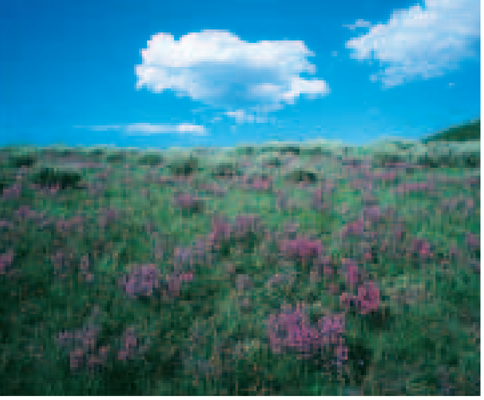

Figure 7-18

What connection might there be between the name of the locoweed plant and the plant's effect on an animal's behavior?

Selenium Some people supplement their diet with tablets that contain essential vitamins and minerals. These supplements may include a small amount of sodium selenate. Selenium also can be found in such foods as fish, eggs, and grains. Selenium works with vitamin E to prevent cell damage. It may help to inhibit the growth of cancer cells. However, in the case of nutrients, more is not always better. The locoweed plant shown in **Figure 7-18** provides an example of this principle related to selenium. When a locoweed plant absorbs selenium from the soil, the concentration of selenium increases to a toxic level. Grazing animals that feed on locoweed can become quite ill.

Because selenium can convert light into electricity, it is used in solar panels. Selenium's ability to conduct electricity increases as its exposure to light increases. Meters that photographers use to measure the level of available light contain selenium. Photocopiers work because charged particles of selenium create an "image" of the item being copied. Selenium also is used in semiconductors, as is tellurium, which is a relatively rare element.

Group 7A: The Halogens

7A
Fluorine 9 **F** $[He]2s^2 2p^5$
Chlorine 17 **Cl** $[Ne]3s^2 3p^5$
Bromine 35 **Br** $[Ar]4s^2 3d^{10} 4p^5$
Iodine 53 **I** $[Kr]5s^2 4d^{10} 5p^5$
Astatine 85 **At** $[Xe]6s^2 4f^{14} 5d^{10} 6p^5$

The elements in group 7A are named for their ability to form compounds with almost all metals. Because these compounds are called salts, the group 7A elements are called "salt formers," or halogens. You are familiar with one salt, sodium chloride, which is known as table salt. The halogens differ in their physical properties, as shown in **Figure 7-19.** Chlorine is a gas at room temperature. Bromine is a liquid, but it evaporates easily. Iodine is a solid that can change directly into a vapor.

The chemical behavior of the halogens is quite similar with one exception. Astatine is a radioactive element with no known uses. The other halogens share the following general properties. They are reactive nonmetals that are always found combined with other elements in nature. Because they have seven valence electrons, halogens tend to share one electron or gain one electron to attain a stable, noble-gas electron configuration. They tend to form ions with a 1− charge.

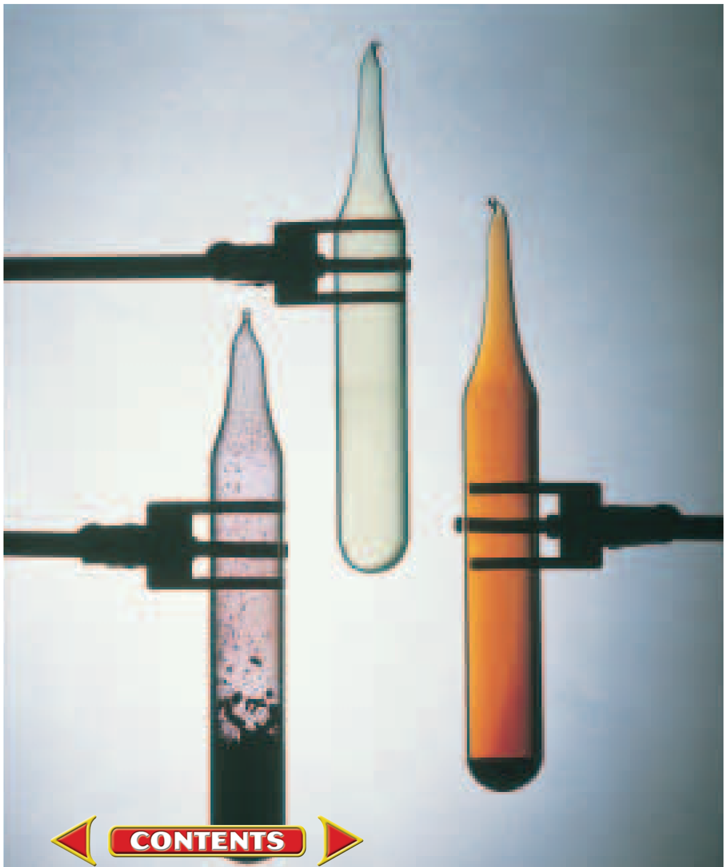

Figure 7-19

Three states of matter are represented by solid iodine (left), chlorine gas (middle), and liquid bromine (right) at room temperature.

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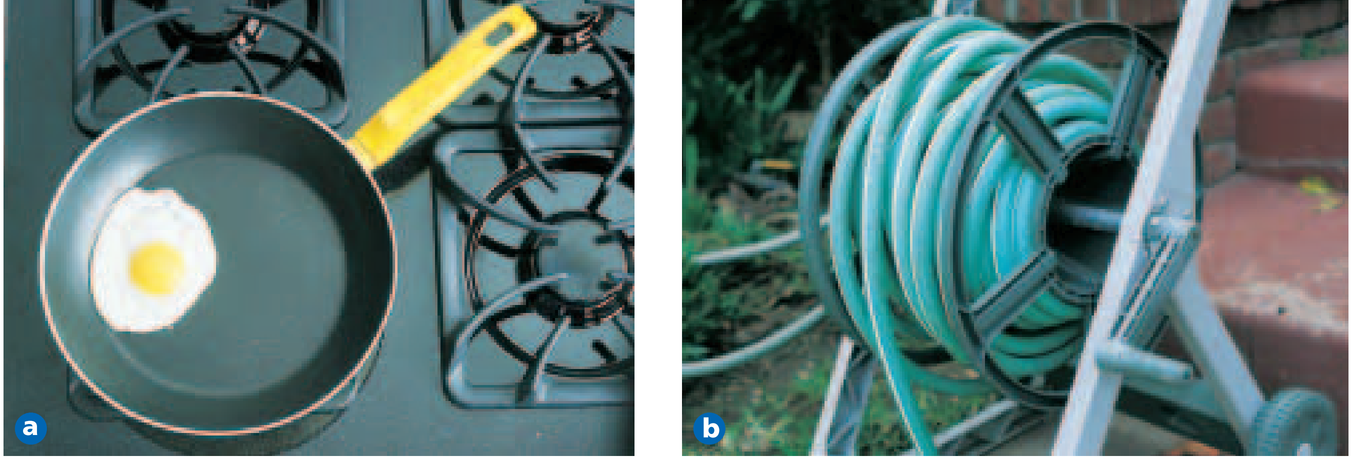


Figure 7-20

a Cookware with a non-stick surface is easy to clean and can reduce the use of cooking oils and fats. **b** A garden hose made from polyvinyl chloride is sturdy and flexible.

Fluorine Because fluorine is the halogen with the lowest atomic number, it has a small atom that provides little shielding of its valence electrons from the nucleus. Fluorine is the most electronegative element on the periodic table; that is, it has the greatest tendency to attract electrons. Thus, it is logical that fluorine also is the most active of all elements. In fact, it reacts with every element except helium, neon, and argon.

Fluorine comes from the Latin word *fluere,* which means "to flow." The mineral fluorite, which contains fluorine and calcium, is used to lower the melting points of other minerals to make it easier to separate them from their ores. Fluorine compounds are added to toothpaste and drinking water to protect tooth enamel from decay. A compound of fluorine and carbon provides a non-stick coating for the cookware shown in **Figure 7-20a.** When fluorine reacts with isotopes of uranium, the gases that form are separated by differences in mass. This process is called uranium enrichment; it provides the uranium-235 fuel for nuclear reactors.

Chlorine Chlorine reacts with nearly all of the elements. Although chlorine is a deadly gas, compounds of chlorine have many uses, including some that can save lives. In 1848, a cholera epidemic began in London. About 25 000 people died during the epidemic, which was blamed on raw sewage flowing into the river Thames. In 1855, London became the first city to use chlorine compounds to disinfect sewage.

Chlorine compounds are used as bleaching agents by the textile and paper industries. Homeowners use chlorine bleach to remove stains from clothing. The substances dentists use to block the nerves that carry pain signals to the brain often are chlorine compounds. Hydrochloric acid in your stomach helps you digest food; this acid also is used to remove rust from steel in a process called pickling. Much of the chlorine gas produced is combined with products from oil refineries to make plastics such as polyvinyl chloride (PVC). Floor tiles, pipes for indoor plumbing, and the garden hose in **Figure 7-20b** are a few of the products made from PVC.

Bromine and iodine Compared to chlorine, much less bromine and iodine are produced annually because there are fewer commercial uses for their compounds. Silver bromide and silver iodide are used to coat photographic film. Your body needs iodine to maintain a healthy thyroid gland. This gland produces hormones that control growth and your metabolic rate—the speed at which biochemical reactions occur. A lack of iodine causes the thyroid gland to enlarge, a condition called goiter. Seafood is an excellent source of iodine. So is iodized salt, which contains potassium iodide or sodium iodide in addition to sodium chloride. Because iodine kills bacteria, campers use iodine tablets or crystals to disinfect water.

8A
Helium 2 **He** $1s^2$
Neon 10 **Ne** $[He]2s^22p^6$
Argon 18 **Ar** $[Ne]3s^23p^6$
Krypton 36 **Kr** $[Ar]4s^23d^{10}4p^6$
Xenon 54 **Xe** $[Kr]5s^24d^{10}5p^6$
Radon 86 **Rn** $[Xe]6s^24f^{14}5d^{10}6p^6$

Group 8A: Noble Gases

The noble gases were among the last naturally occurring elements to be discovered because they are colorless and unreactive. Scientists assumed that noble gases could not form compounds. In 1962, the inorganic chemist Neil Bartlett created compounds from xenon and fluorine. Why do you think he chose fluorine for his experiments?

Despite this breakthrough, group 8A elements are still known primarily for their stability. Remember that noble gases have the maximum number of electrons in their outermost energy levels—eight—except for helium, which has two. Noble gases rarely react because of their stable electron configurations. In fact, there are no known compounds of helium, neon, or argon.

Helium The lightest noble gas, helium, was discovered first in the emission spectrum of the Sun. Although helium is light enough to escape Earth's gravity, it can be found on Earth in natural-gas wells. Helium is the lighter-than-air gas used in blimps, airships, and balloons. A mixture of helium and oxygen is used by deep-sea divers. By replacing the nitrogen in air with helium, divers can return to the surface quickly without experiencing a painful condition called the "bends." Liquid helium is used as a coolant for superconducting magnets.

Neon Neon is used in light displays that are commonly referred to as neon lights. When high-voltage electricity passes through the neon gas stored in a gas discharge tube, electrons in the atoms become excited. When the electrons return to a lower energy state, the atoms emit a bright orange light. The color of neon lights is not a constant because gases other than neon can be used in the displays. For example, argon emits blue light and helium emits a pale yellow light.

Argon and krypton Argon is the most abundant of the noble gases on Earth; it makes up about 1% of Earth's atmosphere. Argon provides an inert atmosphere for procedures such as high-temperature welding. This substitution avoids the dangerous mixture of electrical sparks, heat, and oxygen. Argon and krypton are used to prolong the life of filaments in incandescent light bulbs and as a layer of insulation between panes of glass. In Chapter 25, you will learn about another noble gas, the radioactive gas radon, which can be dangerous when inhaled.

Section 7.2 Assessment

9. In general, how do p-block elements differ from s-block elements?

10. How do animals obtain the nitrogen they need to build compounds such as proteins?

11. Explain why noble gases were among the last naturally occurring elements to be discovered.

12. What is an allotrope? Describe two allotropes of carbon.

13. Compare the physical and chemical properties of fluorine, chlorine, bromine, and iodine.

14. How do a mineral and an ore differ?

15. **Thinking Critically** Although carbon and lead are in the same group, one is a nonmetal and the other a metal. Explain how two elements with the same number of valence electrons can have such different properties.

16. **Predicting** A place has been left for element 113 on the periodic table. To what group does it belong? How many valence electrons will it have? What element will it most closely resemble?

Section 7.3

Properties of d-Block and f-Block Elements

Beginning with period 4, the periodic table is expanded to make room for the elements whose d or f orbitals are being filled. These elements are called transition elements. They are subdivided into d-block and f-block elements—the transition metals and inner transition metals, respectively. Note that the groups of transition elements are labeled "B" to distinguish them from the groups containing representative elements. Recall that a transition metal is any element whose final electron enters a d sublevel. An inner transition metal is any element whose final electron enters an f sublevel.

Figure 7-21 reviews the locations of the d-block and f-block elements on the periodic table. Recall that the f-block elements are placed below the main body of the periodic table with an arrow to indicate their proper locations on the table. The f-block elements are further divided into two series of elements that reflect those locations. The f-block elements from period 6 are named the **lanthanide series** because they follow the element lanthanum. The f-block elements from period 7 are named the **actinide series** because they follow the element actinium.

Objectives

- **Compare** the electron configurations of transition and inner transition metals.
- **Describe** the properties of transition elements.
- **Explain** why some transition metals form compounds with color and some have magnetic properties.

Vocabulary

lanthanide series
actinide series
ferromagnetism
metallurgy

Transition Metals

Transition metals share properties such as electrical conductivity, luster, and malleability with other metals. There is little variation in atomic size, electronegativity, and ionization energy across a period. However, there are differences in properties among these elements, especially physical properties. For example, silver is the best conductor of electricity. Iron and titanium are used as structural materials because of their relative strength.

The physical properties of transition metals are determined by their electron configurations. Most transition metals are hard solids with relatively high melting and boiling points. Differences in properties among transition metals are based on the ability of unpaired d electrons to move into the valence level. The more unpaired electrons in the d sublevel, the greater the hardness and the higher the melting and boiling points.

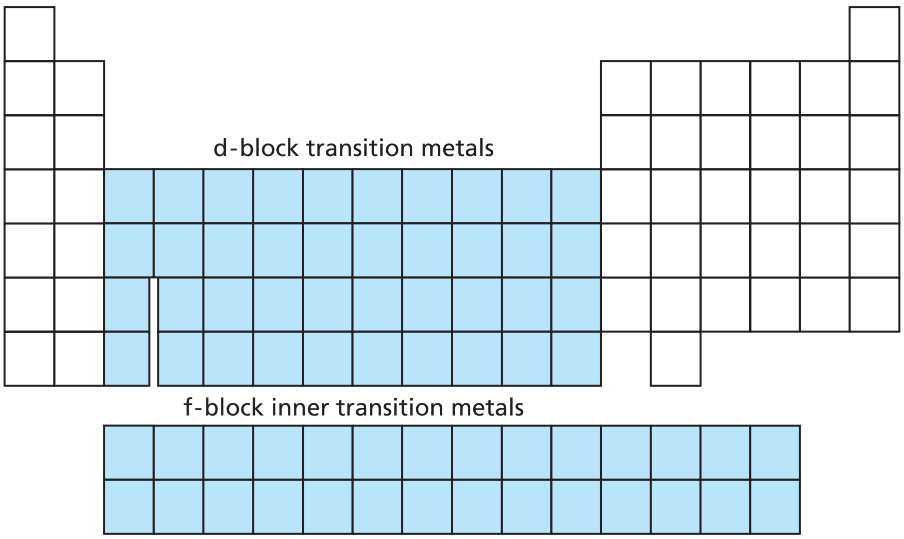


Figure 7-21

In which periods are the d-block and f-block elements located?

Figure 7-22

From left to right, the compounds contain the following transition metals: scandium (white), titanium (white), vanadium (light blue), chromium (yellow), manganese (light pink), iron (red-orange), cobalt (violet), nickel (green), copper (blue), and zinc (white).

Consider, for example, the period 4 transition metals. Moving from left to right across the period, scandium has one unpaired d electron, titanium has two, vanadium has three, and manganese has five unpaired d electrons. Chromium, with six unpaired electrons—five unpaired d electrons and one unpaired s electron—is the hardest, and has a high melting point. Iron, cobalt, nickel, and copper form pairs of d electrons. Thus, their melting points, and hardness decrease from left to right. Zinc has the lowest melting and boiling points and is a relatively soft metal because its 3d and 4s orbitals are completely filled.

Formation of ions Transition metals can lose two s electrons and form ions with a 2+ charge. Because unpaired d electrons can move to the outer energy level, these elements also can form ions with a charge of 3+ or higher. When a transition metal reacts with a highly electronegative element such as fluorine or oxygen, the positive ions formed can have a charge as high as 6+.

Figure 7-22 shows a compound of each transition metal in period 4 in order from left to right. Note that most of the compounds have color. The metal ions in these compounds have partially filled d sublevels. Electrons in these sublevels can absorb visible light of specific wavelengths. The exceptions are the white compounds that contain scandium, titanium, or zinc. The scandium and titanium ions have an empty d sublevel. The zinc ion has a completely filled and stable d sublevel. Electrons in zinc, scandium, and titanium can be excited to higher levels, but not by wavelengths of visible light. The energy required corresponds to wavelengths in the ultraviolet range of the electromagnetic spectrum.

For those transition metals that can form more than one type of ion, a change from one to another often can be detected by a color change, as shown in **Figure 7-23**. There are vanadium ions in all four solutions. The ions in the yellow solution have a 5+ charge. When zinc is added to the solution, a reaction occurs that changes the charge on vanadium from 5+ to 4+. This change is indicated by a color change in the solution from yellow to blue. If the reaction is allowed to continue, the charge changes from 4+ to 3+ and the color of the solution changes from blue to green. The final change in charge is from 3+ to 2+ with a corresponding color change from green to violet.

Figure 7-23

Each solution contains different vanadium ions.

Magnetism and metals The ability of a substance to be affected by a magnetic field is called *magnetism*. A moving electron creates a magnetic field. Because paired electrons spin in opposite directions, their magnetic fields tend to cancel out. When all of the electrons in atoms or ions are paired, the substance is either unaffected or slightly repelled by a magnetic field. This property is called *diamagnetism*. When there is an unpaired electron in the valence orbital of an atom or ion, the electron is attracted to a magnetic field. This property is called *paramagnetism*. Most substances act as temporary magnets; that is, their magnetic properties disappear after the magnetic field is removed.

Now recall the materials you tested in the **DISCOVERY LAB.** Did any of them contain iron? The transition metals iron, cobalt, and nickel have a property called ferromagnetism. **Ferromagnetism** is the strong attraction of a substance to a magnetic field. **Figure 7-24** shows how the ions in a ferromagnetic metal respond to a magnetic field. The ions align themselves in the direction of the field. When the field is removed, the ions stay aligned and the metal continues to act as a magnet. Thus, iron, cobalt, and nickel can form permanent magnets.

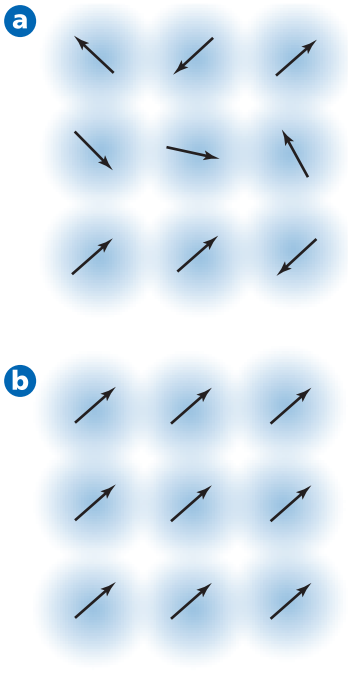


Figure 7-24

a Each ion in a ferromagnetic metal acts as a magnet. **b** If all of the ions are aligned in the same direction, they can form a permanent magnet.

Sources of transition metals Copper, silver, gold, platinum, and palladium are the only transition metals that are unreactive enough to be found in nature uncombined with other elements. All other transition metals are found in nature combined with nonmetals in minerals such as oxides and sulfides. Recall that minerals are mixed with other materials in ores. **Metallurgy** is the branch of applied science that studies and designs methods for extracting metals and their compounds from ores. The methods are divided into those that rely on high temperatures to extract the metal, those that use solutions, and those that rely on electricity. Electricity also is used to purify a metal extracted by high temperatures or solutions.

Figure 7-25 shows a blast furnace in which iron is extracted from its ore. Ore enters the furnace at the top, where the temperature is about 200°C. As the ore travels down through the furnace, carbon monoxide reacts with compounds in iron ore to remove the iron. The temperature increases along the way until molten iron at about 2000°C flows from the bottom. The product, which is called pig iron, contains about 3%–4% carbon. Most pig iron is purified and mixed with other elements in alloys called steel.

Figure 7-25

This blast furnace is named for the blast of hot air that moves rapidly up the furnace. The hot air carries carbon monoxide, which reacts with compounds in iron ore to remove the iron.

Figure 7-26

Are any strategic materials found in only one location?

Transition metals play a vital role in the economy of many countries because they have a wide variety of uses. As the uses of transition metals increase, so does the demand for these valuable materials. Ores that contain transition metals are located throughout the world, as shown in **Figure 7-26.** The United States now imports more than 60 materials that are classified as "strategic and critical" because the economy and the military are dependent on these materials. The list includes platinum, chromium, cobalt, manganese, and tungsten.

Uses of transition metals Copper is used in electrical wiring, zinc as a protective coating for other metals, and iron in making steel. Many transition metals are found in alloys used to make items such as jet engines, drill bits, surgical instruments, and armor. The plastics, petroleum, and food industries use transition metals such as platinum, palladium, and nickel to control the conditions at which a reaction will occur. In Chapter 17, you will learn how some elements and compounds affect the rate of reactions and increase the amount of products produced in a reaction.

Your body needs large amounts of a few elements to function: carbon, oxygen, hydrogen, nitrogen, sulfur, phosphorus, sodium, potassium, calcium, magnesium, and chlorine. Other elements are essential, but are required only in trace amounts. Many trace elements are transition metals. Except for scandium and titanium, all period 4 transition metals play vital roles in organisms. An iron ion is in the center of each hemoglobin molecule. Hemoglobin picks up oxygen from blood vessels in the lungs and carries it to cells throughout the body. Molecules that help your body digest proteins and eliminate carbon dioxide contain zinc. Manganese and copper are involved in cell respiration. Cobalt is needed for the development of red blood cells.

Table 7-1 shows some of the elements included in vitamin and mineral supplements. The contents and quantities vary among supplements. Daily value (DV) means the amount of each element recommended daily. Which elements would qualify as trace elements?

Table 7-1

Supplement Contents Per Tablet

Element	Amount	% DV
Calcium	161 mg	16%
Chromium	25 μg	20%
Copper	2 mg	100%
Iodine	150 μg	100%
Manganese	2.5 mg	125%
Magnesium	100 mg	25%
Molybdenum	25 μg	33%
Phosphorus	109 mg	11%
Potassium	40 mg	1%
Selenium	20 μg	28%
Zinc	15 mg	100%

Figure 7-27

a What protection do the lanthanide compounds in tinted sunglass lenses provide?
b This smoke detector needs to be replaced after about 10 years because the amount of americium steadily decreases.

Inner Transition Metals

The inner transition metals are divided into two groups: the period 6 lanthanide series and the period 7 actinide series.

Lanthanide series Lanthanides are silvery metals with relatively high melting points. Because there is so little variation in properties among inner transition metals, they are found mixed together in nature and are extremely hard to separate. The name of one lanthanide, dysprosium, comes from a Greek word meaning "hard to get at." Lanthanide ores were first mined in Ytterby, Sweden. Which four elements are named for this town?

The glass in welder's goggles contains neodymium and praseodymium, which absorb high-energy radiation that can damage the eyes. Oxides of yttrium and europium are found in television screens and color computer monitors. The yttrium and europium ions in the oxides emit bright red light when excited by a beam of electrons. An alloy called misch metal, which is 50% cerium, is used by the steel industry to remove carbon from iron and steel. Compounds of lanthanides are used in movie projectors, high-intensity searchlights, lasers, and tinted sunglasses such as those in **Figure 7-27a.**

Actinide series Actinides are radioactive elements. Only three actinides exist in nature. The rest are synthetic elements called transuranium elements. A transuranium element is an element whose atomic number is greater than 92, the atomic number of uranium. Transuranium elements are created in particle accelerators or nuclear reactors. Most transuranium elements decay quickly. One notable exception is plutonium-239. A sample of this isotope can remain radioactive for thousands of years. Plutonium is used as a fuel in nuclear power plants. The home smoke detector in **Figure 7-27b** uses americium.

Chemistry Online

Topic: Forensics
To learn more about forensics, visit the Chemistry Web site at **chemistrymc.com**

Activity: Choose one brand of forensic investigation, such as arson, anthopology, firearms, or toxicology, and report on the elements that provide the most important clues to investigators.

Section 7.3 Assessment

17. How do the electron configurations of transition and inner transition metals differ?

18. Why do transition metals share properties with other transition metals in their period?

19. How do transuranium elements differ from other inner transition metals?

20. Explain how some transition metals can form ions with more than one charge.

21. What factor determines the magnetic properties of an element and the color of its compounds?

22. What is metallurgy?

23. Compare and contrast the lanthanide series and the actinide series.

24. **Thinking Critically** Why is silver not used for electrical wires if it is such a good conductor of electricity?

25. **Using a Database** Vanadium, manganese, and titanium are used to make different types of steel. Find one use for each type of steel alloy.

CHEMLAB 7

Hard Water

The contents of tap water vary among communities. In some areas the water is hard. Hard water is water that contains large amounts of calcium or magnesium ions. Hardness can be measured in milligrams per liter (mg/L) of calcium or magnesium ions. Hard water makes it difficult to get hair, clothes, and dishes clean. In this lab, you will learn how hard water is softened and how softening water affects its ability to clean. You will also collect, test, and classify local sources of water.

Problem

How can hard water be softened? How do hard and soft water differ in their ability to clean?

Objectives

- **Compare** the effect of distilled water, hard water, and soft water on the production of suds.
- **Calculate** the hardness of a water sample.

Materials

3 large test tubes with stoppers
test tube rack
grease pencil
25-mL graduated cylinder
distilled water
dropper
hard water
250-mL beaker
balance
filter paper
washing soda
dish detergent
metric ruler

Safety Precautions

- **Always wear safety goggles and a lab apron.**
- **Washing soda is a skin and eye irritant.**

Pre-Lab

1. Read the entire **CHEMLAB.**
2. Hypothesize about the effect hard and soft water will have on the ability of a detergent to produce suds. Then, predict the relative sudsiness of the three soap solutions.
3. Prepare a data table similar to the one shown below. Leave space to record your qualitative observations.

Production of Suds	
Sample	**Level of suds (cm)**
Distilled water	
Hard water	
Soft water	

4. Are there any other safety precautions you need to consider?
5. Suppose you accidentally add more than one drop of detergent to one of the test tubes. Is there a way to adjust for this error or must you discard the sample and start over?
6. The American Society of Agricultural Engineers, the U.S. Department of the Interior, and the Water Quality Association agree on the following classification of water hardness. GPG stands for grains per gallon. One GPG equals 17.1 mg/L. If a sample of water has 150 mg/L of magnesium ions, what is its hardness in grains per gallon?

Classification of Water Hardness		
Classification	**mg/L**	**GPG**
Soft	0–60	0–3.5
Moderate	61–120	3.5–7
Hard	121–180	7–10.5
Very hard	> 180	> 10.5

Procedure

1. Use a grease pencil to label three large test tubes D (for distilled water), H (for hard water), and S (for soft water).
2. Use a 25-mL graduated cylinder to measure out 20-mL of distilled water. Pour the water into test tube D. Stopper the tube.
3. Place test tube H next to test tube D and make a mark on test tube H that corresponds to the height of the water in test tube D. Repeat the procedure with test tube S.
4. Obtain about 50-mL of hard water in a beaker from your teacher. Slowly pour hard water into test tube H until you reach the marked height.
5. Place a piece of filter paper on a balance and set the balance to zero. Then measure about 0.2 g of washing soda. Remove the filter paper and washing soda. Reset the balance to zero.
6. Use the filter paper to transfer the washing soda to the beaker containing the remainder of the hard water. Swirl the mixture to soften the water. Record any observations.

7. Slowly pour soft water into test tube S until you reach the marked height.
8. Add one drop of dish detergent to each test tube. Stopper the tubes tightly. Then shake each sample to produce suds. Use a metric ruler to measure the height of the suds.
9. Collect water samples from reservoirs, wells, or rain barrels. Use the sudsiness test to determine the hardness of your samples. If access to a source is restricted, ask a local official to collect the sample.

Cleanup and Disposal

1. Use some of the soapy solutions to remove the grease marks from the test tubes.
2. Rinse all of the liquids down the drain with lots of tap water.

Analyze and Conclude

1. **Comparing and Contrasting** Which sample produced the most suds? Which sample produced the least suds? Set up your own water hardness scale based on your data. What is the relative hardness of the local water samples?
2. **Using Numbers** The hard water you used was prepared by adding 1 gram of magnesium sulfate per liter of distilled water. Magnesium sulfate contains 20.2% magnesium ions by mass. What is its hardness in grains per gallon?
3. **Drawing a Conclusion** The compound in washing soda is sodium carbonate. How did the sodium carbonate soften the hard water?
4. **Thinking Critically** Remember that most compounds of alkaline earth metals do not dissolve easily in water. What is the white solid that formed when washing soda was added to the solution of magnesium sulfate?
5. **Error Analysis** Could the procedure be changed to make the results more quantitative? Explain.

Real-World Chemistry

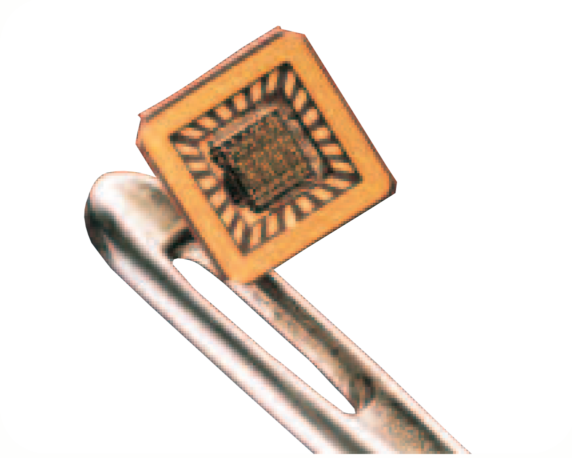
1. Water softeners for washing machines are sold in the detergent section of a store. Look at some of the packages and compare ingredients. Do packages that have different ingredients also have different instructions for how the water softener should be used?
2. Suppose a family notices that the water pressure in their house is not good enough to flush a toilet on the second floor. Other than a leak, what could be interfering with the flow of water?
3. Explain why drinking hard water might be better for your health than drinking soft water. How could a family have the benefit of hard water for drinking and soft water for washing?

How It Works

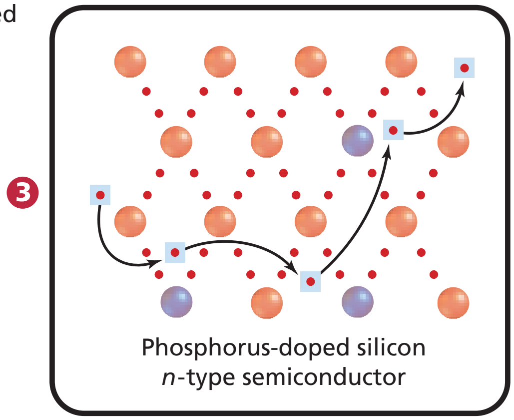
Semiconductor Chips

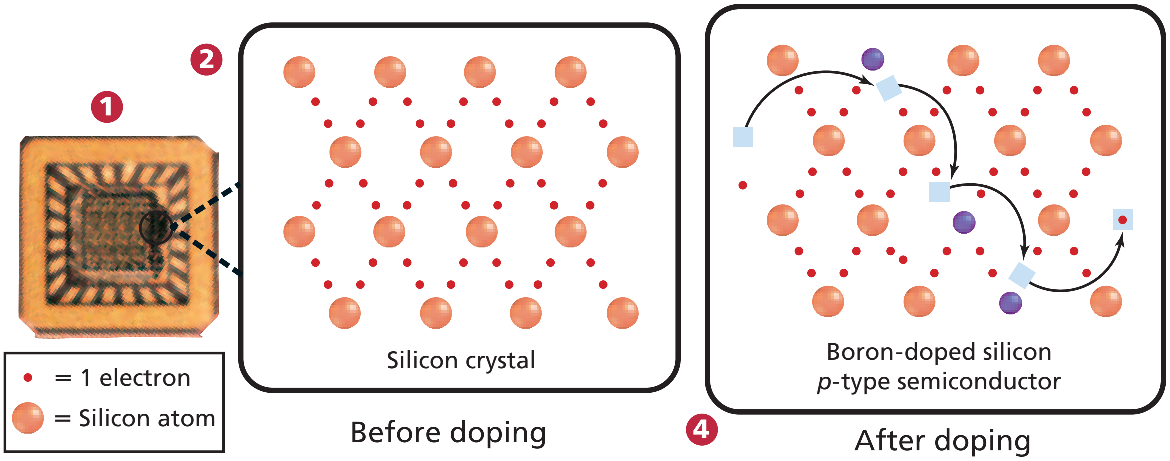
All of the miniature electrical circuits in your television, computer, calculator, and cell phone depend on elements that are semiconductors. Some metalloids, such as silicon and germanium, are semiconductors.

An electric current is a flow of electrons. This movement of electrons can be used to carry information. Metals are good conductors of electricity; nonmetals are poor conductors. Semiconductors fall somewhere in between. Silicon's conductivity can be improved by the addition of phosphorus or boron—a process called doping.



1. Hundreds of tiny electronic circuits form an integrated circuit on a thin slice of silicon called a chip.
2. Valence electrons hold silicon atoms together. No electrons are available to carry electric current.
3. Extra valence electrons from phosphorus are not needed to hold the crystal together. They are free to move throughout the crystal and form an electric current.
4. Boron has fewer valence electrons than silicon. When boron is added to silicon, there are spaces lacking electrons. "Holes" are created in the crystal structure. Movement of electrons into and out of these holes produces an electric current.





Thinking Critically

1. Explain why you would expect germanium to have the same type of structure and semiconducting properties as silicon.
2. What type of semiconductor would you expect arsenic-doped germanium to be?

Summary

7.1 Properties of s-Block Elements

- The number and location of valence electrons determine an element's position on the periodic table and its chemistry.
- Properties within a group are not identical because members have different numbers of inner electrons.
- Similarities between period-2 elements and period-3 elements in neighboring groups are called diagonal relationships.
- The representative elements in groups 1A through 8A have only s and p electrons.
- Because hydrogen has a single electron, it can behave as a metal and lose an electron or behave as a nonmetal and gain an electron.
- The alkali and alkaline earth metals in groups 1A and 2A are the most reactive metals.
- Metals form mixtures called alloys, whose composition can be adjusted to produce different properties.
- Sodium and potassium are the most abundant alkali metals. Many biological functions are controlled by sodium and potassium ions.
- Calcium is essential for healthy teeth and bones. It is most often found as calcium carbonate, which can decompose to form lime—one of the most important industrial compounds.
- Magnesium is used in lightweight, yet strong alloys. Magnesium ions are essential for metabolism, muscle function, and photosynthesis.

7.2 Properties of p-Block Elements

- p-block elements include metals, metalloids, nonmetals, and inert gases.
- Aluminum is the most abundant metal in Earth's crust. Much more energy is needed to extract aluminum from its ore than to recycle aluminum.
- Because a carbon atom can join with up to four other carbon atoms, carbon forms millions of organic compounds.
- Graphite and diamond are allotropes of carbon.
- The most abundant elements in Earth's crust, silicon and oxygen, are usually found in silica, which can be melted and rapidly cooled to form glass.
- Lead, which is still used in storage batteries, was used in pipes, paint, and gasoline until people realized the danger of lead poisoning.
- Nitrogen combines with hydrogen in ammonia, which is used in cleaning products. Nitric acid, which is produced from ammonia, is used to make solid fertilizers, explosives, and dyes.
- Phosphates in fertilizers and cleaning products can harm the environment.
- Sulfur dioxide reacts with water to form one of the acids in acid rain. Most sulfur dioxide is used to make sulfuric acid.
- Halogens are extremely reactive nonmetals. Their compounds are used in toothpaste, disinfectants, and bleaches. Many plastics contain chlorine. Silver bromide or iodide is used to coat photographic film.
- The stable noble gases are used in lighter-than-air blimps, in neon lights, as a substitute for nitrogen in diving tanks, and as an inert atmosphere for welding.

7.3 Properties of d-Block and f-Block Elements

- The d-block transition metals and f-block inner transition metals are more similar across a period than are the s-block and p-block elements.
- The more unpaired electrons in the d sublevel, the harder the transition metal and the higher its melting and boiling points. Ions with partially filled d sublevels often form compounds with color.
- In ferromagnetic metals, ions are permanently aligned in the direction of a magnetic field.
- Many transition metals are strategic materials.
- Lanthanides are silvery metals with high melting points that are found mixed in nature and are hard to separate. Actinides are radioactive elements.

Vocabulary

- actinide series (p. 197)
- allotrope (p. 188)
- diagonal relationship (p. 180)
- ferromagnetism (p. 199)
- lanthanide series (p. 197)
- metallurgy (p. 199)
- mineral (p. 187)
- ore (p. 187)

chemistrymc.com/vocabulary_puzzlemaker

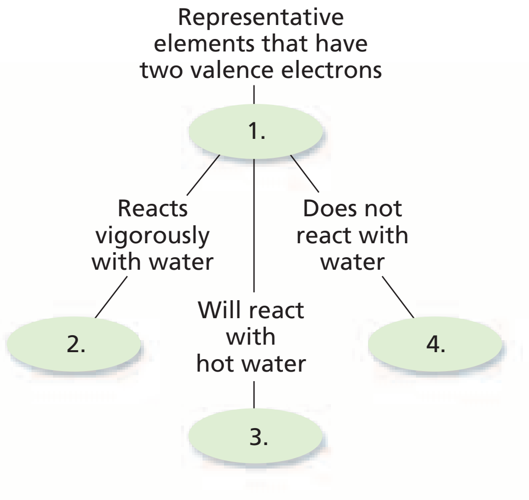
CONTENTS

Chemistry Online

Go to the Chemistry Web site at **chemistrymc.com** *for additional Chapter 7 Assessment.*

Concept Mapping

26. Complete the following concept map using the following terms: beryllium; magnesium; calcium, strontium, and barium; alkaline earth metals.



Mastering Concepts

27. Why are elements within a group similar in chemical and physical properties? (7.1)

28. Which groups have representative elements? (7.1)

29. What is a diagonal relationship? (7.1)

30. What happens when hydrogen reacts with a nonmetal element? (7.1)

31. What is heavy water? (7.1)

32. What is the charge on alkali metal ions? On alkaline earth metal ions? (7.1)

33. Identify the element that fits each description. (7.1)
- **a.** element in baking soda that turns a flame yellow
- **b.** metallic element found in limestone
- **c.** radioactive alkali metal

34. List some ways group 2A elements differ from group 1A elements. (7.1)

35. Explain why cesium is a more reactive alkali metal than sodium. (7.1)

36. Use their electron configurations to explain why calcium is less reactive than potassium. (7.1)

37. List at least one use for each of the following compounds. (7.1)
- **a.** sodium chloride (table salt)
- **b.** calcium oxide (lime)
- **c.** potassium chloride

38. List three types of information that you can obtain from the periodic table. (7.1)

39. Explain why the halogens are extremely reactive nonmetals. (7.2)

40. Explain why most carbon compounds are classified as organic compounds. (7.2)

41. What is the charge on halogen ions? (7.2)

42. Argon has only one more proton than chlorine. Explain why these two gases have such different chemical properties. (7.2)

43. Why is red phosphorus classified as an amorphous solid? (7.2)

44. Why is lead no longer used in paints or for plumbing pipes? (7.2)

45. Compare the allotropes of oxygen. (7.2)

46. Identify the element that fits each description. (7.2)
- **a.** greenish-yellow gas used to disinfect water
- **b.** main element in emeralds and aquamarines
- **c.** lightweight metal extracted from bauxite ore
- **d.** the most abundant element in Earth's crust

47. What could account for the change in color within the mineral in the photograph below? (7.2)

48. Explain why iodine can be substituted for bromine in some compounds. (7.2)

49. Explain why fluorine reacts with all elements except helium, neon, and argon. (7.2)

50. Name the element that combines with oxygen to form a compound that fits each description. (7.2)
  a. the compound that can be melted to form glass
  b. the main compound in ruby and sapphire
  c. a compound used to preserve fruit and produce an inexpensive acid

51. List at least one use for each compound. (7.2)
  a. silicon carbide (carborundum)
  b. aluminum sulfate (alum)
  c. boric acid
  d. nitric acid

52. When the metal gallium melts, is the liquid that forms an allotrope? Explain your answer. (7.2)

53. How do transition metals differ from inner transition metals in their electron configurations? (7.3)

54. Explain why compounds of zinc are white but compounds containing copper have a color.

55. Name three general methods for extracting a metal from its ore. (7.3)

56. What does it mean for a metal to be listed as strategic or critical? (7.3)

57. Predict which of the transition metals in period 4 is diamagnetic. Explain your answer. (7.3)

58. Explain how the electron configurations of chromium and copper determine that one is used to strengthen alloys and the other to make jewelry. (7.3)

Mixed Review

Sharpen your problem-solving skills by answering the following.

59. What distinguishes a metal from a nonmetal?

60. Where are the most reactive nonmetals located on the periodic table? The most reactive metals?

61. Which families contain metalloids?

62. What chemical property does zinc share with calcium?

63. Name at least three elements that are commonly found in fertilizers.

64. What physical property is shown by the element in the photograph? Identify the element.

65. Of the period-5 elements, palladium, tin, and silver, which will display noticeably different properties from the other two? Explain your choice.

66. What do rubidium and white phosphorus have in common?

67. Identify the block on the periodic table where you are likely to find:
  a. a synthetic radioactive element.
  b. a highly reactive element that forms salts with halogens.
  c. an element that forms millions of compounds.

68. For each period-3 element, Na through Cl, identify the following:
  a. the metals, nonmetals, and metalloids.
  b. the appearance of the element and its state at room temperature.

69. What is the most common ion or ions for each of these elements: sodium, bromine, neon, cadmium, boron, and hydrogen?

Thinking Critically

70. Applying Concepts Which element would be easiest to extract from its ore, gold or iron? Explain your choice.

71. Hypothesizing Why might countries have different lists of strategic and critical materials?

72. Applying Concepts In 1906, Ferdinand Moissan won a Nobel Prize for producing fluorine in its pure elemental form. Why do you think his achievement was considered worthy of such a prize?

73. Analyze and Conclude Why were metals such as copper and gold discovered long before gases such as oxygen and nitrogen?

74. Drawing a Conclusion The most important function of blood is to carry oxygen to all cells in the body. What could happen if blood flow to a cell were blocked?

75. Using a Database Find out the following:
a. the trend for the melting point of alkali metals
b. the color of copper compounds
c. the colors of the ions of chromium

76. Observing and Predicting If you were given two solutions, one colorless and the other a light blue, which solution would probably contain an ion from a transition metal? Explain your answer.

Writing in Chemistry

77. Research the local city or state regulations for removal of lead paint and write a report on your findings.

78. Use the example of ozone to argue that a single chemical can be both beneficial and harmful.

79. Describe the uses of fluorine, chlorine, and iodine compounds related to drinking water and wastewater.

80. Research and write a report on the use of silver iodide for seeding clouds.

81. Research the history of the term *bromide*, which is used to describe a remedy designed to ease tension.

82. Find out how the daily values for vitamins and minerals are determined. Compare supplements to see whether they all contain the same minerals in the same quantities per tablet. In your report, suggest reasons for any variations you discover.

83. Research the processes of recycling aluminum, plastic, and glass. Design a poster or a multimedia presentation for members of your community about one of the processes. Include the following considerations: Why is it cost effective to recycle? What resources are conserved? What recycling is available in your area? How can the members of your community use this information to make responsible choices about the products they purchase?

84. Find out how the elements are assigned their names. What elements are named after people? Choose one and research why this person was given such an honor.

Cumulative Review

Refresh your understanding of previous chapters by answering the following.

85. Determine the correct number of significant figures in each of the following. (Chapter 2)
a. 708.4 mL
b. 1.0050 g
c. 1.000 mg
d. 6.626×10^{-34} s
e. 2000 people

86. A quarter has a mass of 5.627 g. What is its mass in milligrams? (Chapter 2)

87. A solution of sugar has a density of 1.05 g/cm^3. If you have 300.0 mL of sugar solution, what is the mass of the solution? (Chapter 2)

88. A substance is said to be volatile if it readily changes from a liquid to a gas at room temperature. Is this a physical change or a chemical change? (Chapter 3)

89. How many electrons, protons, and neutrons are there is the following: (Chapter 4)
a. carbon-13
b. chromium-50
c. tin-119

90. An AM radio signal broadcasts at 6.00×10^5 Hz. What is the wavelength of this signal in meters? What is the energy of one photon of this signal? (Chapter 5)

91. Determine the energy of a photon with a wavelength of 4.80×10^2 nm. (Chapter 5)

92. Identify which of the following orbitals cannot exist according to quantum theory: 4s, 1p, 2p, 3f, 2d. Briefly explain your answer. (Chapter 5)

93. Mendeleev left a space on his periodic table for the undiscovered element germanium and in 1886 Winkler discovered it. Write the electron configuration for germanium. (Chapter 6)

94. Select the atom or ion in each pair that has the larger radius. (Chapter 6)
a. Cs or Fr
b. Br or As
c. O^{2-} or O

95. Arrange the following in order of increasing ionization energy: Li, C, Si, Ne. (Chapter 6)

96. Arrange the following in order of increasing ionization energy: K, Ca, Fr, Mg. (Chapter 6)

CONTENTS

STANDARDIZED TEST PRACTICE
CHAPTER 7

Use these questions and the test-taking tip to prepare for your standardized test.

1. Which of the following descriptions does NOT apply to gold?

a. transition metal
b. ferromagnetic
c. element
d. nonconductor

2. On the periodic table, metalloids are found only in

a. the d-block.
b. groups 3A through 6A.
c. the f-block.
d. groups 1A and 2A.

3. The majority of __________ are radioactive.

a. actinides
b. lanthanides
c. halogens
d. alkali metals

4. Which of the following groups is composed entirely of nonmetals?

a. 1A
b. 3A
c. 5A
d. 7A

5. Which is a major component of organic compounds?

a. sodium
b. calcium
c. carbon
d. potassium

6. Although metals in the same group on the periodic table have the same number of valence electrons, they do not have identical properties. Which of the following is NOT an explanation for differences in properties within a group?

a. The metals have different numbers of nonvalence electrons.
b. The reactivity of metals increase as their ionization energies decrease.
c. The ionization energies of metals decrease as their atomic masses increase.
d. The reactivity of metals increase as their atomic masses decrease.

7. Throughout history, dangerous products were used before people understood their harmful effects. Which of the following historic practices was NOT discontinued because of the health hazard it posed?

a. using radium paint to make watch hands glow in the dark
b. lining steel cans with tin to prevent corrosion
c. using arsenic sulfide to treat illnesses
d. adding lead to gasoline to increase engine efficiency

Interpreting Tables Use the table to answer questions 8 through 10.

Characteristics of Elements		
Element	**Block**	**Characteristic**
X	s	soft solid; reacts readily with oxygen
Y	p	gas at room temperature; forms salts
Z	—	inert gas

8 In which group does Element X most likely belong?

a. 1A
b. 7A
c. 8A
d. 4B

9. Element Y is probably

a. an alkaline metal.
b. an alkaline earth metal.
c. a halogen.
d. a transition metal.

10. Element Z is most likely found in the

a. s-block.
b. p-block.
c. d-block.
d. f-block.

TEST-TAKING TIP

Plan Your Work and Work Your Plan
Plan your workload so that you do a little work each day rather than a lot of work all at once. The key to retaining information is repeated review and practice. You will retain more if you study one hour a night for five days in a row instead of cramming for five hours on a Sunday night.