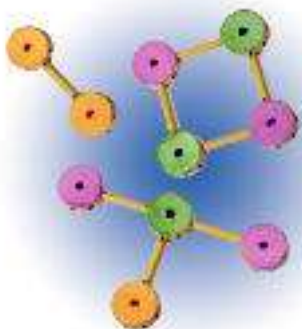


8.1 Molecular Compounds

Connecting to Your World

These toy models are made from circular pieces joined together in units by sticks. Although the types of pieces are limited, there can be many different models depending on

how many pieces are used and how they are arranged. As with the circular pieces, there are a limited number of different types of atoms. But, atoms can also be arranged in different ways to make a variety of products. In this section, you will learn how atoms can share electrons to form a bond, called a covalent bond, and how the atoms join to form units called molecules.



Molecules and Molecular Compounds

In nature, matter takes many forms. The noble gas elements, such as helium and neon shown in Figure 8.1, exist as atoms. They are monatomic; that is, they consist of single atoms. You learned in the previous chapter that atoms of some elements combine to form ionic compounds. These compounds are crystalline solids with high melting points.

Other compounds, however, can have very different properties. Hydrogen chloride (HCl), for example, is a gas at room temperature. Water (H₂O) is a liquid at room temperature. These two compounds are so different from ionic compounds that you might correctly suspect that attractions between ions fail to explain their bonding. Such compounds are not ionic. Their combining atoms do not give up electrons or accept electrons.

Instead, a “tug of war” for the electrons takes place between the atoms, bonding the atoms together. The atoms held together by sharing electrons are joined by a **covalent bond**.

Figure 8.1 The noble gases, including helium and neon, are monatomic. That means they exist as single atoms. Helium, being less dense than air, is often used to inflate balloons. The colors produced in what we commonly call neon lights are a result of passing an electric current through one or more noble gases.



Guide for Reading

Key Concepts

- How are the melting points and boiling points of molecular compounds different from those of ionic compounds?
- What information does a molecular formula provide?

Vocabulary

covalent bond
molecule
diatomic molecule
molecular compound
molecular formula

Reading Strategy

Building Vocabulary As you read the section, write a definition of each vocabulary term in your own words.

8.1

1 FOCUS

Objectives

- 8.1.1 Distinguish** between the melting points and boiling points of molecular compounds and ionic compounds.
- 8.1.2 Describe** the information provided by a molecular formula.

Guide for Reading

Build Vocabulary

L2

Word Parts The word *covalent* is a combination of the prefix *co-* from the Latin *com* meaning “with” or “together” and the verb *valere* meaning “to be strong.” Two electrons together have the strength to hold two atoms together in a bond. Ask students what other words they know beginning with *co-*. (e.g. *cooperate*, *coexist*, *coagulate*)

Reading Strategy

L2

Relate Text and Visuals Encourage students to examine the illustrations carefully as they read and compare them with representations of ionic bonding from Chapter 7. Have them note the differences.

2 INSTRUCT

Connecting to Your World

Ask, **Could you take these models apart and make different models?** (yes) **How might the models you make be different from these?** (The new models could be different shapes and sizes.)

Molecules and Molecular Compounds

Use Visuals

L1

Figure 8.1 Point out that some other elements are most stable when two atoms are joined together. Ask, **Do you think H₂ could be an ionic compound?** (No, ionic bonds do not form between two atoms of the same element.) Tell students that H₂ is a molecule held together not by the transfer of an electron but by the sharing of a pair of electrons.



Section Resources

Print

- **Guided Reading and Study Workbook**, Section 8.1
- **Core Teaching Resources**, Section 8.1 Review
- **Transparencies**, T85–T86

Technology

- **Interactive Textbook with ChemASAP**, Assessment 8.1
- **Go Online**, Section 8.1

Section 8.1 (continued)

Use Visuals

L1

Figure 8.3 Ask students, **How do the submicroscopic illustrations of NaCl and H₂O differ?** (*The ions of sodium and chlorine are separate and arrayed in a regular pattern; two hydrogen atoms and one oxygen atom are bonded together in one molecule.*) **Compare the formulas for NaCl and H₂O.** (*They look similar, but NaCl represents just one unit in the array of sodium and chloride ions, whereas H₂O represents one separate molecule of water.*)

Discuss

L1

Use the hydrogen molecule to introduce the shared nature of covalent bonding. Remind students that atoms bond to reach a more stable state, one in which the orbitals related to the highest energy levels of atoms are filled, as in the highly unreactive noble gases. A transfer of electrons between hydrogen atoms would not work; what factor could determine which hydrogen atom donated and which received an electron? However, if the hydrogen atoms share their electrons, they can each achieve the stable arrangement of a helium atom. Show the various ways that the bonding in a hydrogen molecule can be represented: molecular formula, structural formula, electron-dot structure, and orbital diagram showing the overlap of the 1s orbitals. Then introduce the octet rule and repeat the exercise for a chlorine molecule.



Download a worksheet on **Covalent Bonds** for students to complete, and find additional teacher support from NSTA SciLinks.

Figure 8.2 Water is a molecular compound with molecules composed of two hydrogen atoms and one oxygen atom. Carbon monoxide is a molecular compound with molecules composed of one carbon atom and one oxygen atom.

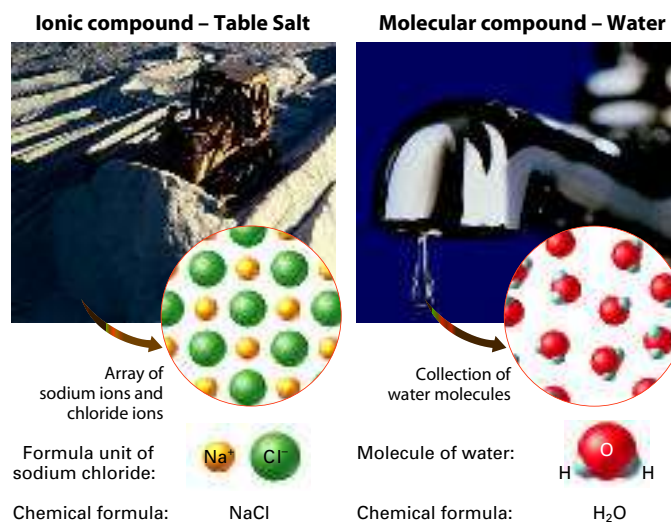


Some elements found in nature are in the form of molecules. A **molecule** is a neutral group of atoms joined together by covalent bonds. For example, air contains oxygen molecules. Each oxygen molecule consists of two oxygen atoms joined by covalent bonds. A **diatomic molecule** is a molecule consisting of two atoms. An oxygen molecule is a diatomic molecule.

Atoms of different elements can combine chemically to form compounds. In many compounds, atoms are bonded to each other to form molecules. Examples include water and carbon monoxide, which are described in Figure 8.2. A compound composed of molecules is called a **molecular compound**. The molecules of a given molecular compound are all the same. Remember, there is no such thing as a molecule of sodium chloride or magnesium chloride. Instead, these ionic compounds exist as collections of positively and negatively charged ions arranged in repeating three-dimensional patterns. Recall from Chapter 7 that the composition of ionic compounds is expressed as formula units.

Molecular compounds tend to have relatively lower melting and boiling points than ionic compounds. Many molecular compounds are gases or liquids at room temperature. In contrast to ionic compounds, which are formed from a metal combined with a nonmetal, most molecular compounds are composed of atoms of two or more nonmetals. For example, one atom of carbon can combine with one atom of oxygen to produce one molecule of a compound known as carbon monoxide. Carbon monoxide is a poisonous gas produced by burning gasoline in internal combustion engines. Figure 8.3 illustrates some differences between ionic and molecular compounds, using sodium chloride and water as examples.

Figure 8.3 Sodium chloride, which is an ionic compound, and water, which is a molecular compound, are compared here. **Interpreting Diagrams** *How do molecular compounds differ from ionic compounds?*





Ethane (C₂H₆)

Figure 8.4 Ethane is a component of natural gas. **Inferring** What information about the ethane molecule given by its molecular formula C₂H₆ is also given by the drawing shown here?

Molecular Formulas

TEACHER Demo

Molecular Structures and Formulas

L1

Purpose Students see the structure associated with molecular formulas.

Materials molecular model kit or foam balls and toothpicks

Procedure Construct models of these pairs of molecules: O₂ and O₃; CO and CO₂; H₂O and H₂O₂. Show students each pair and ask them how many of each type of atom is in each molecule. Write the corresponding chemical formulas on the chalkboard.

Expected Outcome Students will see that the addition of one more oxygen atom to O₂, CO, and H₂O results in new molecules that have very different structures.

Discuss

L2

Point out that the recipe for a cake provides information about what type and how much of each ingredient is needed. Varying the types and amounts of ingredients leads to cakes that have different tastes and textures. Ask, **How does a molecular formula provide similar information about a compound?** (*The subscripts in a molecular formula tell the number of atoms of each element in a compound.*) Explain that the subscripts are not always in the smallest whole-number ratio of the atoms. For example, ethane is correctly represented by the formula C₂H₆ because the molecule actually contains two carbon atoms and six hydrogen atoms. It would be incorrect to represent ethane as CH₃. Ask, **How many atoms of nitrogen are in N₂H₄?** (*two*) **How many atoms of hydrogen?** (*four*)

Molecular Formulas

A **molecular formula** is the chemical formula of a molecular compound. **A molecular formula shows how many atoms of each element a molecule contains.** A water molecule consists of two hydrogen atoms and one oxygen atom. The molecular formula of water is H₂O. Notice that a subscript written after the symbol indicates the number of atoms of each element in the molecule. If there is only one atom, the subscript 1 is omitted. The molecular formula of carbon dioxide is CO₂. This formula represents a molecule containing one carbon atom and two oxygen atoms. As shown in Figure 8.4, ethane, a component of natural gas, is also a molecular compound. The molecular formula for ethane is C₂H₆. According to this formula, one molecule of ethane contains two carbon atoms and six hydrogen atoms. A molecular formula reflects the actual number of atoms in each molecule. The subscripts are not necessarily lowest whole-number ratios.

Molecular formulas also describe molecules consisting of one element. Because the oxygen molecule consists of two oxygen atoms bonded together, its molecular formula is O₂.

A molecular formula does not tell you about a molecule's structure. In other words, it does not show either the arrangement of the various atoms in space or which atoms are covalently bonded to one another. A variety of diagrams and molecular models, some of them illustrated in Figure 8.5, can be used to show the arrangement of atoms in a molecule. Diagrams and models like these will be used throughout the textbook.

Checkpoint What is the molecular formula for ammonia?

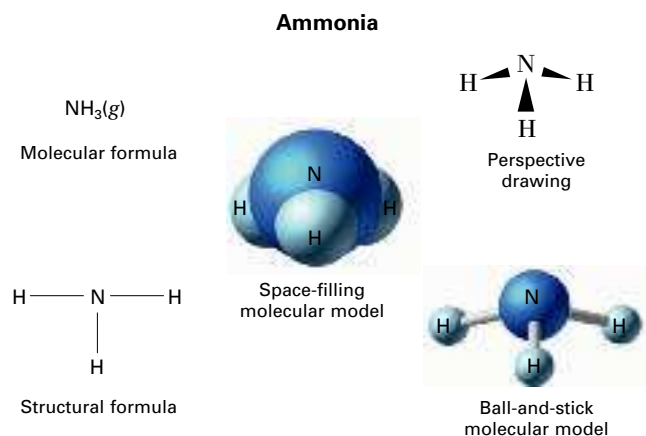


Figure 8.5 Ammonia (NH₃) is used in solution as a cleaning agent. You can represent the ammonia molecule by its molecular formula, its structural formula, a space-filling molecular model, a perspective drawing, or by a ball-and-stick molecular model.

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Differentiated Instruction

English Learners

L1

Prepare large, three-dimensional models of ammonia similar to the two in Figure 8.5. Also, write the molecular and structural formulas for ammonia on large cards. Hold the models and cards up one by one and point out the information that each model or formula provides. Make a summary list on the chalkboard.

Answers to...

Figure 8.3 Molecular compounds are made up of molecules and usually have lower melting and boiling points than ionic compounds, which are made up of ions.

Figure 8.4 It contains two carbon atoms and six hydrogen atoms.

Checkpoint C₂H₆

Section 8.1 (continued)

ASSESS

Evaluate Understanding L2

Have students label the following statements true or false:

- All molecular compounds are composed of atoms of two or more different elements. (*True*)
- All compounds contain molecules. (*False*)
- No elements exist as molecules. (*False*)
- Most molecular compounds are composed of two or more nonmetallic elements. (*True*)
- Atoms in molecular compounds share electrons. (*True*)
- Molecular compounds tend to have higher melting and boiling points than ionic compounds. (*False*)

Reteach L1

Write a series of formulas on the chalkboard: Br_2 , KBr , CH_4 , SO_3 , N_2H_2 , Ne_2 .

Ask students to identify any substance that does not exist. (Ne_2) Ask them to identify any ionic compounds. (KBr)

Ask, **Which formulas represent molecules?** (Br_2 , CH_4 , SO_3 , N_2H_2) Ask, **Which formulas represent compounds?** (KBr , CH_4 , SO_3 , N_2H_2) Ask, **How many atoms are in SO_3 ?** (4)

Writing Activity

Students should write that a molecular compound is a compound composed of molecules. A molecular formula shows how many atoms of each element a molecule contains.

Interactive Textbook

If your class subscribes to the Interactive Textbook, use it to review concepts in Section 8.1.

with ChemASAP

Figure 8.6 The formula of a molecular compound indicates the numbers and kinds of atoms. The arrangement of the atoms within a molecule is called its molecular structure. **Using Models** Which of these molecules has the greatest number of oxygen atoms?

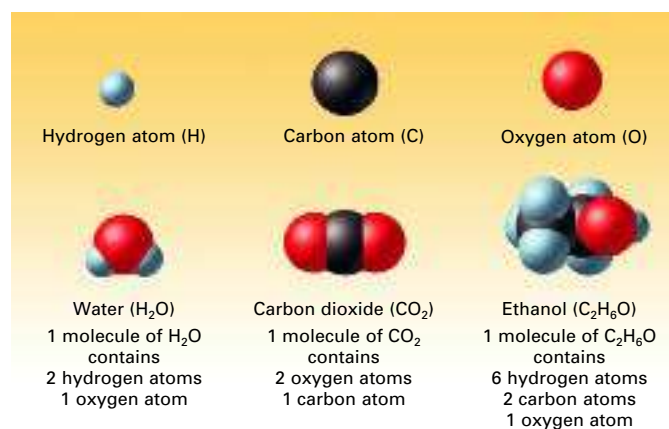


Figure 8.6 shows the chemical formulas and structures of some other molecular compounds. Carbon dioxide, for example, is a gas produced by the complete burning of carbon. It is found in Earth's atmosphere and dissolved in seawater. It is also used to carbonate many beverages. The molecular structure of carbon dioxide in Figure 8.6 shows how the carbon atom in each molecule has two oxygen atoms on opposite sides of it. It shows how the three atoms are arranged in a row. The molecular structure of water shows how the hydrogen atoms, in contrast, are mainly on one side of the water molecule. The molecular structure of ethanol is more complicated, but the molecular structure illustrated in Figure 8.6 also shows how many of each kind of atom are in each molecule, and how the atoms are arranged with respect to one another.

8.1 Section Assessment

- Key Concept** How are the melting points and boiling points of molecular compounds usually different from those of ionic compounds?
- Key Concept** What information does a molecular formula provide?
- What are the only elements that exist in nature as uncombined atoms? What term is used to describe such elements?
- Describe how the molecule whose formula is NO is different from the molecule whose formula is N_2O .
- Give an example of a diatomic molecule found in Earth's atmosphere.
- What information does a molecule's molecular structure give?

Writing Activity

Molecular Compounds and Formulas Describe what a molecular compound is. Explain how a molecular formula is the chemical formula of a molecular compound.

Interactive Textbook

Assessment 8.1 Test yourself on the important concepts of Section 8.1.

with ChemASAP

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Section 8.1 Assessment

- Molecular compounds tend to have relatively lower melting points and boiling points.
- Molecular formulas show how many atoms of each element one molecule of a compound contains.
- noble gases; monatomic
- NO has 1 N atom and 1 O atom; N_2O has 2 N atoms and 1 O atom.
- nitrogen (N_2) or oxygen (O_2)
- Molecular structures show the arrangement of atoms in a molecule.

Answers to...

Figure 8.6 carbon dioxide