Section 3
Covalent and Metallic Bonds

Key Concept Covalent bonds form when atoms share electrons. Metallic bonds form by the attraction of metal ions and the electrons around them.

What You Will Learn

- Covalent compounds form when atoms of elements share electrons.
- Molecules are particles of covalent compounds and can be simple or complex.
- Atoms of metals are held together by metallic bonds.
- Metallic bonding gives metals certain properties.

Why It Matters

Learning about covalent and metallic bonds can help you understand the properties of covalent compounds, such as water and sugar, and metals, such as copper and aluminum.

Imagine bending a wooden coat hanger and a wire coat hanger. The wire one will bend easily. But the wooden one will break. Why do these objects behave differently?

One reason is that the bonds between the atoms of each object are different. The atoms of the wood are held together by covalent bonds. But the atoms of the wire are held together by metallic bonds. Read on to learn about the difference between these kinds of chemical bonds.

Covalent Bonds

Most things around you, such as water, sugar, oxygen, and the cellulose in 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, so oxygen is a gas at room temperature. And cellulose is brittle, so wood 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 nonmetal atoms don’t transfer electrons to fill their outermost energy levels. Instead, the atoms bond by sharing electrons with one another, as shown in the model in **Figure 1.**

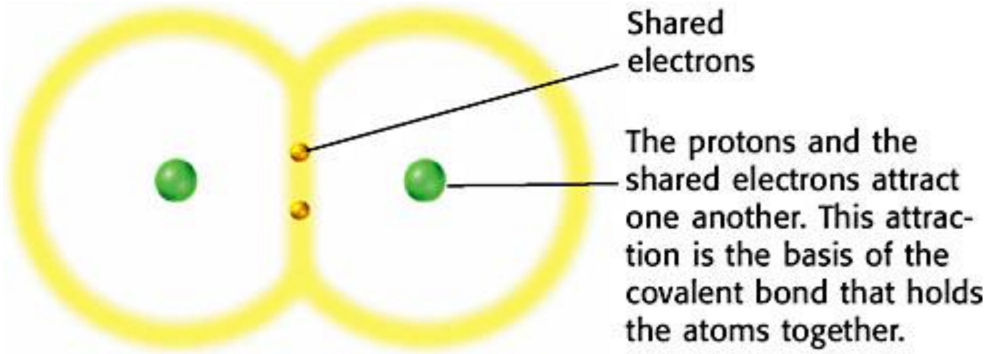

Figure 1 By sharing electrons in a covalent bond, each hydrogen atom (the smallest atom) has a full outermost energy level containing two electrons.

Standards Check What is a covalent bond?

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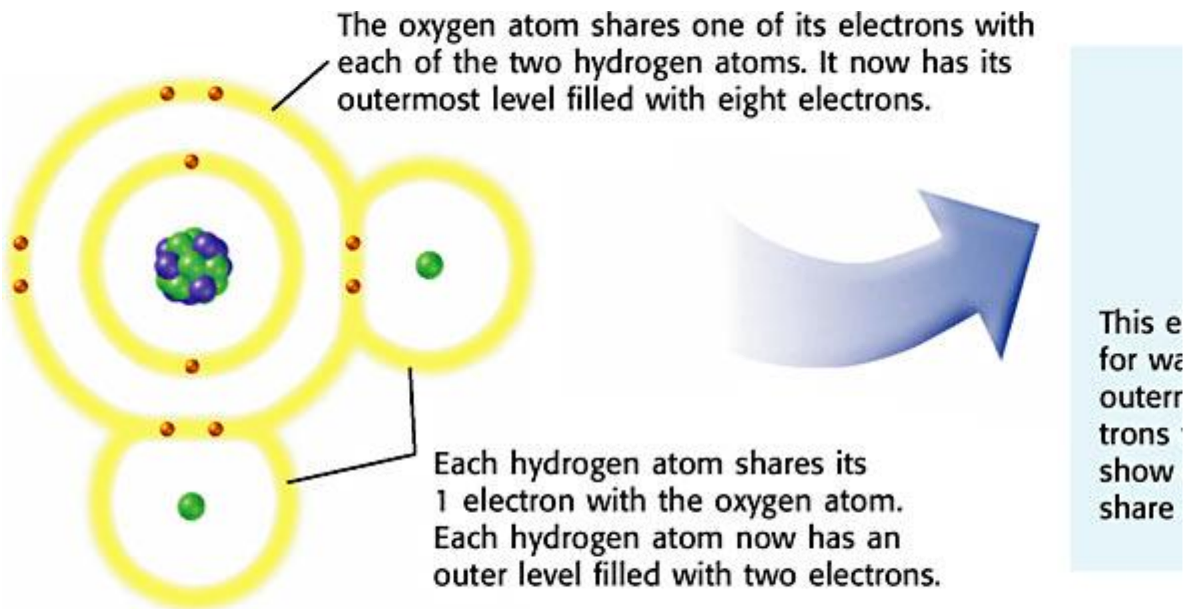
Covalent Bonds and Molecules

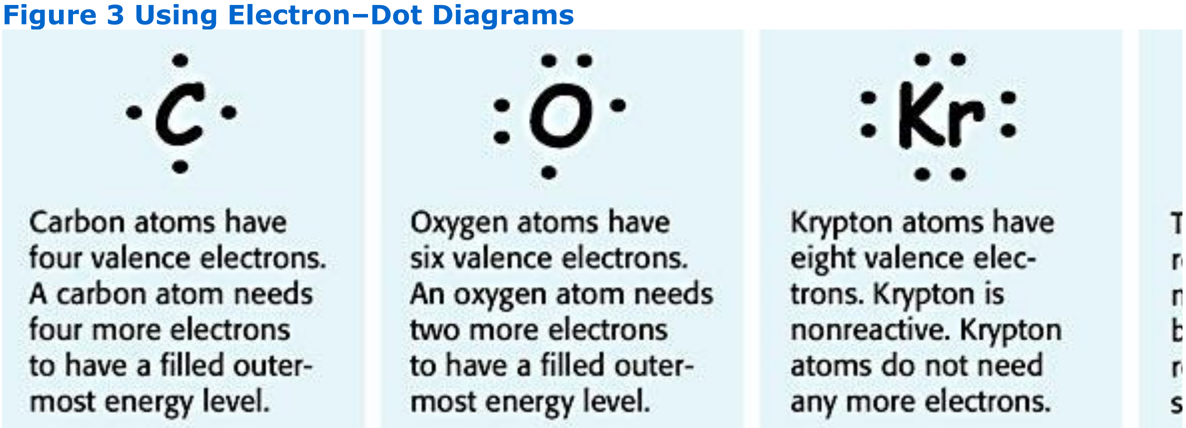
Substances that have covalent bonds consist of particles called molecules. A **molecule** is usually made of two or more atoms joined in a definite ratio. A hydrogen molecule is made of two covalently bonded hydrogen atoms. However, most molecules are composed of atoms of two or more elements. The models in **Figure 2** show two ways to represent the covalent bonds in a water molecule.

Figure 2 Covalent Bonds in a Water Molecule



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 four dots alone on each side, and then pair up any remaining dots.

Figure 3 Using Electron–Dot Diagrams



Covalent Compounds and Molecules

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. The models in **Figure 4** show how a sample of water is made up of many individual molecules of water. Imagine dividing water again and again. You would finally 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.

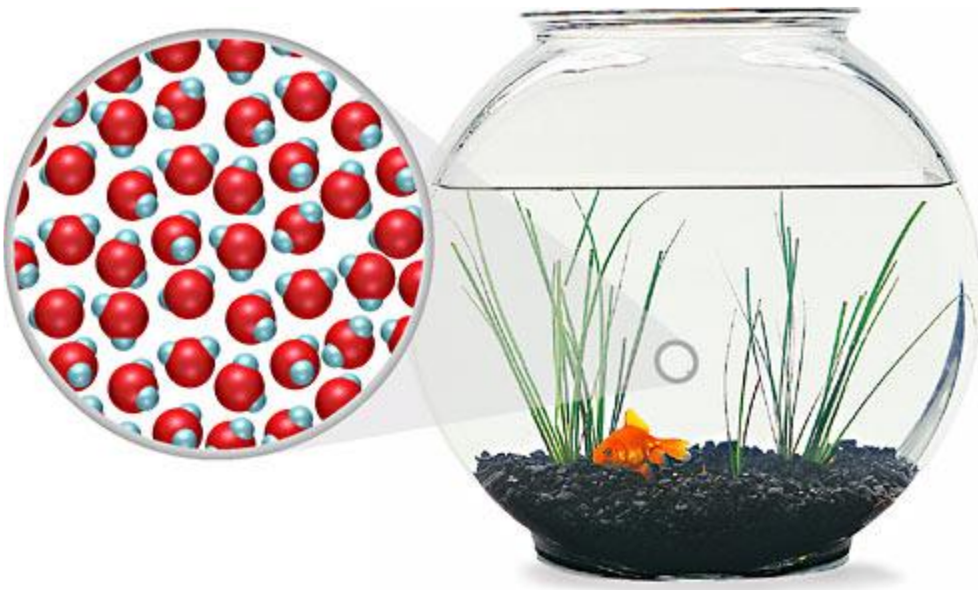


Figure 4 The water in this fishbowl is made up of many tiny water molecules. Each molecule is the smallest particle that has the chemical properties of water.

Standards Check How do the properties of oxygen and hydrogen compare with the properties of water?

The Simplest Molecules

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 and is written as H_2. Oxygen, nitrogen, and the halogens fluorine, chlorine, bromine, and iodine are also diatomic elements. In a molecule of any of these elements, the shared electrons are counted as valence electrons for each atom. So, both atoms of the molecule have filled outermost energy levels.

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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 eight valence electrons. These bonds can be with atoms of other elements or with other carbon atoms, as shown in the model in **Figure 5.**

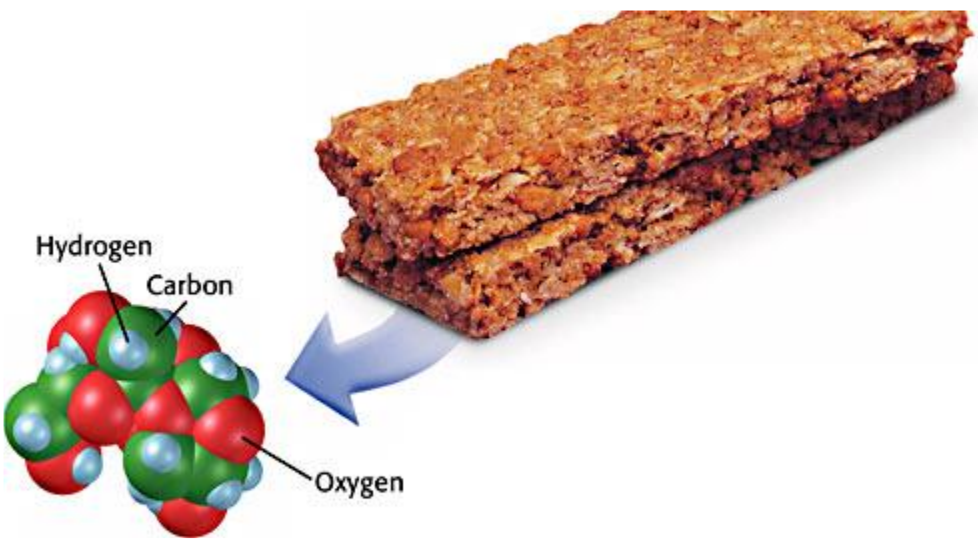

Figure 5 A granola bar contains sucrose, or table sugar. A molecule of sucrose is composed of carbon atoms, hydrogen atoms, and oxygen atoms joined by covalent bonds.

Metallic Bonds

Look at the unusual metal sculptures shown in **Figure 6.** Some metal pieces have been flattened, and others 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 metallic bonds, a special kind of chemical bond. A **metallic bond** is a bond formed by the attraction between positively charged metal ions and the electrons around the ions. Positively charged metal ions form when metal atoms lose electrons.

Figure 6 The different shapes of metal in these sculptures are possible because of the bonds that hold the metal together.

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Movement of Electrons Throughout a Metal

Bonding in metals is a result of many metal atoms being so close to one another that their outermost energy levels overlap. Because of this overlapping, metallic bonds extend throughout the metal in all directions. So, valence electrons can move throughout the metal. You can think of a metal as being made up of positive metal ions that have valence electrons “swimming” around, as shown in **Figure 7.** The electrons keep the ions together and cancel the positive charge of the ions.

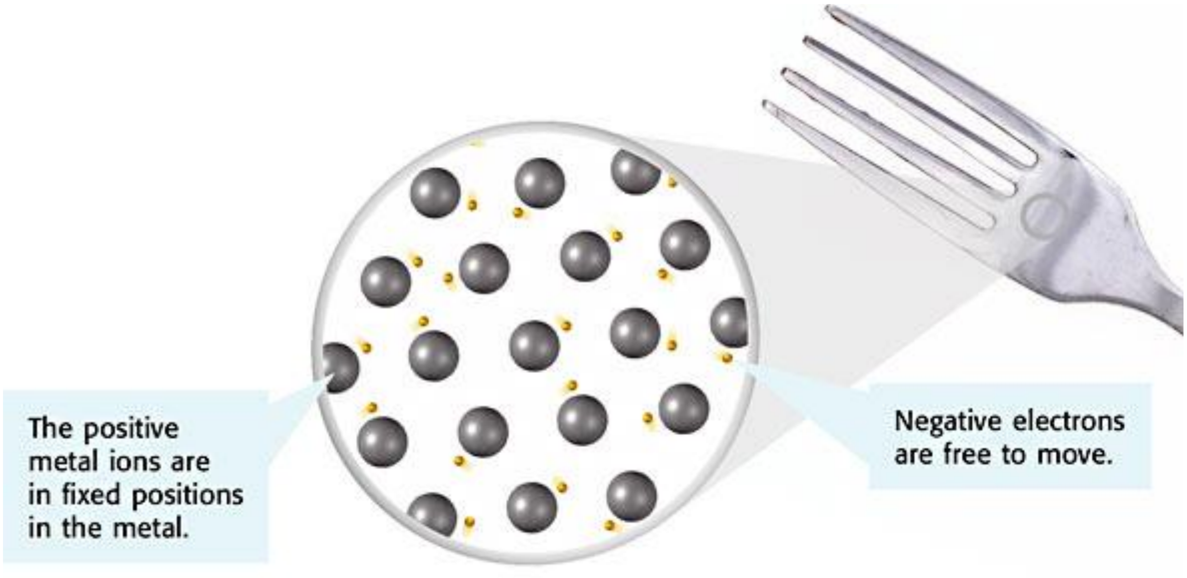


Figure 7 Free-moving electrons are attracted to the metal ions, and the attraction forms metallic bonds.

Properties of Metals

Metallic bonding 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 move 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 rolled or pounded) 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.

Standards Check What allows metals to be reshaped?

Bending Without Breaking

When a piece of metal is bent, some of the metal ions are forced closer together. You may 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 8.**

Figure 8 Metal can be reshaped without breaking because metallic bonds occur in many directions.

Section 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 metallic bond is formed by the attraction between positive metal ions and the electrons in the metal.
- Properties of metals include electrical conductivity, ductility, and malleability.

Chapter Summary

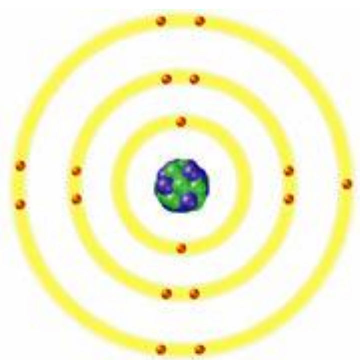
The Big Idea

Atoms combine by forming ionic, covalent, and metallic bonds.

Section 1
Electrons and Chemical Bonding

Key Concept Atoms share, gain, or lose electrons when chemical bonds form.

- Chemical bonding is the joining of atoms to form new substances.
- Valence electrons are used to form chemical bonds.
- The number of valence electrons in an atom determines whether the atom will form bonds.

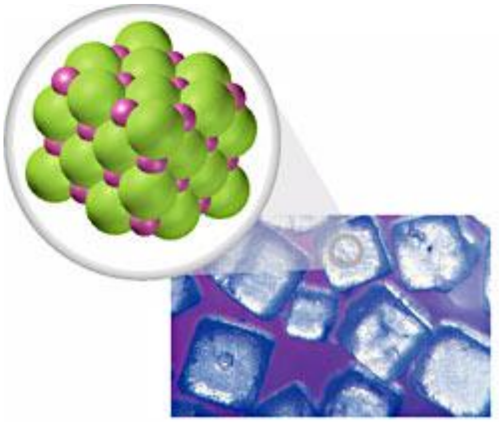


This model shows how a chlorine atom's 17 electrons are arranged in energy levels.

Section 2
Ionic Bonds

Key Concept Ionic bonds form when electrons are transferred from one atom to another atom.

- Ions of different elements can combine by forming ionic bonds.
- Positive ions and negative ions form when atoms lose or gain electrons.
- Ionic compounds form solids by building up a repeating pattern called a *crystal lattice.*



The ions in sodium chloride are arranged in a crystal lattice.

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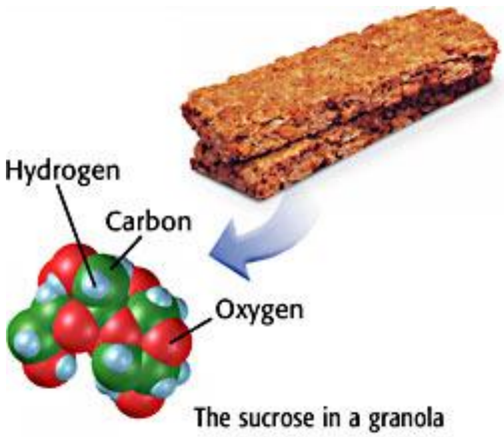

The sucrose in a granola bar is made up of covalently bonded atoms.

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