5.3 Representative Groups

Reading Focus

Key Concepts

- Why do the elements in a group have similar properties?
- What are some properties of the A groups in the periodic table?

Vocabulary

- valence electron
- alkali metals
- alkaline earth metals
- halogens
- noble gases

Reading Strategy

Monitoring Your Understanding Copy the table below. As you read, record an important fact about each element listed.

Element	Important Fact
Magnesium	a. ?
Aluminum	b. ?
Chlorine	c. ?

Why is hydrogen located on the left side of the periodic table with the active metals? It is a nonmetal gas that seems to have more in common with the nonmetals in Group 17. Hydrogen's location is related to its electron configuration, not its properties.

Valence Electrons

Did you wonder why there are two numbering schemes on the periodic table in Figure 7? When the A groups are numbered from 1 through 8, they provide a useful reminder about the electron configurations of the elements in those groups. The number of an A group matches the number of valence electrons in an electron configuration for an element in that group. A **valence electron** is an electron that is in the highest occupied energy level of an atom. These electrons play a key role in chemical reactions. Properties vary across a period because the number of valence electrons increases from left to right.

Elements in a group have similar properties because they have the same number of valence electrons. These properties will not be identical because the valence electrons are in different energy levels. Valence electrons explain the location of hydrogen. Because hydrogen has a single valence electron, it is grouped with other elements, such as lithium, that have only one valence electron.

Figure 14 Because hydrogen is flammable, it can be used as a fuel in automobiles like this one. An engine that burns hydrogen has a key advantage over an engine that burns gasoline. Only water is produced when hydrogen burns.

Section Resources

Print

- ***Laboratory Manual,*** Investigation 5B
- ***Reading and Study Workbook With Math Support,*** Section 5.3
- ***Transparencies,*** Section 5.3

Technology

- ***Interactive Textbook,*** Section 5.3
- ***Presentation Pro CD-ROM,*** Section 5.3
- ***Go Online,*** *Science News,* Elements

Section 5.3

1 FOCUS

Objectives

5.3.1 **Relate** the number of valence electrons to groups in the periodic table and to properties of elements in those groups.

5.3.2 **Predict** the reactivity of some elements based on their locations within a group.

5.3.3 **Identify** some properties of common A group elements.

Reading Focus

Build Vocabulary L2

Concept Map Have students construct a concept map with eight branches and title it Groups in the Periodic Table. As students read, they can add the names of groups to each branch, the group's number of valence electrons, elements in the group, and some properties of these elements.

Reading Strategy L2

Possible answers: **a.** Magnesium plays a key role in the production of sugar in plants. Mixtures of magnesium and other metals can be as strong as steel, but much lighter. **b.** Aluminum is the most abundant metal in Earth's crust. Much less energy is needed to purify recycled aluminum than to extract aluminum from bauxite. **c.** Chlorine is a highly reactive, nonmetal gas that is used to kill bacteria in water.

2 INSTRUCT

Valence Electrons

Integrate Space Science L2

Hydrogen exhibits metallic properties under extreme conditions. Scientists have theorized for decades that metallic hydrogen exists in the core of planets such as Jupiter. Interior pressure on Jupiter is millions of times greater than the pressure at the surface of Earth. At this pressure, electrons flow easily between hydrogen molecules. Have students do research and write a paragraph that compares and contrasts the cores of Jupiter and Earth, according to the current state of scientific knowledge.

Verbal, Portfolio

The Alkali Metals

Use Visuals

L1

Figure 15 Ask students to study the two photos and the column of elements in Figure 15. Ask, **What properties of sodium are shown in the photos?** *(Sodium is a soft solid at room temperature with a metallic luster when first exposed to air. Sodium is extremely reactive and it reacts violently with water to form hydrogen gas.)* Point out to students that the reactivity of the alkali metals increases from the top of the group to the bottom. Ask, **Which alkali metals are less reactive than cesium but more reactive than lithium?** *(Sodium, potassium, and rubidium)* **Visual, Logical**

Build Science Skills

L2

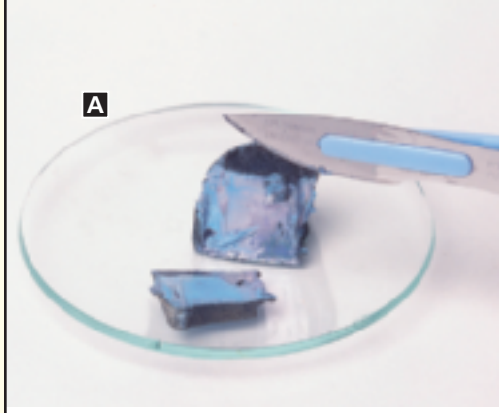
Communicating Results Explain to students that Robert Bunsen and Gustav Kirchoff discovered cesium in 1840 and rubidium in 1841 by burning the substances and observing the color of the flames. Have students research the origin of the terms *cesium* and *rubidium*. Have students explain why these names are appropriate. *(Cesium comes from the Latin word* caesium, *which means "heavenly blue." Rubidium comes from the Latin word* rubidus, *which means "dark red." The names describe the colors of light emitted when the elements are burned.)* **Logical**

FYI

Francium has been described as the most unstable element among the first 103 elements. Its longest-lived isotope, francium-223, has a half-life of only 22 minutes. The estimate is that there is only about one ounce of francium on Earth at any moment.

Go Online SCIENCE NEWS

Science News provides students with current information on elements.



Group 1A

3 Li Lithium	
11 Na Sodium	
19 K Potassium	
37 Rb Rubidium	
55 Cs Cesium	
87 Fr Francium	

Figure 15 The element sodium is an alkali metal **A** Unlike most metals, sodium is soft enough to cut with a knife. **B** When sodium reacts with water, enough energy is released to ignite the hydrogen that is produced. **Predicting** ***What happens when potassium comes in contact with water?***

The Alkali Metals

The elements in Group 1A are called **alkali metals.** These metals have a single valence electron and are extremely reactive. Because they are so reactive, alkali metals are found in nature only in compounds. The most familiar of these compounds is table salt—a compound of sodium and chlorine (sodium chloride). Sodium chloride can be obtained through the evaporation of seawater or from large salt deposits on the surface of Earth or underground.

Not all the elements in a group are equally reactive. Sodium is more reactive than lithium, potassium is more reactive than sodium, and rubidium is more reactive than potassium. **The reactivity of alkali metals increases from the top of Group 1A to the bottom.**

Sodium is about as hard as cold butter and can be cut with a sharp knife, as shown in Figure 15A. Sodium melts at about 98°C and has a lower density than water. A piece of sodium may be able to float on water, but Figure 15B shows that it won't be there for long. The sodium reacts violently with water and releases enough energy to ignite the hydrogen gas that is produced. Sodium and potassium are stored under oil to keep them from reacting with the oxygen and water vapor in air. Cesium is so reactive that it reacts with water at temperatures as low as –115°C. Cesium is usually stored in a sealed glass tube containing argon gas.

Go Online SCIENCE NEWS

For: Articles on elements
Visit: PHSchool.com
Web Code: cce-1053

Reading Checkpoint

How many valence electrons does an alkali metal have?

Customize for English Language Learners

Compare/Contrast Chart
After students have read about Groups 1A and 2A, create a chart on the board with the title Alkali Metals vs. Alkaline Earth Metals. Separate the chart into two columns labeled Similarities and Differences. Ask for student responses to help you fill in the chart. After all correct answers have been recorded, keep the chart displayed as a reference for students.

The Alkaline Earth Metals

The elements in Group 2A are called **alkaline earth metals**. All alkaline earth metals have two valence electrons. Metals in Group 2A are harder than metals in Group 1A. The melting point of magnesium is 650°C, which is much higher than the melting point of sodium—98°C.

Differences in reactivity among the alkaline earth metals are shown by the ways they react with water. Calcium, strontium, and barium react easily with cold water. Magnesium will react with hot water, but no change appears to occur when beryllium is added to water. Magnesium and calcium have essential biological functions and they provide materials used in construction and transportation.

Group 2A

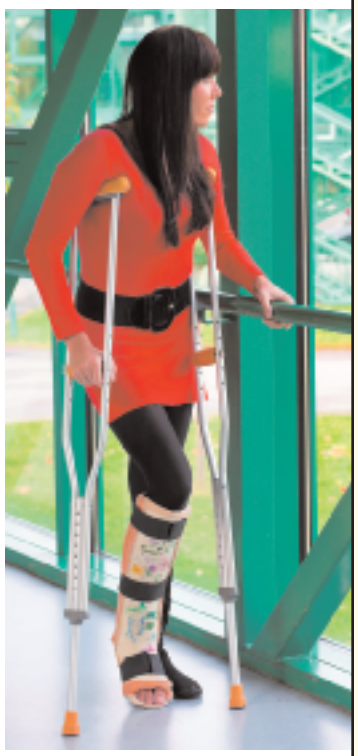
4	Be Beryllium
12	Mg Magnesium
20	Ca Calcium
38	Sr Strontium
56	Ba Barium
88	Ra Radium

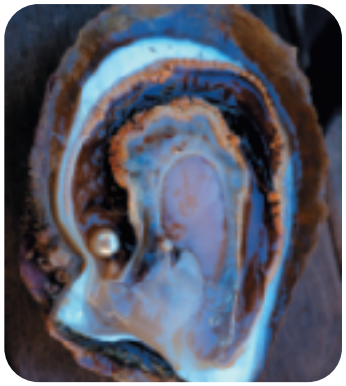
Magnesium

Magnesium plays a key role in the process that uses sunlight to produce sugar in plants like the one in Figure 16. The compound at the center of this process is chlorophyll (KLAWR uh fil), and at the center of chlorophyll is magnesium. A mixture of magnesium and other metals can be as strong as steel, but much lighter. Reducing overall mass without sacrificing strength is an important consideration in transportation. The frames of bicycles and backpacks often contain magnesium.

Calcium

Your body needs calcium to keep your bones and teeth strong. Calcium carbonate—a compound of calcium, carbon, and oxygen—is the main ingredient in chalk, limestone, coral, and the pearl in Figure 16. Your toothpaste may contain the compound calcium carbonate because this hard substance can polish your teeth. The plaster cast in Figure 16 contains calcium sulfate, which is a compound of calcium, sulfur, and oxygen.





Oyster shell with pearl

Spinach plant

Figure 16 Chlorophyll molecules in spinach contain magnesium. An oyster shell and a pearl are both made from calcium carbonate. A plaster cast contains the compound calcium sulfate.

The Alkaline Earth Metals

FYI

The mineral gypsum is heated to produce a white powdery substance called plaster of Paris. When water is added to plaster of Paris, heat is released as the plaster quickly hardens. During the process, the plaster expands by about 0.3–0.6%. A plaster cast is often replaced by a sturdier, more lightweight fiberglass cast after the swelling around an injury subsides.

Egyptians used plaster to join blocks of stone in pyramids. Romans made plaster casts of Greek statues. In the 1700s, wooden houses in Paris were often covered in plaster to protect against fire. This measure was taken in response to the destruction of London by fire in 1666.

Answer to . . .

Figure 15 *When potassium reacts with water, enough energy is released to ignite the hydrogen that is produced.*

Reading Checkpoint *An alkali metal has one valence electron.*

The Boron Family

Use Community Resources

L2

Invite a representative from a community recycling program or a commercial recycler to speak to your class about the importance of recycling materials such as aluminum. Have students ask questions about the kinds of materials that are recycled and how the recycling process is different for each of them. They may also ask how recycling has changed over the past 10 years and what changes are expected in the future.

Interpersonal, Portfolio

The Carbon Family

Integrate Math

L2

Tell students that silicon dioxide is the most abundant substance in Earth's crust. It is, of course, a compound of the elements silicon and oxygen. Point out to students that only eight elements make up 98.5% of Earth's crust: oxygen (46.6%), silicon (27.7%), aluminum (8.1%), iron (5.0%), calcium (3.6%), sodium (2.8%), potassium (2.6%), and magnesium (2.1%). Have students work in pairs to create a circle graph that shows this data. Remind students that they may need to combine some elements under a category labeled Other. If students need help constructing a circle graph, you may want to refer them to the **Math Skills** in the **Skills and Reference Handbook** at the end of the student text.

Visual, Logical

The Boron Family

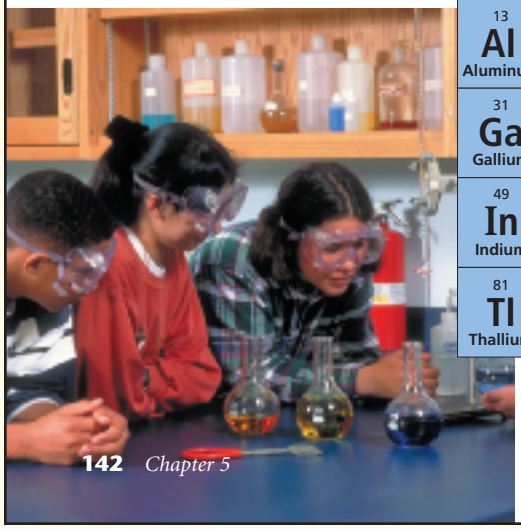
Group 3A contains the metalloid boron, the well-known metal aluminum, and three less familiar metals (gallium, indium, and thallium). All these elements have three valence electrons.

Aluminum is the most abundant metal in Earth's crust. It is often found combined with oxygen in a mineral called bauxite (BAWKS eyet). Aluminum is less reactive than sodium and magnesium. It is strong, lightweight, malleable, and a good conductor of electric current.

More than 10 percent of the aluminum produced is used as packaging. Some aluminum is used in window screens, window frames, and gutters. Parts of cars and airplanes are also made from aluminum. People are encouraged to recycle aluminum because the energy needed to purify recycled aluminum is only about 5 percent of the energy needed to extract aluminum from bauxite.

A compound of boron, silicon, and oxygen is used to make a type of glass that does not shatter easily when it undergoes a rapid change in temperature. Glass that contains boron is used to make laboratory glassware, such as the flasks in Figure 17. It is also used in cookware that can go directly from the oven to the refrigerator.

Figure 17 These students are using flasks made from glass that contains boron. This type of glass does not shatter as easily as glass without boron.



Group 3A

5	13	31	49	81
B	Al	Ga	In	Tl
Boron	Aluminum	Gallium	Indium	Thallium

Group 4A

6	14	32	50	82
C	Si	Ge	Sn	Pb
Carbon	Silicon	Germanium	Tin	Lead

Figure 18 The clay used to make this pottery contains compounds called silicates. These compounds always contain silicon and oxygen. They usually contain aluminum and often contain other elements such as iron.

The Carbon Family

Group 4A contains a nonmetal (carbon), two metalloids (silicon and germanium), and two metals (tin and lead). Each of these elements has four valence electrons. Notice that the metallic nature of the elements increases from top to bottom within the group. In keeping with this trend, germanium is a better conductor of electric current than silicon.

Life on Earth would not exist without carbon. **Except for water, most of the compounds in your body contain carbon.** Reactions that occur in the cells of your body are controlled by carbon compounds. Carbon and its compounds are discussed in Chapter 9, Carbon Chemistry.

Silicon is the second most abundant element in Earth's crust. It is found as silicon dioxide in quartz rocks, sand, and glass. The clay used to produce the pottery in Figure 18 contains silicon compounds called silicates. Silicon carbide, a compound of silicon and carbon, is extremely hard. Saw blades tipped with silicon carbide last many times longer than ordinary steel blades.

Reading Checkpoint

Which Group 3A element is a nonmetal?

142 Chapter 5

The Nitrogen Family

Group 5A contains two nonmetals (nitrogen and phosphorus), two metalloids (arsenic and antimony), and one metal (bismuth). Like the groups on either side of it, Group 5A includes elements with a wide range of physical properties. Nitrogen is a nonmetal gas, phosphorus is a solid nonmetal, and bismuth is a dense metal. Despite their differences, all the elements in Group 5A have five valence electrons. Nitrogen and phosphorus are the most important elements in Group 5A.

When air is cooled, the oxygen condenses before the nitrogen because nitrogen has a lower boiling point than oxygen. Much of the nitrogen obtained from air is used to produce fertilizers, like the three shown in Figure 19. **Besides nitrogen, fertilizers often contain phosphorus.** Your body uses compounds containing nitrogen and phosphorus to control reactions and release energy from food.

Phosphorus exists as an element in several forms with different properties. White phosphorus is so reactive that it bursts into flame when it is in contact with oxygen. Red phosphorus is less reactive and is used to make matches ignite.

Figure 19 The composition of a fertilizer varies with its intended use. The numbers on the bags of fertilizer are, from left to right, the relative amounts of nitrogen, phosphorus, and potassium.
Analyzing Data *Which type of fertilizer contains the most phosphorus?*

Group 5A

7 N Nitrogen	
15 P Phosphorus	
33 As Arsenic	
51 Sb Antimony	
83 Bi Bismuth	

Group 6A

8 O Oxygen	
16 S Sulfur	
34 Se Selenium	
52 Te Tellurium	
84 Po Polonium	

Figure 20 Sulfur is often found in nature in its elemental form—not combined with other elements. Inferring *What does this information tell you about the reactivity of sulfur?*

The Oxygen Family

Group 6A has three nonmetals (oxygen, sulfur, and selenium), and two metalloids (tellurium and polonium). All the elements in Group 6A have six valence electrons.

Oxygen is the most abundant element in Earth's crust. Complex forms of life need oxygen to stay alive because oxygen is used to release the energy stored in food. Oxygen can be stored as a liquid under pressure in oxygen tanks. There must be no sparks or flames near an oxygen tank because materials that are flammable burn easily in pure oxygen.

Ozone is another form of the element oxygen. At ground level, ozone can irritate your eyes and lungs. At upper levels of the atmosphere, ozone absorbs harmful radiation emitted by the sun.

Sulfur was one of the first elements to be discovered because it is found in large natural deposits like the one in Figure 20. The main use of sulfur is in the production of sulfuric acid, a compound of sulfur, hydrogen, and oxygen. More sulfuric acid is produced in the United States than any other chemical. About 65 percent of the sulfuric acid produced is used to make fertilizers.

Facts and Figures

Phosphorus The element phosphorus has 10 forms, which are usually grouped as white, red, and black phosphorus for simplicity. The white phosphorus forms are the least stable.

In 1680, Robert Boyle demonstrated that phosphorus ignited by friction could be used to light wooden splints that had been dipped in sulfur. There are two types of matches. In a strike-anywhere match, all of the required ingredients (often phosphorus sulfide and potassium chlorate) are in the match head. In a safety match, the ingredients are divided between the match head and a rough striking surface on the side of the matchbox. A safety match can be lit only when the tip is drawn across the striking surface, which contains phosphorus sulfide.

The Nitrogen Family

Build Reading Literacy L1

Identify Main Idea/Details Refer to **page 98D** in **Chapter 4**, which provides the guidelines for identifying main ideas and details.

Guide students in applying this strategy to the text on page 143. Tell students to look for the main idea of each paragraph and then list one or two supporting details. If the paragraph has no topic sentence, have students list two important facts from the paragraph. **Verbal, Portfolio**

FYI

Of the 18 elements essential for plant growth, nitrogen, phosphorus, and potassium are most likely to be lacking. The numbers on the fertilizer packages shown in Figure 19 represent percent N, percent P_2O_5, and percent K_2O. (In the past, oxides were often used as standards for chemical comparisons.) Nitrogen and phosphorus are often present as nitrates and phosphates.

The Oxygen Family

Address Misconceptions L2

Students may think that the air they breathe is pure oxygen. Challenge this misconception by reminding students that air is a mixture of gases. Air is 78% nitrogen and 21% oxygen. Have students research what gases make up the remaining 1% of air. *(Answers should include carbon dioxide, water vapor, argon, and other noble gases.)* **Logical**

Answer to . . .

Figure 19 *Tomato food*

Figure 20 *Sulfur is not highly reactive under ordinary conditions.*

Reading Checkpoint *Carbon*

The Halogens

Build Reading Literacy

L1

KWL Refer to **page 124D** in this chapter, which provides the guidelines for KWL (Know/Want to Know/Learned).

Teach this independent study skill as a whole-class exercise. **1.** Draw a three-column KWL chart on the board for students to copy. **2.** Have students complete the Know column with facts, examples, and other information that they already know about the Group 7A elements (the halogens). **3.** Tell students to complete the Want to Know column with questions about the halogens. **4.** Have students read p. 144 to learn more about the halogens. As they read, have them note answers to their questions in the Learned column, along with other facts, examples, and details they learned. **5.** Have students draw an Information I Expect to Use box below their KWL chart. Have them review the information in the Learned column and categorize the useful information in the box.

Verbal

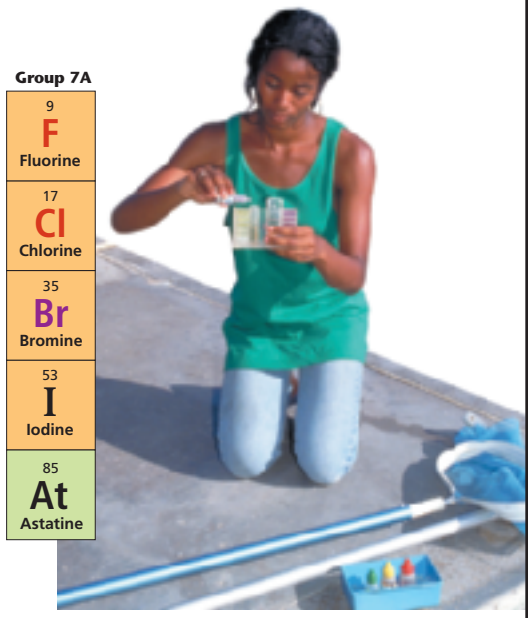


Figure 21 At room temperature, chlorine is a gas, bromine is a liquid, and iodine is a solid. Halogens react easily with metals, such as the iron in steel wool. At a swimming pool, the chlorine content must be tested frequently. **Applying Concepts** ***What process causes iodine vapor to collect in a flask of solid iodine?***

Chlorine reacting with steel wool

The Halogens

The elements in Group 7A are called **halogens.** Each halogen has seven valence electrons. Figure 21 shows the range of physical properties among the halogens. Fluorine and chlorine are gases, bromine is a liquid that evaporates quickly, and iodine is a solid that sublimes. **Despite their physical differences, the halogens have similar chemical properties.** They are highly reactive nonmetals, with fluorine being the most reactive and chlorine a close second. Halogens react easily with most metals. Figure 21 shows what happens when heated steel wool is plunged into chlorine.

Recall that a fluorine compound is used to prevent tooth decay. If you use pans with a nonstick coating to make omelets or muffins, you have seen another use of a fluorine compound. Have you ever noticed a sharp smell when adding bleach to a load of clothes? The smell comes from a small amount of chlorine gas that is released from a chlorine compound in the bleach. Chlorine is also used to kill bacteria in drinking water and swimming pools. The woman in Figure 21 is testing the level of chlorine in a swimming pool.

Your body needs iodine to keep your thyroid gland working properly. This gland controls the speed at which reactions occur in your body. Seafood is a good source of iodine. At a time when fresh fish was not available in all parts of the United States, people began to add iodine compounds to table salt. Salt that contains such compounds is called iodized salt.

Facts and Figures

Halogens The name astatine comes from the Greek *astatos*, meaning "unstable." Astatine is a radioactive element whose most stable isotope, At-210, has a half-life of only 8.1 h. Astatine is the most metallic of the halogens. It is usually classified as a metalloid, but is sometimes regarded as a nonmetal. Because of its rarity and instability, astatine has no practical uses.

Both bromine and iodine are volatile. Iodine comes from the Greek *ioeides,* meaning "violet colored." It is named for the color of iodine vapor, not the color of its solid crystals, which are dark gray.

The Noble Gases

The elements in Group 8A are called **noble gases.** Helium has two valence electrons. Each of the other noble gases has eight valence electrons. **The noble gases are colorless and odorless and extremely unreactive.** In Chapter 6, you will study the relationship between the electron configurations of the noble gases and their low reactivity.

It is not easy to discover a colorless, odorless gas. It is even harder if the gas rarely reacts. Scientists discovered argon when they noticed that the density of nitrogen collected from air did not match the density of nitrogen formed during chemical changes. In time, the scientists figured out that the "impurity" in atmospheric nitrogen was an unknown element.

An element that does not react easily with other elements can be very useful. For example, during one stage in the process of making computer chips, pure silicon is heated in a furnace at 1480°C. At this temperature, silicon reacts with both oxygen and nitrogen. So the heating must take place in an argon atmosphere.

Some light bulbs are filled with argon because the glowing filament in the bulb will not react with argon as it would react with oxygen. Using argon increases the number of hours the bulb can be lit before it burns out. All the noble gases except radon are used in "neon" lights like those shown in Figure 22.

Group 8A
2 He Helium
10 Ne Neon
18 Ar Argon
36 Kr Krypton
54 Xe Xenon
86 Rn Radon

Figure 22 When electric current passes through noble gases, they emit different colors. Helium emits pink, neon emits orange-red, argon emits lavender, krypton emits white, and xenon emits blue.

Section 5.3 Assessment

Reviewing Concepts

1. Explain why elements in a group have similar properties.
2. What is the relationship between an alkali metal's location in Group 1A and its reactivity?
3. What element exists in almost every compound in your body?
4. Which Group 5A elements are found in fertilizer?
5. Which group of elements is the least reactive?
6. Why is hydrogen located in a group with reactive metals?
7. What biological function requires magnesium?
8. Why is aluminum recycled?
9. What is the main use of sulfur?
10. Why is chlorine added to drinking water?

Critical Thinking

11. **Comparing and Contrasting** In which class of elements is there a greater range of properties, the metals or the nonmetals? Give an example to support your answer.
12. **Making Generalizations** What happens to the reactivity of nonmetals within a group from the top of the group to the bottom?

Connecting Concepts

Using Physical Properties In Section 2.2, three ways to use physical properties are discussed. Find one example in Section 5.3 that illustrates each use. If necessary, reread pages 48 and 50.

Section 5.3 Assessment

1. They have similar properties because they have the same number of valence electrons.
2. The reactivity of alkali metals increases from the top of Group 1A to the bottom.
3. Carbon
4. Nitrogen and phosphorus
5. The noble gases (Group 8A)
6. Hydrogen is placed with other elements that have a single valence electron.
7. The process that uses sunlight to produce sugar in plants
8. The energy needed to purify recycled aluminum is only about 5% of the energy needed to extract aluminum from bauxite.
9. To produce sulfuric acid
10. Chlorine is added to drinking water to kill bacteria.
11. Accept all answers that are supported by reasonable arguments. Students may choose nonmetals and say that they display a greater range of physical properties and reactivity.
12. The reactivity of nonmetals decreases from the top to the bottom of a group.

The Noble Gases

Build Science Skills L2

Inferring Hold up an incandescent light bulb and tell students that the filament in the light bulb is made of tungsten, which emits light when it is heated to a high temperature. Explain that a light bulb with a tungsten filament contains small amounts of gases, such as argon, that do not react easily. Ask, **Why isn't air used in the light bulb?** *(The heated filament would burn in air, which contains oxygen.)*
Visual, Logical

3 ASSESS

Evaluate Understanding L2

Write the names of A group elements discussed in Section 3.3 on separate index cards. Distribute one card to each pair of students and have them add the following information to the card: chemical symbol, atomic number, group number and group name, number of valence electrons, physical state at room temperature, class of element (metal, nonmetal, or metalloid), and one or two properties of the element.

Reteach L1

Use the segments of the periodic table that appear throughout the section to review each A group. Emphasize how the metallic properties of elements increase from top to bottom within a group and how the number of valence electrons changes from left to right across the periodic table.

Connecting Concepts

Examples of Identifying Materials: Distinguish halogens by their states and colors at room temperature.

Examples of Choosing Materials: Using hard calcium carbonate to polish teeth; using argon to increase the life of a light bulb.

Examples of Separating Materials: Sodium chloride from seawater by evaporation; nitrogen from oxygen based on their boiling points.

Interactive Textbook If your class subscribes to the Interactive Textbook, use it to review key concepts in Section 5.3.

Answer to . . .

Figure 21 *Sublimation*