SECTION 3

Covalent and Metallic Bonds

Imagine bending a wooden coat hanger and a wire coat hanger. The wire one would bend easily, but the wooden one would break. Why do these things behave differently?

One reason is that the bonds between the atoms of each object are different. The atoms of the wooden hanger are held together by covalent bonds (KOH VAY luhnt BAHNDZ). But the atoms of the wire hanger are held together by metallic bonds. Read on to learn about the difference between these kinds of chemical bonds.

What You Will Learn

- Explain how covalent bonds form.
- Describe molecules.
- Explain how metallic bonds form.
- Describe the properties of metals.

Vocabulary

covalent bond
molecule
metallic bond

READING STRATEGY

Reading Organizer As you read this section, create an outline of the section. Use the headings from the section in your outline.

covalent bond a bond formed when atoms share one or more pairs of electrons

Covalent Bonds

Most things around you, such as water, sugar, oxygen, and wood, are held together by covalent bonds. Substances that have covalent bonds tend to have low melting and boiling points and are brittle in the solid state. For example, oxygen has a low boiling point, which is why it is a gas at room temperature. And wood is brittle, so it breaks when bent.

A **covalent bond** forms when atoms share one or more pairs of electrons. When two atoms of nonmetals bond, a large amount of energy is needed for either atom to lose an electron. So, two nonmetals don't transfer electrons to fill the outermost energy levels of their atoms. Instead, two nonmetal atoms bond by sharing electrons with each another, as shown in the model in **Figure 1.**

Reading Check **What is a covalent bond?** (*See the Appendix for answers to Reading Checks.*)

Figure 1 *By sharing electrons in a covalent bond, each hydrogen atom (the smallest atom) has a full outermost energy level containing two electrons.*

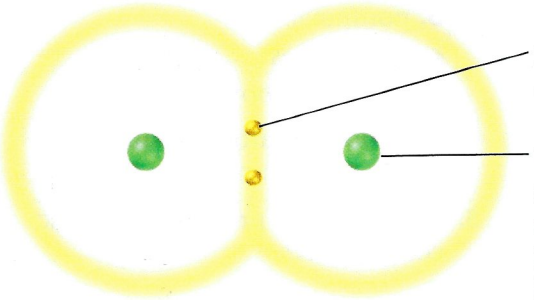
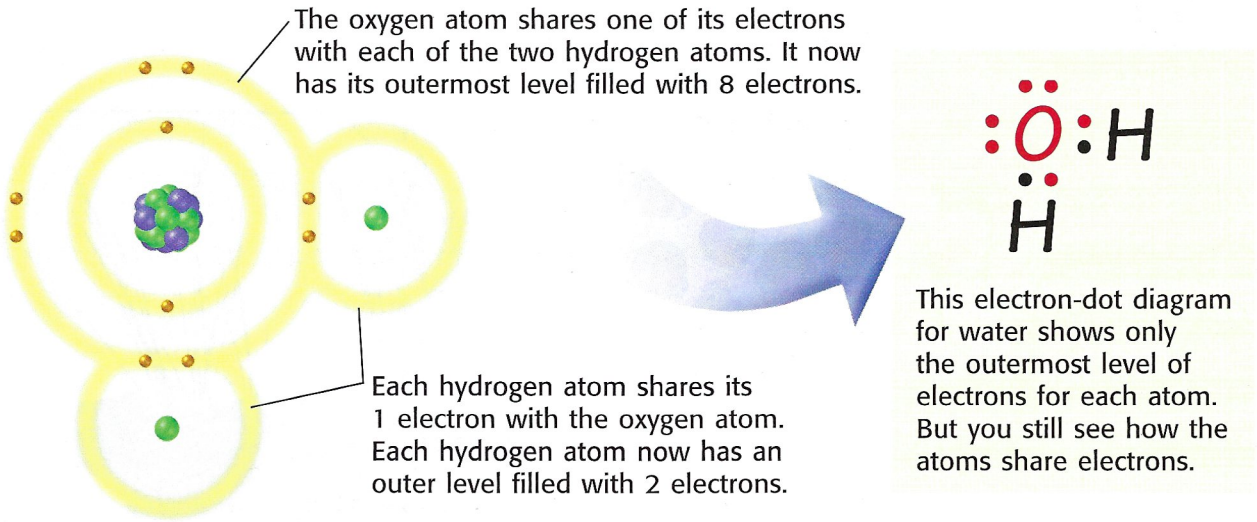


Figure 2 **Covalent Bonds in a Water Molecule**



Covalent Bonds and Molecules

Substances containing covalent bonds consist of individual particles called molecules (MAHL i KYOOLZ). A **molecule** usually consists of two or more atoms joined in a definite ratio. A hydrogen molecule is composed of two covalently bonded hydrogen atoms. However, most molecules are composed of atoms of two or more elements. The models in **Figure 2** show two ways to represent the covalent bonds in a water molecule.

molecule the smallest unit of a substance that keeps all of the physical and chemical properties of that substance

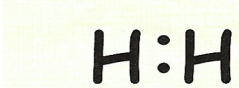
One way to represent atoms and molecules is to use electron-dot diagrams. An electron-dot diagram is a model that shows only the valence electrons in an atom. Electron-dot diagrams can help you predict how atoms might bond. To draw an electron-dot diagram, write the symbol of the element and place one dot around the symbol for every valence electron in the atom, as shown in **Figure 3.** Place the first 4 dots alone on each side, and then pair up any remaining dots.

Figure 3 **Using Electron-Dot Diagrams**

Carbon atoms have 4 valence electrons. A carbon atom needs 4 more electrons to have a filled outermost energy level.

Oxygen atoms have 6 valence electrons. An oxygen atom needs only 2 more electrons to have a filled outermost energy level.

Krypton atoms have 8 valence electrons. Krypton is nonreactive. Krypton atoms do not need any more electrons.



This diagram represents a hydrogen molecule. The dots between the letters represent a pair of shared electrons.

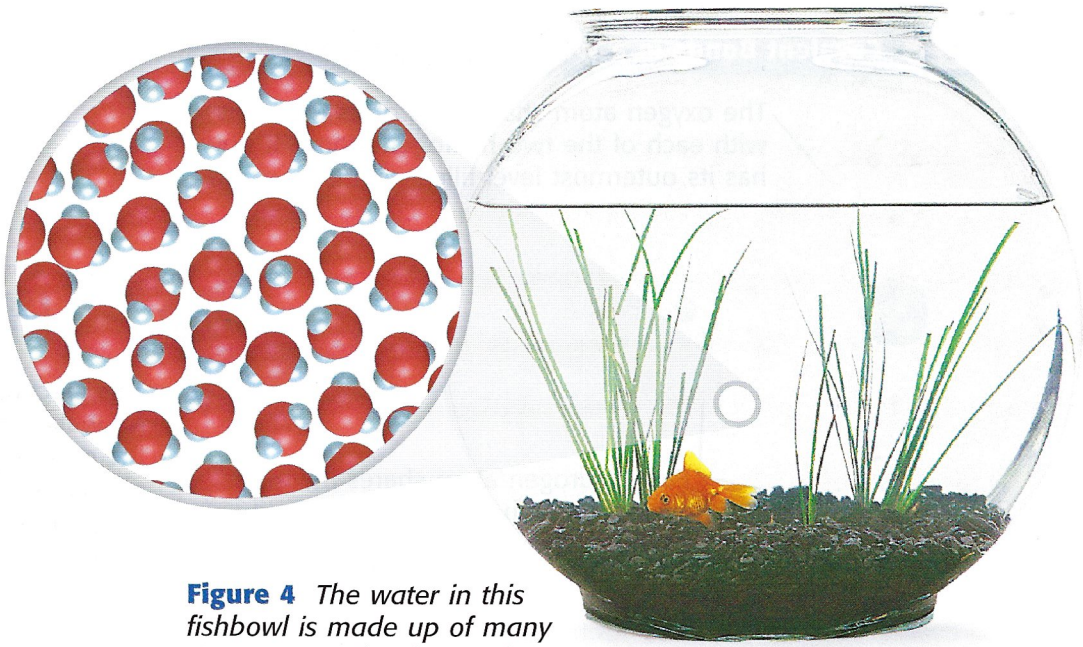


Figure 4 *The water in this fishbowl is made up of many tiny water molecules. Each molecule is the smallest particle that has the chemical properties of water.*

Covalent Compounds and Molecules

INTERNET ACTIVITY

For another activity related to this chapter, go to **go.hrw.com** and type in the keyword **HP5BNDW.**

An atom is the smallest particle into which an element can be divided and still be the same element. Likewise, a molecule is the smallest particle into which a covalently bonded compound can be divided and still be the same compound. Look at the three-dimensional models in **Figure 4.** They show how a sample of water is made up of many individual molecules of water. Imagine dividing water over and over. You would eventually end up with a single molecule of water. What would happen if you separated the hydrogen and oxygen atoms that make up a water molecule? Then, you would no longer have water.

The Simplest Molecules

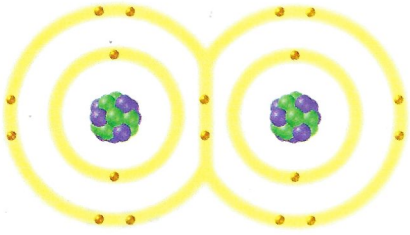


Figure 5 *Two covalently bonded fluorine atoms have filled outermost energy levels. The two electrons shared by the atoms are counted as valence electrons for each atom.*

Molecules are composed of at least two covalently bonded atoms. The simplest molecules are made up of two bonded atoms. Molecules made up of two atoms are called *diatomic molecules*. Elements that are found in nature as diatomic molecules are called *diatomic elements*. Hydrogen is a diatomic element. Oxygen, nitrogen, and the halogens fluorine, chlorine, bromine, and iodine are also diatomic elements. Look at **Figure 5.** The shared electrons are counted as valence electrons for each atom. So, both atoms of the molecule have filled outermost energy levels.

Reading Check **How many atoms are in a diatomic molecule?**

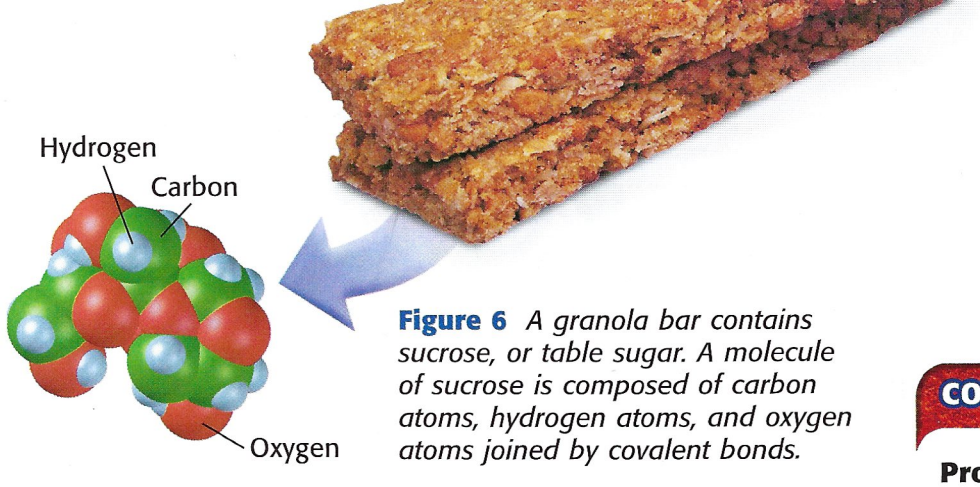


Figure 6 *A granola bar contains sucrose, or table sugar. A molecule of sucrose is composed of carbon atoms, hydrogen atoms, and oxygen atoms joined by covalent bonds.*

More-Complex Molecules

Diatomic molecules are the simplest molecules. They are also some of the most important molecules. You could not live without diatomic oxygen molecules. But other important molecules are much more complex. Soap, plastic bottles, and even proteins in your body are examples of complex molecules. Carbon atoms are the basis of many of these complex molecules. Each carbon atom needs to make four covalent bonds to have 8 valence electrons. These bonds can be with atoms of other elements or with other carbon atoms, as shown in the model in **Figure 6.**

CONNECTION TO Biology

Proteins Proteins perform many functions throughout your body. A single protein can have thousands of covalently bonded atoms. Proteins are built from smaller molecules called *amino acids*. Make a poster showing how amino acids are joined to make proteins.

ACTIVITY

Metallic Bonds

Look at the unusual metal sculptures shown in **Figure 7.** Some metal pieces have been flattened, while other metal pieces have been shaped into wires. How could the artist change the shape of the metal into all of these different forms without breaking the metal into pieces? Metal can be shaped because of the presence of a metallic bond, a special kind of chemical bond. A **metallic bond** is a bond formed by the attraction between positively charged metal ions and the electrons in the metal. Positively charged metal ions form when metal atoms lose electrons.

metallic bond a bond formed by the attraction between positively charged metal ions and the electrons around them

Figure 7 *The different shapes of metal in these sculptures are possible because of the bonds that hold the metal together.*

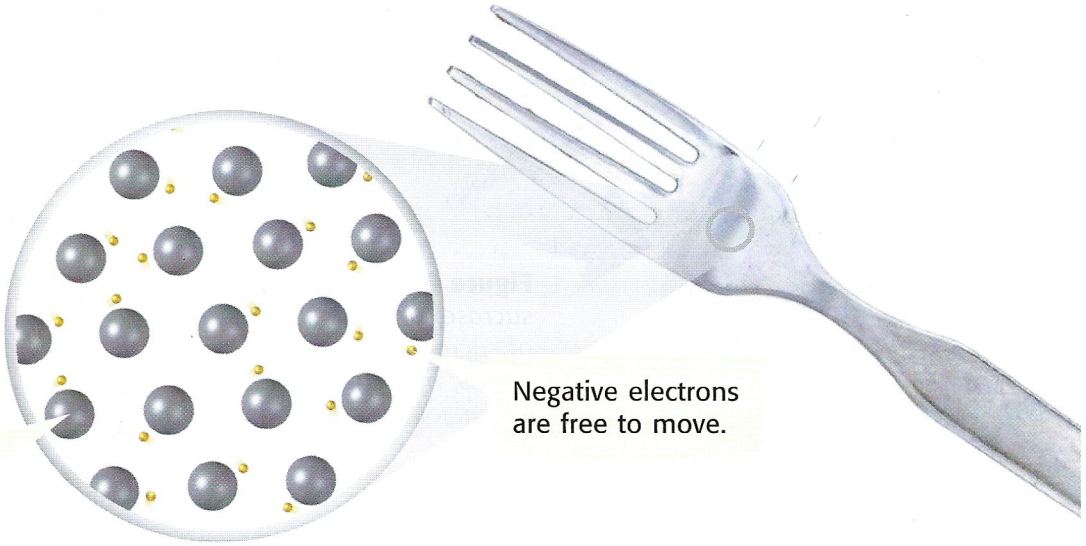


Figure 8 *Moving electrons are attracted to the metal ions, and the attraction forms metallic bonds.*

Movement of Electrons Throughout a Metal

Bonding in metals is a result of the metal atoms being so close to one another that their outermost energy levels overlap. This overlapping allows valence electrons to move throughout the metal, as shown in **Figure 8.** You can think of a metal as being made up of positive metal ions that have enough valence electrons "swimming" around to keep the ions together. The electrons also cancel the positive charge of the ions. Metallic bonds extend throughout the metal in all directions.

QUICK LAB

Bending with Bonds

1. Straighten out a **wire paper clip.** Record your observations.
2. Bend a **piece of chalk.** Record your observations.
3. Chalk is composed of calcium carbonate, a compound containing ionic bonds. What kind of bond is present in the paper clip?
4. Explain why you could change the shape of the paper clip but could not bend the chalk without breaking it.

Properties of Metals

Metallic bonding is what gives metals their particular properties. These properties include electrical conductivity, malleability, and ductility.

Conducting Electric Current

Metallic bonding allows metals to conduct electric current. For example, when you turn on a lamp, electrons move within the copper wire that connects the lamp to the outlet. The electrons that move are the valence electrons in the copper atoms. These electrons are free to move because the electrons are not connected to any one atom.

Reshaping Metals

Because the electrons swim freely around the metal ions, the atoms in metals can be rearranged. As a result, metals can be reshaped. The properties of *ductility* (the ability to be drawn into wires) and *malleability* (the ability to be hammered into sheets) describe a metal's ability to be reshaped. For example, copper is made into wires for use in electrical cords. Aluminum can be pounded into thin sheets and made into aluminum foil.

Reading Check **What is ductility?**

Bending Without Breaking

When a piece of metal is bent, some of the metal ions are forced closer together. You might expect the metal to break because all of the metal ions are positively charged. Positively charged ions repel one another. However, positive ions in a metal are always surrounded by and attracted to the electrons in the metal—even if the metal ions move. The electrons constantly move around and between the metal ions. The moving electrons maintain the metallic bonds no matter how the shape of the metal changes. So, metal objects can be bent without being broken, as shown in **Figure 9.**

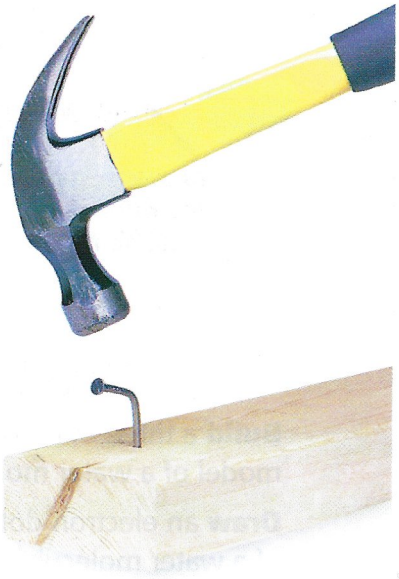


Figure 9 *Metal can be reshaped without breaking because metallic bonds occur in many directions.*

SECTION Review

Summary

- In covalent bonding, two atoms share electrons. A covalent bond forms when atoms share one or more pairs of electrons.
- Covalently bonded atoms form a particle called a *molecule*. A molecule is the smallest particle of a compound that has the chemical properties of the compound.
- In metallic bonding, the valence electrons move throughout the metal. A bond formed by the attraction between positive metal ions and the electrons in the metal is a metallic bond.
- Properties of metals include conductivity, ductility, and malleability.

Using Key Terms

1. Use each of the following terms in a separate sentence: *covalent bond* and *metallic bond*.
2. In your own words, write a definition for the term *molecule*.

Understanding Key Ideas

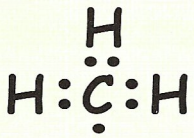
3. Between which of the following atoms is a covalent bond most likely to occur?
   - **a.** calcium and lithium
   - **b.** sodium and fluorine
   - **c.** nitrogen and oxygen
   - **d.** helium and argon
4. What happens to the electrons in covalent bonding?
5. How many dots does an electron-dot diagram of a sulfur atom have?
6. List three properties of metals that are a result of metallic bonds.
7. Describe how the valence electrons in a metal move.
8. Explain the difference between ductility and malleability. Give an example of when each property is useful.

Critical Thinking

9. **Identifying Relationships** How do the metallic bonds in a staple allow it to function properly?
10. **Applying Concepts** Draw an electron-dot diagram for ammonia (a nitrogen atom covalently bonded to three hydrogen atoms).

Interpreting Graphics

11. This electron-dot diagram is not complete. Which atom needs to form another bond? Explain.



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Topic: Types of Chemical Bonds; Properties of Metals

SciLinks code: HSM1565; HSM1231

Chapter Review

USING KEY TERMS

Complete each of the following sentences by choosing the correct term from the word bank.

crystal lattice	ionic bond
molecule	chemical bond
chemical bonding	metallic bond
valence electron	ion
covalent bond	

1. An interaction that holds two atoms together is a(n) ___.
2. A charged particle that forms when an atom transfers electrons is a(n) ___.
3. A bond formed when atoms share electrons is a(n) ___.
4. Electrons free to move throughout a material are associated with a(n) ___.
5. An electron in the outermost energy level of an atom is a(n) ___.
6. Ionic compounds are bonded in a three-dimensional pattern called a(n) ___.

UNDERSTANDING KEY IDEAS

Multiple Choice

7. Which element has a full outermost energy level containing only two electrons?

   a. fluorine, F
   b. helium, He
   c. hydrogen, H
   d. oxygen, O

8. Which of the following describes what happens when an atom becomes an ion with a 2– charge?

   a. The atom gains 2 protons.
   b. The atom loses 2 protons.
   c. The atom gains 2 electrons.
   d. The atom loses 2 electrons.

9. The properties of ductility and malleability are associated with which type of bonds?

   a. ionic
   b. covalent
   c. metallic
   d. All of the above

10. What type of element tends to lose electrons when it forms bonds?

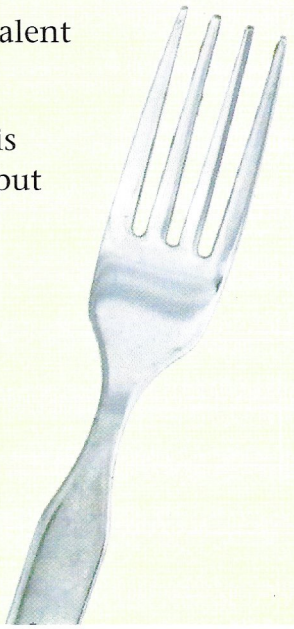
    a. metal
    b. metalloid
    c. nonmetal
    d. noble gas

11. Which pair of atoms can form an ionic bond?

    a. sodium, Na, and potassium, K
    b. potassium, K, and fluorine, F
    c. fluorine, F, and chlorine, Cl
    d. sodium, Na, and neon, Ne

Short Answer

12. List two properties of covalent compounds.
13. Explain why an iron ion is attracted to a sulfide ion but not to a zinc ion.
14. Compare the three types of bonds based on what happens to the valence electrons of the atoms.



Math Skills

15 For each atom below, write the number of electrons it must gain or lose to have 8 valence electrons. Then, calculate the charge of the ion that would form.

- **a.** calcium, Ca
- **b.** phosphorus, P
- **c.** bromine, Br
- **d.** sulfur, S

CRITICAL THINKING

16 **Concept Mapping** Use the following terms to create a concept map: *chemical bonds, ionic bonds, covalent bonds, metallic bonds, molecule,* and *ions*.

17 **Identifying Relationships** Predict the type of bond each of the following pairs of atoms would form:

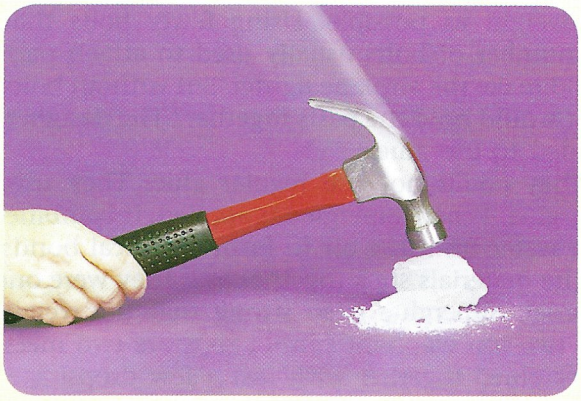
- **a.** zinc, Zn, and zinc, Zn
- **b.** oxygen, O, and nitrogen, N
- **c.** phosphorus, P, and oxygen, O
- **d.** magnesium, Mg, and chlorine, Cl

18 **Applying Concepts** Draw electron-dot diagrams for each of the following atoms, and state how many bonds it will have to make to fill its outer energy level.

- **a.** sulfur, S
- **b.** nitrogen, N
- **c.** neon, Ne
- **d.** iodine, I
- **e.** silicon, Si

19 **Predicting Consequences** Using your knowledge of valence electrons, explain the main reason so many different molecules are made from carbon atoms.

20 **Making Inferences** Does the substance being hit in the photo below contain ionic or metallic bonds? Explain your answer.



INTERPRETING GRAPHICS

Use the picture of a wooden pencil below to answer the questions that follow.

21 In which part of the pencil are metallic bonds found?

22 List three materials in the pencil that are composed of molecules that have covalent bonds.

23 Identify two differences between the properties of the material that has metallic bonds and the materials that have covalent bonds.