Section 2
Atoms, Bonding, and the Periodic Table

Objectives
After this lesson, students will be able to
L.1.2.1 Explain how the reactivity of elements is related to valence electrons in atoms.
L.1.2.2 State what the periodic table tells you about atoms and the properties of elements.

Target Reading Skill
Building Vocabulary Explain that knowing the definitions of key terms helps students understand what they read.

Answers
Sample definitions: **Valence electrons:** electrons that are in the highest energy level and held most loosely; **Electron dot diagram:** diagram of an atom that includes the symbol for the element surrounded by dots that stand for valence electrons; **Chemical bond:** the force of attraction that holds two atoms together as a result of the rearrangement of electrons between them; **Noble gas:** any element in Group 18, which consists of elements with eight valence electrons; **Halogen:** any element in Group 17, which consists of elements with seven valence electrons; **Alkali metal:** any element in Group 1, which consists of elements with one valence electron

Preteach

Build Background Knowledge
L2

Organizing Elements
Ask: **If you go into a music store, how do you find a particular CD?** *(Sample answer: You find the section for that type of music, search alphabetically for the artist, and then find the title among that artist's recordings.)* **Why do you think music stores organize CDs in this way?** *(The organization makes it easier to find specific types of music, artists, and recordings.)* Tell students that in this section they will learn how elements, like CDs, are organized based on certain similarities among them.

Section 2
Atoms, Bonding, and the Periodic Table

Reading Preview

Key Concepts
- How is the reactivity of elements related to valence electrons in atoms?
- What does the periodic table tell you about atoms and the properties of elements?

Key Terms
- valence electrons
- electron dot diagram
- chemical bond
- symbol • atomic number
- period • group • family
- noble gas • halogen
- alkali metal

Target Reading Skill
Building Vocabulary After you read this section, reread the paragraphs that contain definitions of Key Terms. Use all the information you have learned to write a definition of each Key Term in your own words.

Lab zone Discover Activity

What Are the Trends in the Periodic Table?
1. Examine the periodic table of the elements that your teacher provides. Look in each square for the whole number located above the symbol of the element. As you read across a row from left to right, what trend do you see?
2. Now look at a column from top to bottom. What trend do you see in these numbers?

Think It Over
Interpreting Data Can you explain why one row ends and a new row starts? Why are certain elements in the same column?

Why isn't the world made only of elements? How do the atoms of different elements combine to form compounds? The answers to these questions are related to electrons and their energy levels. And the roadmap to understanding how electrons determine the properties of elements is the periodic table.

Valence Electrons and Bonding
In Section 1 you learned about electrons and energy levels. An atom's **valence electrons** (VAY luns) are those electrons that have the highest energy level and are held most loosely. **The number of valence electrons in an atom of an element determines many properties of that element, including the ways in which the atom can bond with other atoms.**

FIGURE 8
Valence Electrons
Skydivers in the outer ring are less securely held to the group than are members of the inner ring. Similarly, valence electrons are more loosely held by an atom than are electrons of lower energy.

Lab zone Discover Activity

Skills Focus Interpreting data L1
Materials periodic table
Time 10 minutes
Tip You may want to explain the concept of atomic number.
Expected Outcome Students will most likely recognize that the elements are arranged from left to right and from top to bottom in order of increasing atomic number.
Think It Over Students may not know that one row ends and a new row starts when the number of valence electrons reaches 8. However, students may connect changes in atomic number with changes in the number of electrons.

Electron Dot Diagrams Each element has a specific number of valence electrons, ranging from 1 to 8. Figure 9 shows one way to depict the number of valence electrons in an element. An **electron dot diagram** includes the symbol for the element surrounded by dots. Each dot stands for one valence electron.

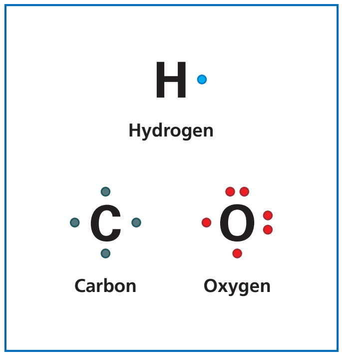
Chemical Bonds and Stability Most atoms are more stable—less likely to react—when they have eight valence electrons. For example, atoms of neon, argon, krypton, and xenon all have eight valence electrons and are very unreactive. These elements do not easily form compounds. Some small atoms, such as helium, are stable with just two valence electrons.

Atoms usually react in a way that makes each atom more stable. One of two things can happen: Either the number of valence electrons increases to eight (or two, in the case of hydrogen). Or, the atom gives up loosely held valence electrons. Atoms that react this way can become chemically combined, that is, bonded to other atoms. A **chemical bond** is the force of attraction that holds two atoms together as a result of the rearrangement of electrons between them.

Chemical Bonds and Chemical Reactions When atoms bond, electrons may be transferred from one atom to another, or they may be shared between the atoms. In either case, the change results in a chemical reaction—that is, new substances form. Later in this chapter, you will learn which elements are likely to gain electrons, which are likely to give up electrons, and which are likely to share electrons. You will also learn how the periodic table of the elements can help you predict how atoms of different elements react.

Reading Checkpoint **What information does an electron dot diagram show?**

FIGURE 9
Electron Dot Diagrams
An atom's valence electrons are shown as dots around the symbol of the element. Notice that oxygen atoms have 6 valence electrons. **Predicting** *How many more electrons are needed to make an oxygen atom stable?*



Instruct

Valence Electrons and Bonding

Teach Key Concepts L2

Visualizing Valence Electrons

Focus Introduce electron dot diagrams as a model to help students visualize valence electrons and understand their role in bonding.

Teach Read aloud the definition of valence electrons. Then, draw an electron dot diagram on the board for strontium (Sr). Explain that each dot represents one of strontium's two valence electrons. Next, draw an electron dot diagram for selenium (Se). Ask: **How many valence electrons does selenium have?** *(Six)*

Apply Tell students that krypton's chemical symbol is Kr and that krypton has eight valence electrons. Call on a volunteer to go to the board and draw an electron dot diagram for krypton. **learning modality: visual**

Help Students Read

Building Vocabulary Help students distinguish between the closely related terms *chemical bond* and *chemical reaction.* Have students scan the text on this page to find the definition of each term. Call on students to read aloud the definitions. Ask: **How are the two terms related?** *(Sample answer: A chemical bond is a force of attraction between two atoms that can result in a chemical reaction, or the formation of new substances.)*

Independent Practice L2

All in One Teaching Resources

- Guided Reading and Study Worksheet: *Atoms, Bonding, and the Periodic Table*

Student Edition on Audio CD

Differentiated Instruction

Gifted and Talented L3

Critical Writing Challenge students to write a concise paragraph explaining how electron dot diagrams simplify the structure of the atom as it is represented by the modern atomic model. Remind students that the modern atomic model is described in the section *Elements and Atoms.* Tell students also to explain why the diagrams are still useful for modeling how and why chemical reactions occur, despite their limitations. **learning modality: logical/mathematical**

Monitor Progress L2

Writing Have students define the key terms on these two pages.

Answers

Figure 9 Two more electrons

Reading Checkpoint The number of valence electrons an atom has

The Periodic Table

Teach Key Concepts L2

Using the Periodic Table

Focus Guide students in understanding how to use the periodic table.

Teach Have students look at the periodic table in Figure 10 and read the caption and labels. Read the definition of atomic number, and point out that the atomic number is the number above each element's one- or two-letter symbol. Check students' understanding by asking: **What is the atomic number of zinc (Zn)?** *(30)* **How many protons does chromium (Cr) have?** *(24)*

Apply Ask: **Which element has an atomic number of 53?** *(Iodine)* **Does any other element in the periodic table have that atomic number?** *(No, the atomic number of each element is unique.)* **learning modality: visual**

Go Online active art

For: Periodic table activity
Visit: PHSchool.com
Web Code: cgp-1032

Students can interact with a periodic table activity online.

All in One Teaching Resources

- Transparency L4

Lab zone Build Inquiry L3

Atomic Mass

Materials periodic table (Figure 10)
Time 5 minutes

Focus Guide students in interpreting the meaning of atomic mass.

Teach Remind students that most of an atom's mass is in the nucleus. Ask: **Which two types of particles contribute most to an atom's mass?** *(Protons and neutrons)* Point out that most atomic masses listed in the periodic table are not whole numbers. Tell students that while the atoms of an element all have the same number of protons, they may have different numbers of neutrons. Explain that these different forms of atoms of an element are called isotopes. The atomic masses listed in the periodic table are averages that reflect the abundances of isotopes of a given element. Ask: **In which period are many of the atomic masses whole numbers?** *(Period 7)* Tell students that these values indicate the atomic masses of the most stable isotopes of these elements.

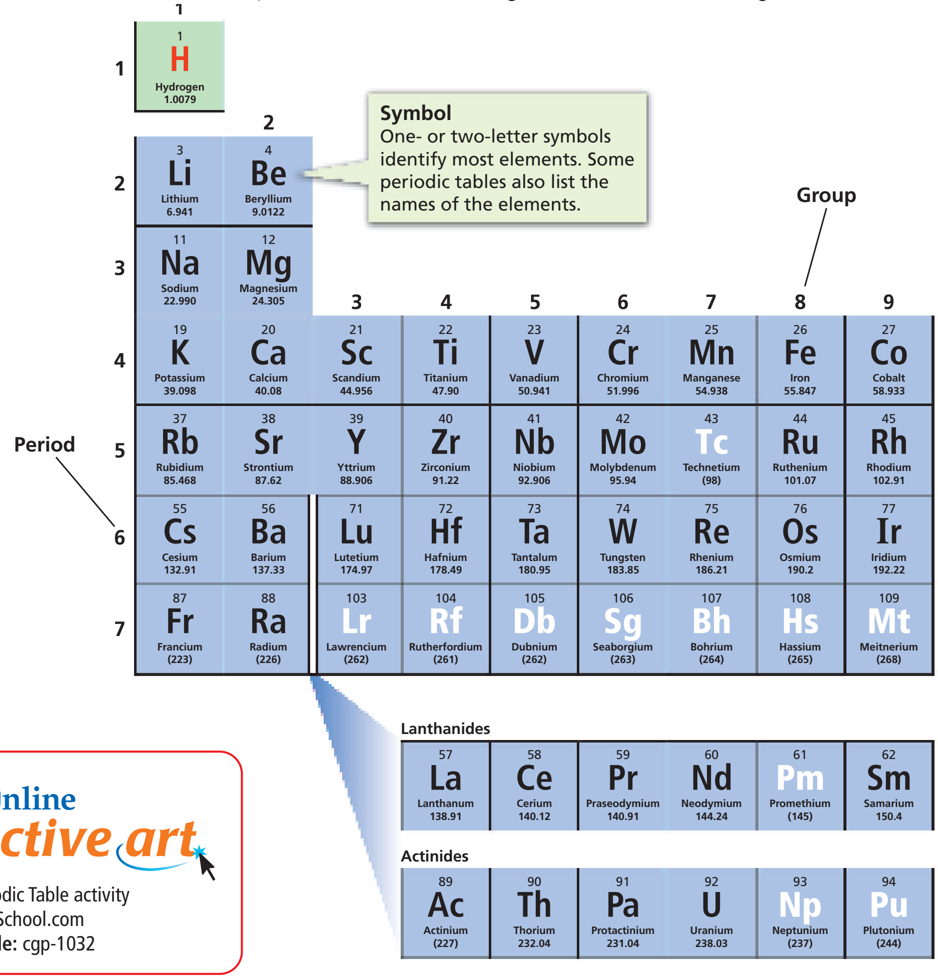
Apply Ask: **If all the atoms of an element have the same atomic number, why do their isotopes have different atomic masses?** *(Neutrons contribute to an atom's mass, so if the number of neutrons is different, the atomic mass will be different.)* **learning modality: logical/mathematical**

The Periodic Table

The periodic table is a system used worldwide for organizing elements into categories. The way the elements are organized gives you important information about the arrangement of the electrons in their atoms. If you know the number of valence electrons that atoms of different elements have, you have a clue as to which elements combine and how.

Organizing the Elements Look at the periodic table in Figure 10. Each element is represented by a **symbol,** usually consisting of one or two letters. Above the symbol is the element's atomic number. The **atomic number** of an element is the number of protons in the nucleus of an atom. Notice that the elements are arranged in order of increasing atomic number.

FIGURE 10
The Periodic Table
Elements are organized into rows and columns based on their atomic number. **Interpreting Tables** *What other element is in the same period as hydrogen? What is the next element in the same group as oxygen?*



Go Online active art

For: Periodic Table activity
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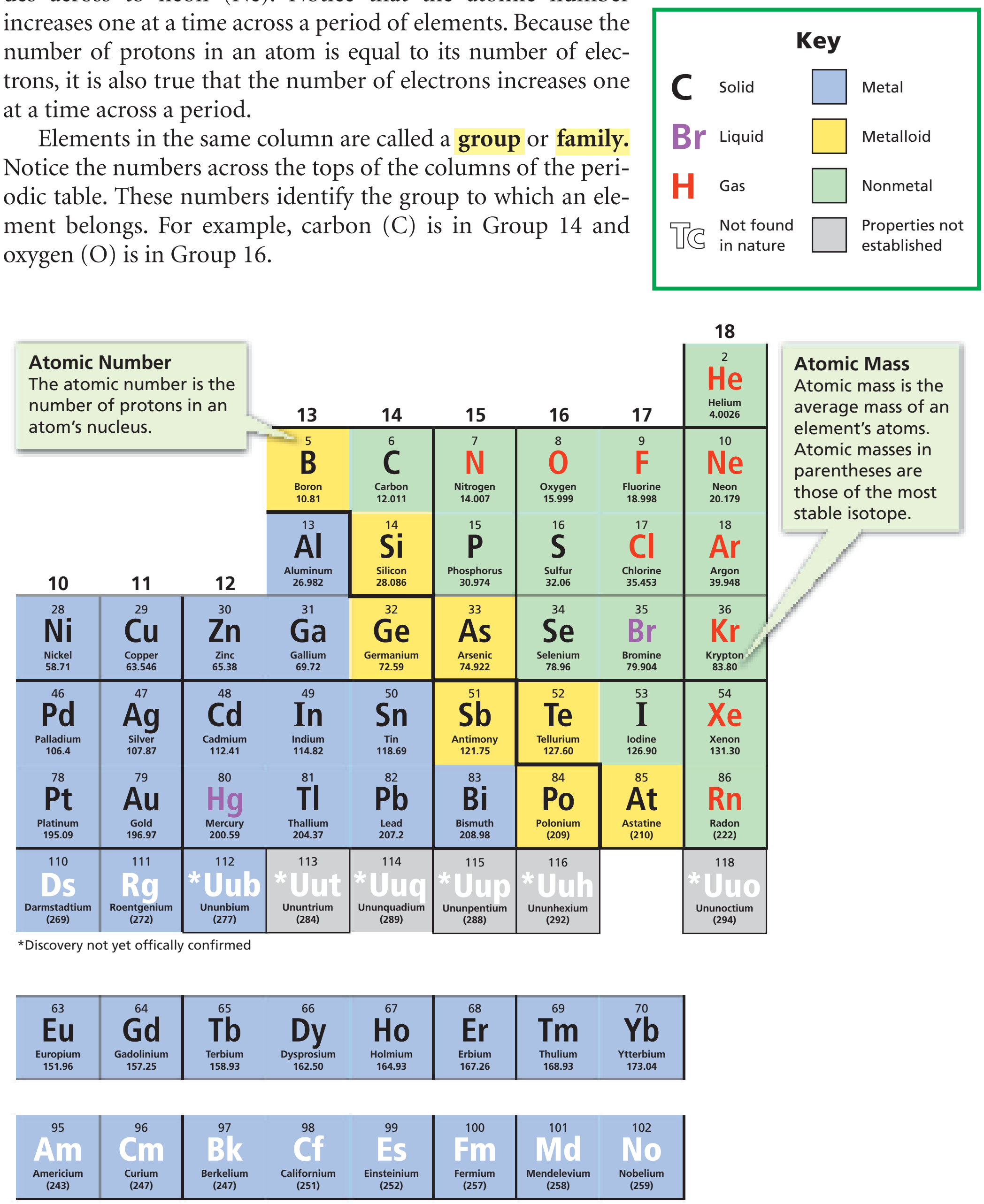
Periods and Groups A row of elements across the periodic table is called a **period.** Hydrogen and helium make up the first period. The second period starts with lithium (Li) and continues across to neon (Ne). Notice that the atomic number increases one at a time across a period of elements. Because the number of protons in an atom is equal to its number of electrons, it is also true that the number of electrons increases one at a time across a period.

Elements in the same column are called a **group** or **family.** Notice the numbers across the tops of the columns of the periodic table. These numbers identify the group to which an element belongs. For example, carbon (C) is in Group 14 and oxygen (O) is in Group 16.



Use Visuals: Figure 10 L2

Periods and Groups

Focus Guide students in identifying the basis of the organization of the periodic table in terms of periods and groups.

Teach Explain that each row of the periodic table in Figure 10 is called a period and that each column is called a group or family. Ask: **Which elements are in Period 1?** *(Hydrogen and helium).* **Which elements are in Group 1?** *(Hydrogen, lithium, sodium, potassium, rubidium, cesium, and francium)*

Apply Ask: **What is the next element in the same period as potassium?** *(Calcium)* **What is the next element in the same group as carbon?** *(Silicon)* **learning modality: visual**

Lab zone Build Inquiry L2

Interpreting Symbols

Materials periodic table (Figure 10)

Time 5 minutes

Focus Challenge students to interpret the color-coded symbols in the periodic table.

Teach Call students' attention to the key of the periodic table. Have them use the key to find a metal, a metalloid, and a nonmetal in the table.

Apply Ask: **Which element is not found in nature, curium or zirconium?** *(Curium)* **Which element is a solid, chlorine or iodine?** *(Iodine)* **Which two elements in the table are liquids?** *(Mercury and bromine)* **learning modality: visual**

Differentiated Instruction

English Learners/Beginning L1

Comprehension: Ask Questions Check that students understand the difference between periods and groups. Ask **Which period is sodium in?** *(Period 3)* **Which group is sodium in?** *(Group 1)* If necessary, remind students that periods are rows and groups are columns. **learning modality: visual**

English Learners/Intermediate L2

Comprehension: Ask Questions Reinforce the meanings of period and group. Then, check students' comprehension of the overall organization of the periodic table. Ask **Which element is in Period 6 and also in Group 6?** *(Tungsten)* **Is manganese (Mn) in Period 7 or Group 7?** *(Group 7)* **learning modality: visual**

Monitor Progress L2

Oral Presentation Ask students to identify the period and group of several elements in the periodic table.

Answer

Figure 10 Helium is in the same period as hydrogen. The next element in the same family as oxygen is sulfur.

Use Visuals: Figure 11 L2

Valence Electron Patterns

Focus Guide students in recognizing that all the elements in a group have the same number of valance electrons, and help them appreciate the significance of valence electrons.

Teach Point out the pattern of valence electrons in the electron dot diagrams in Figure 11. Ask: **Which two elements are in Group 1?** *(Lithium and sodium)* **How many valence electrons does each one have?** *(One)* In a similar way, have students name the elements and numbers of valence electrons in a few examples in Groups 2 and 13 through 18. Instruct students to look at Figure 10 if they are unsure to which group any of the elements belong.

Apply After students have recognized the pattern of valence electrons in groups, explain that elements with the same number of valence electrons have similar properties. For example, lithium, sodium, and the other elements in Group 1 are all alkali metals, which are very reactive. **learning modality: visual**

All in One Teaching Resources

- Transparency L5

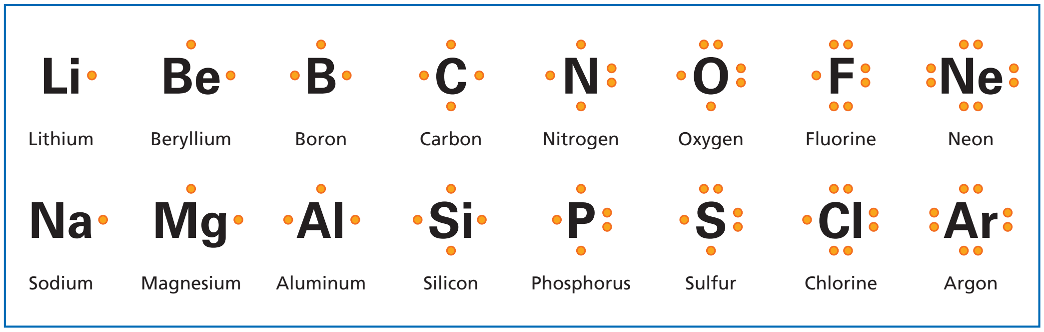


Figure 11
Patterns of Valence Electrons
After the number of valence electrons reaches 8, a new period begins.
Comparing and Contrasting *How does the number of valence electrons in elements within the same group compare?*

How the Periodic Table Works The periodic table is based on the structure of atoms, especially the arrangement of electrons. Think of how atoms change from left to right across a period. **As the number of protons—or atomic number—increases, the number of electrons also increases. As a result, the properties of the elements change in a regular way across a period.** Figure 11 compares the electron dot diagrams of the elements in Periods 2 and 3 from left to right across the table. Notice that each element has one more valence electron than the element to its left.

Except for Period 1, a period ends when the number of valence electrons reaches eight. The next period begins with atoms having valence electrons of higher energy than those in the period before it. This repeating pattern means the elements within a group always have the same number of valence electrons. For example, all the Group 1 elements have one valence electron, and all the Group 2 elements have two. Elements in Group 17 have seven valence electrons. The elements within a group have similar properties because they all have the same number of valence electrons in their atoms.

Noble Gases The Group 18 elements are known as the **noble gases.** Atoms of these elements have eight valence electrons, except for helium, which has two. Recall that when atoms have the maximum number of valence electrons, they become stable. This is already the case with the noble gases. As a result, noble gases do not react easily with other elements. Even so, chemists have been able to make noble gases form compounds with a few other elements.

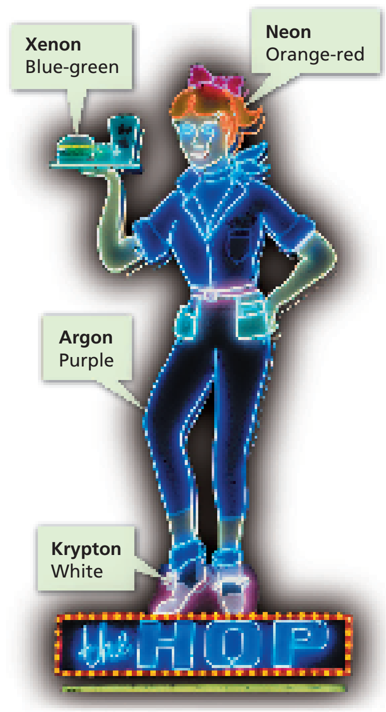


Figure 12
"Neon" Signs
The variety of colors in a "neon" sign results from passing an electric current through sealed glass tubes containing different noble gases.

Reactive Nonmetals and Metals Now look at the elements in the column just to the left of the noble gases. The elements in Group 17 are called the **halogens.** Atoms in the halogen family have seven valence electrons. A gain of just one more electron gives these atoms the stable number of eight electrons, as in the noble gases. As a result, elements in the halogen family react easily with other elements whose atoms can give up or share electrons.

At the far left side of the periodic table is Group 1, called the **alkali metal** family. Atoms of the alkali metals have only one valence electron. Except for lithium, losing this electron leaves a Group 1 atom with a stable set of eight electrons that have lower energy. (Lithium atoms are left with a stable set of two electrons.) Therefore, alkali metal atoms can become chemically more stable by losing their one valence electron. This property makes the alkali metals very reactive.

Reading Checkpoint **Where on the periodic table are the halogens found?**

Lab zone **Skills Activity**

Classifying

Match each element on the left with the element on the right that has the most similar chemical properties. Use the periodic table to help you.

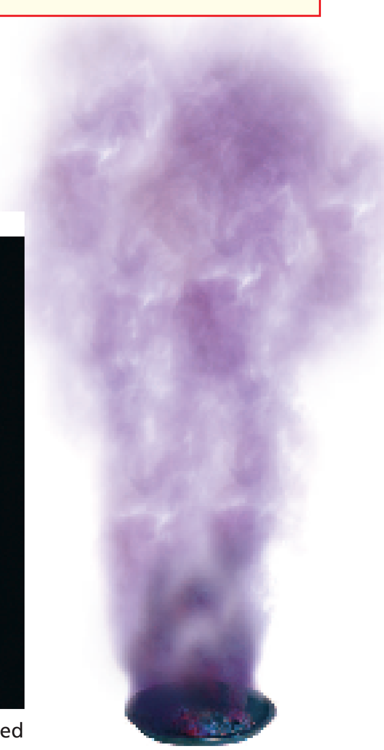
Krypton (Kr)	Sodium (Na)
Phosphorus (P)	Neon (Ne)
Potassium (K)	Calcium (Ca)
Magnesium (Mg)	Sulfur (S)
Silicon (Si)	Nitrogen (N)
Oxygen (O)	Carbon (C)

Why did you match the pairs as you did?

FIGURE 13
Reactive Elements
Elements in Group 17 (the halogens) and Group 1 (the alkali metals) are highly reactive.
Relating Cause and Effect *Why are elements in these two groups so reactive?*

▼ Sodium, an alkali metal, reacts vigorously with bromine, a halogen.

▲ Steel wool burns when exposed to the halogen chlorine.



▲ When iodine, a halogen, reacts with aluminum, a purple gas is produced.

Lab zone **Build Inquiry** L2

Predicting Reactivity of Metals

Focus Help students understand why halogens and alkali metals are both highly reactive, even though they have very different numbers of valence electrons.

Teach Say that halogens are found in Group 17 of the periodic table. Ask: **How many valence electrons are in Group 17 elements?** *(Seven)* Explain that elements with seven valence electrons react easily by gaining one electron because this gives them a stable set of eight valence electrons. Then, say that alkali metals are found in Group 1 of the periodic table. Ask: **How many valence electrons are in Group 1 elements?** *(One)* Explain that elements with just one valence electron can react easily by losing one electron because this leaves them with a stable set of eight electrons at the next energy level.

Apply Ask: **Would you predict that elements with four valence electrons would be more or less reactive than halogens and alkali metals?** *(Students may correctly predict that elements with four valence electrons would be less reactive.)* **learning modality: logical/mathematical**

Monitor Progress L2

Drawing Have students draw an electron dot diagram of a noble gas, an alkali metal, and a halogen.

Answers
Figure 11 Elements within a group always have the same number of valence electrons.
Figure 13 Elements in Group 17 are so reactive because they easily gain one electron. Elements in Group 1 are so reactive because they easily lose one electron.

Reading Checkpoint The halogens are found in Group 17.

Lab zone **Skills Activity**

Skills Focus Classifying L2
Materials periodic table
Time 10 minutes

Tip Remind students that the chemical properties of elements are related to their number of valence electrons.

Expected Outcome Elements in the same group should be matched because they have the same number of valence electrons and similar properties: krypton and neon, phosphorous and nitrogen, potassium and sodium, magnesium and calcium, silicon and carbon, oxygen and sulfur.

Extend Have students identify the number of valence electrons of the matched elements. **learning modality: logical/mathematical**

Discovery Channel School Video Field Trip

Atoms and Bonding

Show the Video Field Trip so students can see how elements are arranged in the periodic table, how atoms are structured, and how bonding occurs. Discussion question: **What determines how reactive the atoms of an element are?** *(The natural tendency of atoms to either completely fill or completely empty the outer shell of electrons)*

Lab zone Teacher Demo L2

Observing Reactivity of Alkaline Earth Metals

Materials small amounts of magnesium and calcium, 2 beakers of cold water, 1 beaker of hot water

Time 10 minutes

Focus Show students that metals in the same group have similar but not identical properties.

Teach Tell students that calcium and magnesium, Group 2 metals, are almost as reactive as Group 1 elements. Then, wearing goggles and a lab apron, add a small amount of magnesium to one jar of cold water and a small amount of calcium to the other jar of cold water. Ask: **Which element reacts with cold water?** *(Calcium produces bubbles and turns the water cloudy as it reacts).* Next, add a small amount of magnesium to the jar of hot water. Ask: **Does magnesium react with hot water?** *(Yes)*

Apply Ask: **Which element is more reactive, calcium or magnesium?** *(Calcium)* **learning modality: visual**

Integrating Health Science L2

Tell students that magnesium has essential biological functions: It is an important component of chlorophyll, the plant compound needed for photosynthesis, and humans need it to activate enzymes involved in protein synthesis. Ask: **How can you get magnesium in your diet?** *(Sample answer: Whole grains and green, leafy vegetables, such as spinach.)* **learning modality: verbal**

Discovery Channel School

Atoms and Bonding

Video Preview
▶ Video Field Trip
Video Assessment

Other Metals Look at the elements in Groups 2 through 12 of the periodic table. Like the Group 1 elements, these elements are metals. Most have one, two, or three valence electrons. They react by losing these electrons, especially when they combine with oxygen or one of the halogens.

How reactive a metal is depends on how easily its atoms lose valence electrons. Some metals, such as those in Group 2 (the alkaline earth metals), lose electrons easily and are almost as reactive as the alkali metals of Group 1. Other metals, such as platinum (Pt) in Group 10 and gold (Au) in Group 11, are unreactive. Mercury (Hg) is the only metal that is a liquid at room temperature. All the other metals are solids, although gallium (Ga) melts just above room temperature.

Science and **History**

Discovery of the Elements

In 1869, Dmitri Mendeleev published the first periodic table. At that time, 63 elements were known. Since then, scientists have discovered or created about 50 new elements.

1875
Gallium
The French chemist Paul-Émile Lecoq de Boisbaudran discovered an element that he called gallium. It had properties predicted by Mendeleev for an unknown element that would fit directly below aluminum in the periodic table.

1894
Argon, Neon, Krypton, and Xenon
British chemist William Ramsay discovered an element he named argon, after the Greek word for "lazy." The name fits because argon does not react with other elements. Ramsay looked for other nonreactive gases and discovered neon, krypton, and xenon.

1898
Polonium and Radium
Polish chemist Marie Curie started with three tons of uranium ore before she eventually isolated a few grams of two new elements. She named them polonium and radium.

1830 — 1865 — 1900

Background

Facts and Figures Gallium is known today to be unique in remaining in a liquid state over a greater range of temperatures than any other element. Some compounds of gallium, including gallium arsenide, are excellent semiconductors, used to make integrated circuits in computers.

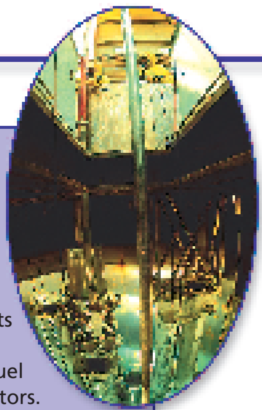
For many years after the noble gases were discovered, scientists believed that they would not react with other elements. Then, in 1962, a British chemist named Neil Bartlett proved that this was incorrect by making the first xenon compound. Later, compounds were made with radon and krypton. These three noble gases are believed to be reactive, even though they have eight valence electrons, because there is so much space and so many other electrons between their valence electrons and their nuclei.

Other Nonmetals Elements in the green section of the periodic table are the nonmetals. Carbon (C), phosphorus (P), sulfur (S), selenium (Se), and iodine (I) are the only nonmetals that are solids at room temperature. Bromine (Br) is the only liquid. All of the nonmetals have four or more valence electrons. Like the halogens, other nonmetals become stable when they gain or share enough electrons to have a set of eight valence electrons.

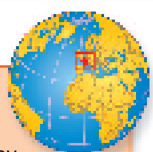
The nonmetals combine with metals usually by gaining electrons. But nonmetals can also combine with other nonmetals by sharing electrons. Of the nonmetals, oxygen and the halogens are highly reactive. In fact, fluorine is the most reactive element known. It even forms compounds with some of the noble gases.

Writing in Science

Research and Write Select three elements that interest you and find out more about them. Who identified or discovered the elements? How did the elements get their names? How are the elements used? To answer these questions, look up the elements in reference books.



1941
Plutonium
American chemist Glenn Seaborg was the first to isolate plutonium, which is found in small amounts in uranium ores. Plutonium is used as fuel in certain nuclear reactors. It has also been used to power equipment used in space exploration.



1939
Francium
Although Mendeleev predicted the properties of an element he called "eka-cesium," the element was not discovered until 1939. French chemist Marguerite Perey named her discovery francium, after the country France.

1997
Elements 101 to 109
The International Union of Pure and Applied Chemists (IUPAC) agreed on names for elements 101 to 109. Many of the names honor scientists, such as Lise Meitner, shown here in 1946. All of the new elements were created in laboratories, and none is stable enough to exist in nature.

2003 to Present
More New Elements
Darmstadtium (110) and roentgenium (111) are named. Reasearch to produce and study new synthetic elements continues.

1935 1970 2005

Science and History

Focus Guide students in appreciating the importance of discovering new elements, and explain how synthetic elements are created.

Teach Describe what the elements in the timeline are used for. For example, say that gallium is used to make faster CPUs in computers; polonium is used to reduce electrostatic charges in printing and photography equipment; radium is used to treat cancer; and plutonium is used to produce nuclear power in nuclear reactors, to make nuclear weapons, and to power equipment on the moon. Ask: **What are noble gases, such as argon and neon, used for?** *(Light bulbs)*

Writing in Science

Writing Mode Research

Scoring Rubric

4 Exceeds criteria; includes a detailed, accurate, and well organized paper that completely answers all three questions
3 Meets criteria
2 Includes answers to only two questions and/or covers only two elements
1 Includes answers to only one question and/or covers only one element and contains errors or other inadequacies

Background

History of Science In 1997, the IUPAC named element 106 seaborgium (Sg) in honor of Glenn Seaborg, who not only helped discover plutonium but also americium, curium, berkelium, californium, and several other heavy elements during the 1940s. The IUPAC also named element 109 meitnerium (Mt) in memory of Austrian physicist Lise Meitner, who helped discover protactinium in 1918 and later was the first scientist to identify nuclear fission. More recently, element 110 was named darmstadtium in honor of physicists in Darmstadt, Germany, who first produced the element in 1994. These same scientists also produced elements 111, 112, and 114 in the mid-1990s. In 2004, Russian and American scientists reported creating elements 113 and 115. The new elements existed for less than a second.

Monitor Progress L2

Skills Check Have students make a Venn diagram comparing and contrasting metals and nonmetals.

Monitor Progress L3

Answer

Reading Checkpoint Because it has only one valence electron like other Group 1 elements

Assess

Reviewing Key Concepts

1. a. Electrons that have the highest energy and are held most loosely **b.** Valence electrons determine the way atoms can bond. When elements react to form compounds, valence electrons may be transferred from one atom to another or shared between atoms. **c.** When oxygen forms compounds, oxygen atoms gain or share valence electrons, making a set of eight. This makes them more stable.
2. a. A row of elements across the periodic table is called a period. Atomic number and number of electrons increase by one from left to right across a period. Elements in the same column are called a group or family. Atomic number increases from top to bottom of a group, but the number of valence electrons is the same within a group. **b.** The properties of elements change in a regular way across a period because the number of valence electrons changes in a pattern that repeats in each period. **c.** The elements of Group 18 are the least reactive elements in the periodic table because they have eight valence electrons, except helium. Helium is stable with two electrons.

Reteach L1

List the following terms on the board: *noble gas, halogen, alkali metal, alkaline earth metal, nonmetal, metalloid.* Call on students to identify properties of each type of element.

Performance Assessment L2

Writing Ask student to list information about elements that is found in the periodic table.

All in One Teaching Resources

- Section Summary: *Atoms, Bonding, and the Periodic Table*
- Review and Reinforcement: *Atoms, Bonding, and the Periodic Table*
- Enrich: *Atoms, Bonding, and the Periodic Table*

◄ The quartz movement of the watch

FIGURE 14
A Metalloid at Work
This quartz-movement watch keeps time with a small quartz crystal, a compound made of the metalloid silicon and the nonmetal oxygen. The crystal vibrates at about 32,000 vibrations per second when a voltage is applied.

Metalloids Several elements known as metalloids lie along a zigzag line between the metals and nonmetals. Depending on the conditions, these elements can behave as either metals or nonmetals. The metalloids have from three to six valence electrons and can either lose or share electrons when they combine with other elements.

Hydrogen Notice that hydrogen is considered to be a nonmetal. It is located above Group 1 in the periodic table because it has only one valence electron. However, even though hydrogen is a reactive element, its properties differ greatly from those of the alkali metals.

Reading Checkpoint **Why is hydrogen grouped above the Group 1 elements even though it is not a metal?**

Section 2 Assessment

Target Reading Skill **Building Vocabulary** Use your definitions to help you answer the questions below.

Reviewing Key Concepts

1. a. **Defining** What are valence electrons?
   b. **Reviewing** What role do valence electrons play in the formation of compounds from elements?
   c. **Comparing and Contrasting** Do oxygen atoms become more stable or less stable when oxygen forms compounds? Explain.
2. a. **Summarizing** Summarize how the periodic table is organized. Use the words *period* and *group.*
   b. **Explaining** Why do the properties of elements change in a regular way across a period?
   c. **Relating Cause and Effect** How reactive are the elements in Group 18? Explain this reactivity in terms of the number of valence electrons.

Lab zone At-Home Activity

Looking for Elements Find some examples of elements at home. Then locate the elements on the periodic table. Show your examples and the periodic table to your family. Point out the positions of the elements on the table and explain what the periodic table tells you about the elements. Include at least two nonmetals in your discussion. (*Hint:* The nonmetals may be invisible.)

Lab zone At-Home Activity

Looking for Elements L2 Students are likely to find more elements if they read through the names of the elements in the periodic table before they look for them at home. Elements students might find at home include aluminum (in soft drink cans), calcium (in dietary supplements), copper (in pots and pans), tungsten (in light bulb filaments), sodium (in table salt), gold (in jewelry), silver (in utensils), chlorine (in bleach), oxygen, (in air), and hydrogen (in water).

Lab zone **Skills Lab**

Comparing Atom Sizes

Problem

How is the radius of an atom related to its atomic number?

Skills Focus

making models, graphing, interpreting data

Materials

- drawing compass
- metric ruler
- calculator
- periodic table of the elements (Appendix D)

Procedure

1. Using the periodic table as a reference, predict whether the size (radius) of atoms will increase, remain the same, or decrease as you go from the top to the bottom of a group, or family, of elements.
2. The data table lists the elements in Group 2 in the periodic table. The atomic radius of each element is given in picometers (pm). Copy the data table into your notebook.
3. Calculate the relative radius of each atom compared to beryllium, the smallest atom listed. Do this by dividing each radius by the radius of beryllium. (*Hint:* The relative radius of magnesium would be 160 pm divided by 112 pm, or 1.4.) Record these values, rounded to the nearest tenth, in your data table.
4. Using a compass, draw a circle for each element with a radius that corresponds to the relative radius you calculated in Step 3. Use centimeters as your unit for the radius of each circle. **CAUTION:** *Do not push the sharp point of the compass against your skin.*
5. Label each model with the symbol of the element it represents.

Data Table

Atomic Number	Element	Radius (pm)*	Relative Radius
4	Be	112	1
12	Mg	160	
20	Ca	197	
38	Sr	215	
56	Ba	222	

**A picometer (pm) is one billionth of a millimeter.*

Analyze and Conclude

1. **Making Models** Based on your models, was your prediction in Step 1 correct? Explain.
2. **Graphing** Make a bar graph of the data given in the first and third columns of the data table. Label the horizontal axis *Atomic Number.* Mark the divisions from 0 to 60. Then label the vertical axis *Radius* and mark its divisions from 0 to 300 picometers.
3. **Interpreting Data** Do the points on your graph fall on a straight line or on a curve? What trend do the data show?
4. **Predicting** Predict where you would find the largest atom in any group, or family, of elements. What evidence would you need to tell if your prediction is correct?
5. **Communicating** Write a paragraph explaining why it is useful to draw a one- to two-centimeter model of an atom that has an actual radius of 100 to 200 picometers.

More to Explore

Look up the atomic masses for the Group 2 elements. Devise a plan to model their relative atomic masses using real-world objects.

Lab zone **Skills Lab** L2

Comparing Atom Sizes

Prepare for Inquiry

Skills Objective

After this lab, students will be able to

- make models to represent the relative sizes of atoms
- graph data showing the trend in atomic size as atomic number increases in a group
- interpret data to predict the positions of elements in the periodic table

Prep Time 10 minutes
Class Time 30 minutes

Safety

Review the safety guidelines in Appendix A.

All in One Teaching Resources

- Lab Worksheet: *Comparing Atom Sizes*

Guide Inquiry

Introduce the Procedure

Have students read through the procedure. Introduce the idea of using the smallest value in a series as the basis for measuring the other values. Use a familiar example, such as pennies as a basis for other coins. Relate this to Step 3 of the Procedure.

Expected Outcome

Students' graphs should show that radius increases as atomic number increases.

Analyze and Conclude

1. Students may have predicted correctly that the radius of atoms will increase from top to bottom of a group.

2. Make sure students have correctly set up and labeled their graphs.

3. The graph should be a curved line. Atoms with higher atomic numbers have larger radii.

4. Students are likely to predict that you would find the largest atom at the bottom of the group. They would need data on the atomic radii of other families to test their predictions.

5. You can drop two zeros to convert the numbers from picometers to centimeters and maintain the correct scale.

Extend Inquiry

More to Explore Relative atomic masses are approximately 1 (Be), 2.7 (Mg), 4.5 (Ca), 9.7 (Sr), and 15.3 (Ba). Sample plan: Use small fruits such as grapes to model the relative masses. Whole grapes would be used for whole numbers, and cut grapes for the decimal portions. For example, 2.7 grapes would model magnesium's relative mass.

Sample Data Table

Atomic Number	Element	Radius (pm)	Relative Radius
4	Be	112	1
12	Mg	160	1.4
20	Ca	197	1.8
38	Sr	215	1.9
56	Ba	222	2.0