

Elements and Chemical Bonds

Compounds, Chemical Formulas, and Covalent Bonds

Key Concepts

- How do elements differ from the compounds they form?
- What are some common properties of a covalent compound?
- Why is water a polar compound?

Study Coach

Make an Outline

Outline the information in this lesson. Use the headings as the main divisions of your outline. Include important details under each heading. Use your outline to review the lesson.

Key Concept Check

1. Differentiate How is a compound different from the elements that make it up?

..... Before You Read

What do you think? Read the two statements below and decide whether you agree or disagree with them. Place an A in the Before column if you agree with the statement or a D if you disagree. After you've read this lesson, reread the statements to see if you have changed your mind.


Before	Statement	After
	3. The atoms in a water molecule are more chemically stable than they would be as individual atoms.	
	4. Many substances dissolve easily in water because opposite ends of a water molecule have opposite charges.	

..... Read to Learn

From Elements to Compounds

Have you ever baked cupcakes? The ingredients in the cupcakes—flour, baking soda, salt, sugar, eggs, vanilla, milk, and butter—all have unique physical and chemical properties. But when you mix the ingredients together and bake them, a new product results—cupcakes. The cupcakes have properties after being baked that are different from the original ingredients.

In some ways, compounds are like the cupcakes. Recall that a compound is a substance made up of two or more different elements. Just as cupcakes are different from their ingredients, compounds are different from their elements. An element is made of one type of atom. Compounds are chemical combinations of different types of atoms. Compounds and the elements that make them up often have different properties.

Chemical bonds join atoms together. Recall that a chemical bond is a force that holds atoms together in a compound. In this lesson, you will learn how atoms can form bonds by sharing valence electrons. You will also learn how to write and read a chemical formula. 

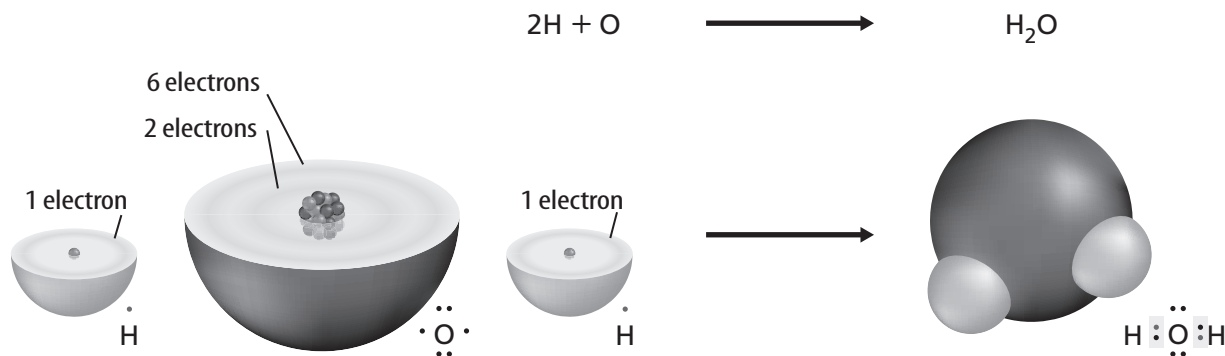
Covalent Bonds—Electron Sharing

Recall that atoms can become more chemically stable by sharing valence electrons. When unstable, nonmetal atoms bond, they do this by sharing valence electrons. A **covalent bond** is a chemical bond formed when two atoms share one or more pairs of valence electrons. The atoms then form a stable covalent compound.

A Noble Gas Electron Arrangement

Hydrogen and oxygen can react to form water (H_2O), as shown in the figure below. Before the reaction, the atoms are chemically unstable. Each hydrogen atom is unstable with one valence electron. The oxygen atom is unstable with six valence electrons.

Recall that most atoms are chemically stable with eight valence electrons. This is the same electron arrangement as a noble gas. An atom with less than eight valence electrons becomes stable by forming chemical bonds until it has eight valence electrons. Therefore, an oxygen atom forms two bonds to become stable. A hydrogen atom is stable with two valence electrons. It forms one bond to become stable.



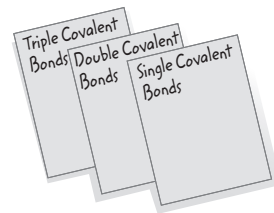
Shared Electrons

Look again at the figure above. How did the oxygen atom and the hydrogen atoms become chemically stable? They shared their unpaired valence electrons and formed a stable covalent compound. Each covalent bond has two valence electrons—one from the hydrogen atom and one from the oxygen atom. These electrons are shared in the bond. They count as valence electrons for both atoms.

Look at the dot diagram for water, on the right side of the figure. Each hydrogen atom now has two valence electrons. The oxygen atom bonded with two hydrogen atoms. As a result, oxygen now has eight valence electrons. All three atoms have the electron arrangement of a noble gas. The compound is stable.

FOLDABLES®

Make three quarter-sheet note cards to organize information about single, double, and triple covalent bonds.



Visual Check

2. State How many valence electrons did the oxygen atom have before bonding?

Visual Check

3. Compare Is the bond stronger between atoms in hydrogen gas (H₂) or nitrogen gas (N₂)? Why?

Each hydrogen atom is chemically unstable with 1 unpaired valence electron.

Single Covalent Bond



In a hydrogen molecule, each hydrogen atom shares its valence electron with the other, forming a single covalent bond.

Each oxygen atom is chemically unstable with 2 unpaired valence electrons. A carbon atom is unstable with 4 unpaired valence electrons.

Double Covalent Bond



In a carbon dioxide molecule, the carbon atom shares 2 pairs of electrons with each oxygen atom, forming a double covalent bond.

Each nitrogen atom is chemically unstable with 3 unpaired valence electrons.

Triple Covalent Bond



In a nitrogen molecule, each nitrogen atom shares 3 valence electrons with the other, forming a triple covalent bond.

Covalent Compounds

When two or more atoms share valence electrons, they form a stable covalent compound. The covalent compound's carbon dioxide and water are different, but they share similar properties. They usually have low melting points and low boiling points. They are also usually gases or liquids at room temperature, but they can be solids. Covalent compounds are poor conductors of thermal energy and electricity.

Molecules


The chemically stable unit of a covalent compound is a molecule. A **molecule** is a group of atoms held together by covalent bonding that acts as an independent unit. Table sugar is a covalent compound. The chemical formula for a molecule of table sugar is C₁₂H₂₂O₁₁. One molecule contains 12 carbon atoms, 22 hydrogen atoms, and 11 oxygen atoms. All these atoms are covalently bonded together. The only way to further break down the molecule would be to chemically separate the carbon, hydrogen, and oxygen atoms. Trillions of sugar molecules make up one grain of sugar.

Key Concept Check

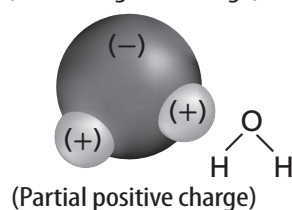
4. Summarize What are some common properties of covalent compounds?

Water and Other Polar Molecules

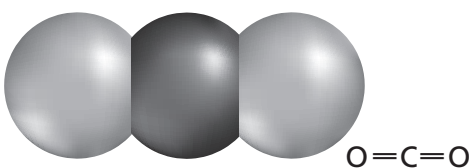
In a covalent bond, one atom can attract the shared electrons more strongly than the other atom can. In a water molecule, shown in the model below on the left, the oxygen atom attracts the electrons more strongly than each hydrogen atom does. As a result, the shared electrons are pulled closer to the oxygen atom. Because electrons have a negative charge, the oxygen atom has a partial negative charge. The hydrogen atoms have a partial positive charge. As a result, a water molecule is polar. A **polar molecule** is a molecule that has a partial positive end and a partial negative end because of unequal sharing of electrons.

The charges on the ends of a polar molecule affect its properties. Sugar, for example, dissolves easily in water because both sugar and water are polar. The negative end of a water molecule pulls on the positive end of a sugar molecule. Also, the positive end of a water molecule pulls on the negative end of a sugar molecule. This causes the sugar molecules to separate from one another and mix with the water molecules. 

Polar
(Partial negative charge)



Nonpolar



Nonpolar Molecules

A molecule is nonpolar if its atoms pull equally on the shared valence electrons. A hydrogen molecule, H_2 , is a nonpolar molecule. Because the two hydrogen atoms are identical, their attraction for shared electrons is equal. A carbon dioxide molecule, CO_2 , is shown in the model on the right above. This molecule is also nonpolar because the carbon atom and the oxygen atoms pull equally on the shared electrons.

A nonpolar compound will not easily dissolve in a polar compound. For example, oil is a nonpolar compound. It will not dissolve in water, which is a polar compound. However, “like dissolves like.” Polar compounds dissolve in other polar compounds. Nonpolar compounds dissolve in other nonpolar compounds.

Key Concept Check

5. State Why is water a polar compound?

Visual Check

6. Identify Which atoms in a water molecule have a partial positive charge?



Think it Over

7. Infer Imagine that you mix table salt with water, and the salt dissolves. Are the molecules of table salt polar or nonpolar? How do you know?

Chemical Formulas and Molecular Models

How do you know which elements make up a compound? A **chemical formula** is a group of chemical symbols and numbers that represent the elements and the number of atoms of each element that make up a compound. Just as a recipe lists the ingredients, a chemical formula lists the elements in a compound. For example, the chemical formula for carbon dioxide is CO_2 . The formula uses chemical symbols to identify the elements in the compound. CO_2 is made up of carbon (C) and oxygen (O). The small number after a chemical symbol is a subscript. A subscript shows the number of atoms of that element in the compound. A symbol without a subscript means one atom. Carbon dioxide (CO_2) contains two atoms of oxygen bonded to one atom of carbon.

A chemical formula identifies the types of atoms in a compound or a molecule. However, a formula does not explain the shape or appearance of the molecule. Models can provide different information about a molecule. Each one can show the molecule in a different way. Common types of models for CO_2 are shown below. ✓

✓ Reading Check

8. Specify What information is given in a chemical formula?

Chemical Formula

A carbon dioxide molecule is made up of carbon (C) and oxygen (O) atoms.



A symbol without a subscript indicates one atom. Each molecule of carbon dioxide has one carbon atom.

The 2 indicates two atoms of oxygen. Each molecule of carbon dioxide has two oxygen atoms.

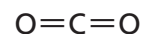
Dot Diagram

- Shows atoms and valence electrons



Structural Formula

- Shows atoms and lines; each line represents one shared pair of electrons



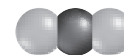
Ball-and-Stick Model

- Balls represent atoms and sticks represent bonds; used to show bond angles



Space-Filling Model

- Spheres represent atoms; used to show three-dimensional arrangement of atoms



✓ Visual Check

9. Interpret According to the structural formula, how many pairs of shared electrons are in a molecule of carbon dioxide?

..... After You Read

Mini Glossary

chemical formula: a group of chemical symbols and numbers that represent the elements and the number of atoms of each element that make up a compound

covalent bond: a chemical bond formed when two atoms share one or more pairs of valence electrons

molecule: a group of atoms held together by covalent bonding that acts as an independent unit

polar molecule: a molecule that has a partial positive end and a partial negative end because of unequal sharing of electrons

1. Review the terms and their definitions in the Mini Glossary. Write a sentence explaining what the chemical formula of glucose, a simple sugar, means. Glucose's chemical formula is $C_6H_{12}O_6$.

2. Complete the table below to compare the different types of covalent bonds.

	Single Bond	Double Bond	Triple Bond
Electrons shared			three pairs of electrons
Example	hydrogen gas		

3. How did making an outline of the lesson help you organize information about compounds, covalent bonds, and chemical formulas?

What do you think NOW?

Reread the statements at the beginning of the lesson. Fill in the After column with an A if you agree with the statement or a D if you disagree. Did you change your mind?



Log on to ConnectED.mcgraw-hill.com and access your textbook to find this lesson's resources.

END OF LESSON