

Lesson 2

Reading Guide

Key Concepts

ESSENTIAL QUESTIONS

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

Vocabulary

covalent bond p. 391

molecule p. 392

polar molecule p. 393

chemical formula p. 394



Multilingual eGlossary

Compounds, Chemical Formulas, and Covalent Bonds




Go to the resource tab in Connected to find the PBL *Model Molecules*.

Inquiry

How do they combine?

A jigsaw puzzle has pieces that connect in a certain way. The pieces fit together by sharing tabs with other pieces. All of the pieces combine and form a complete puzzle. Like pieces of a puzzle, atoms can join together and form a compound by sharing electrons.




How is a compound different from its elements? 

The sugar you use to sweeten foods at home is probably sucrose. Sucrose contains the elements carbon, hydrogen, and oxygen. How does table sugar differ from the elements that it contains?

- 1 Read and complete a lab safety form.
- 2 Air is a mixture of several gases, including oxygen and hydrogen. Charcoal is a form of carbon. Write some properties of oxygen, hydrogen, and carbon in your Science Journal.
- 3 Obtain from your teacher a piece of **charcoal** and a **beaker** with **table sugar** in it.
- 4 Observe the charcoal. In your Science Journal, describe the way it looks and feels.
- 5 Observe the table sugar in the beaker. What does it look and feel like? Record your observations.



Think About This


1. Compare and contrast the properties of charcoal, hydrogen, and oxygen.
2.  **Key Concept** How do you think the physical properties of carbon, hydrogen, and oxygen change when they combined to form sugar?

From Elements to Compounds

Have you ever baked cupcakes? First, combine flour, baking soda, and a pinch of salt. Then, add sugar, eggs, vanilla, milk, and butter. Each ingredient has unique physical and chemical properties. When you mix the ingredients together and bake them, a new product results—cupcakes. The cupcakes have properties that are different from the ingredients.

In some ways, compounds are like 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, but 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 that one way that atoms can form bonds is by sharing valence electrons. You will also learn how to write and read a chemical formula.

1.  **Key Concept Check** How is a compound different from the elements that compose it?

SCIENCE USE V. COMMON USE ...

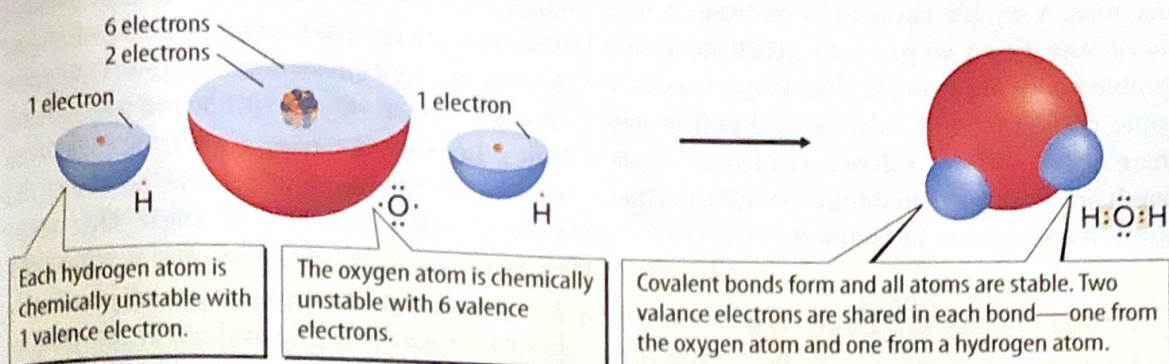
bond

Science Use a force that holds atoms together in a compound

Common Use a close personal relationship between two people



Figure 7 A covalent bond forms when two nonmetal atoms share electrons.



Covalent Bonds—Electron Sharing

As you read in Lesson 1, one way that atoms can become more chemically stable is by sharing valence electrons. When unstable, nonmetal atoms bond together, they bond 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

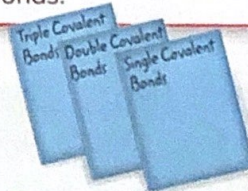
Look at the reaction between hydrogen and oxygen in Figure 7. Before the reaction, each hydrogen atom has one valence electron. The oxygen atom has six valence electrons. Recall that most atoms are chemically stable with eight valence electrons—the same electron arrangement as a noble gas. An atom with 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

If the oxygen atom and each hydrogen atom share their unpaired valence electrons, they can form two covalent bonds and become a stable covalent compound. Each covalent bond contains two valence electrons—one from the hydrogen atom and one from the oxygen atom. Since these electrons are shared, they count as valence electrons for both atoms in the bond. Each hydrogen atom now has two valence electrons. The oxygen atom now has eight valence electrons, since it bonds to two hydrogen atoms. All three atoms have the electron arrangement of a noble gas and the compound is stable.

FOLDABLES

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



Double and Triple Covalent Bonds

As shown in **Figure 8**, a single covalent bond exists when two atoms share one pair of valence electrons. A double covalent bond exists when two atoms share two pairs of valence electrons. Double bonds are stronger than single bonds. A triple covalent bond exists when two atoms share three pairs of valence electrons. Triple bonds are stronger than double bonds. Multiple bonds are explained in **Figure 8**.

Covalent Compounds

When two or more atoms share valence electrons, they form a stable covalent compound. The covalent compounds carbon dioxide, water, and sugar are very different, but they also share similar properties. Covalent compounds usually have low melting points and low boiling points. They are usually gases or liquids at room temperature, but they can also 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 ($C_{12}H_{22}O_{11}$) is a covalent compound. One grain of sugar is made up of trillions of sugar molecules. Imagine breaking a grain of sugar into the tiniest microscopic particle possible. You would have a molecule of sugar. One sugar molecule contains 12 carbon atoms, 22 hydrogen atoms, and 11 oxygen atoms all covalently bonded together. The only way to further break down the molecule would be to chemically separate the carbon, hydrogen, and oxygen atoms. These atoms alone have very different properties from the compound sugar.



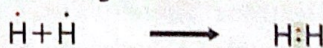
Key Concept Check What are some common properties of covalent compounds?

Multiple Bonds

Figure 8 The more valence electrons that two atoms share, the stronger the covalent bond is between the atoms.

When two hydrogen atoms bond, they form a single covalent bond.

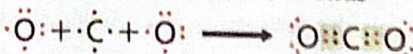
One Single Covalent Bond



In a single covalent bond, 1 pair of electrons is shared between two atoms. Each H atom shares 1 valence electron with the other.

When one carbon atom bonds with two oxygen atoms, two double covalent bonds form.

Two Double Covalent Bonds



In a double covalent bond, 2 pairs of electrons are shared between two atoms. One O atom and the C atom each share 2 valence electrons with the other.

When two nitrogen atoms bond, they form a triple covalent bond.

One Triple Covalent Bond




In a triple covalent bond, 3 pairs of electrons are shared between two atoms. Each N atom shares 3 valence electrons with the other.

Visual Check Is the bond stronger between atoms in hydrogen gas (H_2) or nitrogen gas (N_2)? Why?

Water and Other Polar Molecules

In a covalent bond, one atom can attract the shared electrons more strongly than the other atom can. Think about the valence electrons shared between oxygen and hydrogen atoms in a water molecule. The oxygen atom attracts the shared electrons more strongly than each hydrogen atom does. As a result, the shared electrons are pulled closer to the oxygen atom, as shown in **Figure 9**. Since electrons have a negative charge, the oxygen atom has a partial negative charge. The hydrogen atoms have a partial positive charge. *A molecule that has a partial positive end and a partial negative end because of unequal sharing of electrons is a polar molecule.*

The charges on 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.

 **Key Concept Check** Why is water a polar compound?

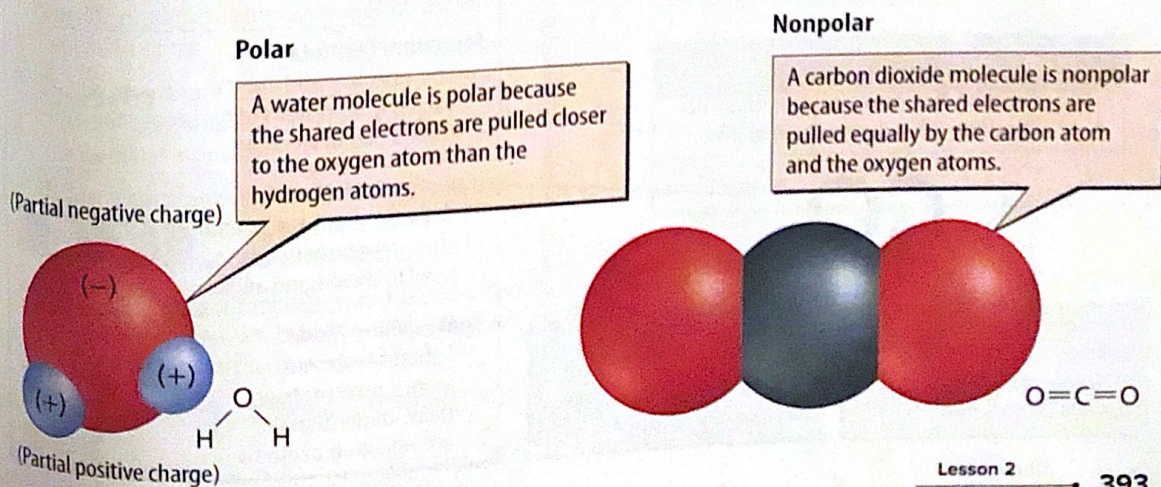
Nonpolar Molecules

A hydrogen molecule, H_2 , is a nonpolar molecule. Because the two hydrogen atoms are identical, their attraction for the shared electrons is equal. The carbon dioxide molecule, CO_2 , in **Figure 9** is also nonpolar. A nonpolar compound will not easily dissolve in a polar compound, but it will dissolve in other nonpolar compounds. Oil is an example of a nonpolar compound. It will not dissolve in water. Have you ever heard someone say “like dissolves like”? This means that polar compounds can dissolve in other polar compounds. Similarly, nonpolar compounds can dissolve in other nonpolar compounds.

WORD ORIGIN

polar
from Latin *polus*, means “pole”

Figure 9 Atoms of a polar molecule share their valence electrons unequally. Atoms of a nonpolar molecule share their valence electrons equally.





MiniLab

20 minutes

How do compounds form?

Use building blocks to model ways in which elements combine to form compounds.

- 1 Examine various types of **interlocking plastic blocks**. Notice that the blocks have different numbers of holes and pegs. Attaching one peg to one hole represents a shared pair of electrons.
- 2 Draw the electron dot diagrams for carbon, nitrogen, oxygen, and hydrogen in your Science Journal. Based on the diagrams, decide which block should represent an atom of each element.
- 3 Use the blocks to make models of H_2 , CO_2 , NH_3 , H_2O , and CH_4 . All pegs on the largest block must fit into a hole, and no blocks can stick out over the edge of a block, either above or below it.



Analyze and Conclude

1. **Explain** how you decided which type of block should be assigned to each type of atom.
2. **Key Concept** Name at least one way that your models show the difference between a compound and the elements that combine and form the compound.

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 ingredients, a chemical formula lists the elements in a compound. For example, the chemical formula for carbon dioxide shown in **Figure 10** is CO_2 . The formula uses chemical symbols that show which elements are in the compound. Notice that CO_2 is made up of carbon (C) and oxygen (O). A subscript, or small number after a chemical symbol, shows the number of atoms of each element in the compound. Carbon dioxide (CO_2) contains two atoms of oxygen bonded to one atom of carbon.

A chemical formula describes the types of atoms in a compound or a molecule, but it does not explain the shape or appearance of the molecule. There are many ways to model a molecule. Each one can show the molecule in a different way. Common types of models for CO_2 are shown in **Figure 10**.

- Reading Check** What information is given in a chemical formula?

Figure 10 Chemical formulas and molecular models provide information about molecules.

Chemical Formula A carbon dioxide molecule is made up of carbon (C) and oxygen (O) atoms.	Dot Diagram • Shows atoms and valence electrons	
CO₂	Structural Formula • Shows atoms and lines; each line represents one shared pair of electrons	
A symbol without a subscript indicates one atom. Each molecule of carbon dioxide has one carbon atom.	Ball-and-Stick Model • Balls represent atoms and sticks represent bonds; used to show bond angles	
The subscript 2 indicates two atoms of oxygen. Each molecule of carbon dioxide has two oxygen atoms.	Space-Filling Model • Spheres represent atoms; used to show three-dimensional arrangement of atoms	



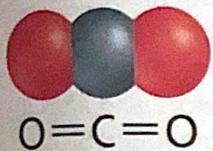
Lesson 2 Review



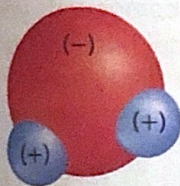
Visual Summary



A chemical formula is one way to show the elements that make up a compound.



A covalent bond forms when atoms share valence electrons. The smallest particle of a covalent compound is a molecule.



Water is a polar molecule because the oxygen and hydrogen atoms unequally share electrons.

FOLDABLES

Use your lesson Foldable to review the lesson. Save your Foldable for the project at the end of the chapter.

What do you think NOW?

You first read the statements below at the beginning of the chapter.

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

Did you change your mind about whether you agree or disagree with the statements? Rewrite any false statements to make them true.

Use Vocabulary

- Define *covalent bond* in your own words.
- The group of symbols and numbers that shows the types and numbers of atoms that make up a compound is a _____.
- Use the term *molecule* in a complete sentence.

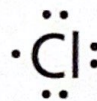
Understand Key Concepts

- Contrast** Name at least one way water (H_2O) is different from the elements that make up water.
- Explain** why water is a polar molecule.
- A sulfur dioxide molecule has one sulfur atom and two oxygen atoms. Which is its correct chemical formula?

A. SO_2	C. S_2O_2
B. $(\text{SO})_2$	D. S_2O

Interpret Graphics

- Examine** the electron dot diagram for chlorine below.



In chlorine gas, two chlorine atoms join to form a Cl_2 molecule. How many pairs of valence electrons do the atoms share?

- Compare and Contrast** Copy and fill in the graphic organizer below to identify at least one way polar and nonpolar molecules are similar and one way they are different.

Polar and Nonpolar Molecules	
Similarities	
Differences	

Critical Thinking

- Develop** an analogy to explain the unequal sharing of valence electrons in a water molecule.



How can you model compounds?

Materials



colored pencils

Chemists use models to explain how electrons are arranged in an atom. Electron dot diagrams are models used to show how many valence electrons an atom has. Electron dot diagrams are useful because they can help predict the number and type of bond an atom will form.

Learn It

In science, **models** are used to help you visualize objects that are too small, too large, or too complex to understand. A model is a representation of an object, idea, or event.

Try It

- 1 Use the periodic table to write the electron dot diagrams for hydrogen, oxygen, carbon, and silicon.
- 2 Using your electron dot diagrams from step 1, write electron dot diagrams for the following compounds: H_2O , CO , CO_2 , SiO_2 , C_2H_2 , and CH_4 . Use colored pencils to differentiate the electrons for each atom. Remember that all the above atoms, except hydrogen and helium, are chemically stable when they have eight valence electrons. Hydrogen and helium are chemically stable with two valence electrons.

Apply It

- 3 Based on your model, describe silicon's electron dot diagram and arrangement of valence electrons before and after it forms the compound SiO_2 .
- 4 **Key Concept** Which of the covalent compounds you modeled contain double bonds? Which contain triple bonds?

