

Covalent Bonds

Reading Preview

Key Concepts

- What holds covalently bonded atoms together?
- What are the properties of molecular compounds?
- How does unequal sharing of electrons occur, and how does it affect molecules?

Key Terms

- covalent bond
- molecule
- double bond
- triple bond
- molecular compound
- polar bond
- nonpolar bond

Target Reading Skill

Asking Questions Before you read, preview the red headings. In a graphic organizer like the one below, ask a *what* or *how* question for each heading. As you read, answer your questions.

Covalent Bonds

Question	Answer
How do covalent bonds form?	Covalent bonds form when...

Lab Zone Discover Activity

Can Water and Oil Mix?

1. Pour water into a small jar that has a tight-fitting lid until the jar is about a third full.
2. Add an equal amount of vegetable oil to the jar. Cover the jar tightly.
3. Shake the jar vigorously for 20 seconds. Observe the contents.
4. Allow the jar to sit undisturbed for 1 minute. Observe again.
5. Remove the top and add 3 drops of liquid detergent. Cover the jar and repeat Steps 3 and 4.

Think It Over

Forming Operational Definitions Based on your observations, write an operational definition of *detergent*. How might your observations relate to chemical bonds in the detergent, oil, and water molecules?

Uh oh, you have a big project due in English class next week! You need to write a story and illustrate it with colorful posters. Art has always been your best subject, but writing takes more effort. Luckily, you're working with a partner who writes well but doesn't feel confident in art. If you each contribute your skills, together you can produce a high-quality finished project.



FIGURE 21

Sharing Skills

One student is a skilled artist, while the other is a skilled writer. By pooling their skills, the students can complete their project.

How Covalent Bonds Form

Just as you and your friend can work together by sharing your talents, atoms can become more stable by sharing electrons. The chemical bond formed when two atoms share electrons is called a **covalent bond**. Covalent bonds usually form between atoms of nonmetals. In contrast, ionic bonds usually form when a metal combines with a nonmetal.

Electron Sharing Recall that the noble gases are not very reactive. In contrast, all other nonmetals, including hydrogen, can bond to other nonmetals by sharing electrons. Most nonmetals can even bond with another atom of the same element, as is the case with fluorine in Figure 22. When you count the electrons on each atom, count the shared pair each time. By sharing electrons, each atom has a stable set of eight. **The force that holds atoms together in a covalent bond is the attraction of each atom's nucleus for the shared pair of electrons.** The two bonded fluorine atoms form a molecule. A **molecule** is a neutral group of atoms joined by covalent bonds.

How Many Bonds? Look at the electron dot diagrams in Figure 23. Count the valence electrons around each atom. The number of covalent bonds these atoms can form equals the number of electrons needed to make a total of eight (or in the case of hydrogen, two).

For example, oxygen has six valence electrons, so it can form two covalent bonds. In a water molecule, oxygen forms one covalent bond with each of two hydrogen atoms. As a result, the oxygen atom has a stable set of eight valence electrons. Each hydrogen atom can form one bond because it needs only a total of two electrons to be stable. Do you see why water's formula is H_2O , instead of H_3O , H_4O , or just HO ?

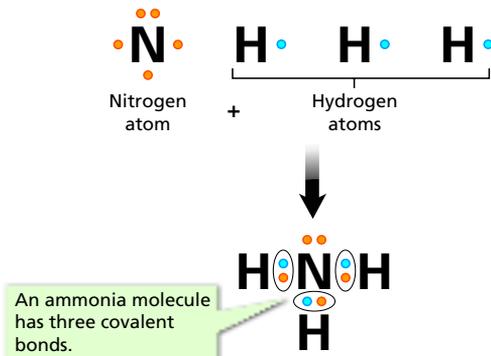
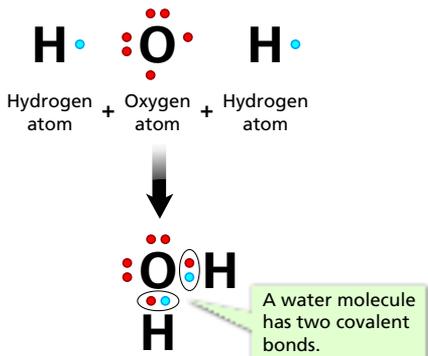


FIGURE 22
Sharing Electrons

By sharing electrons in a covalent bond, each fluorine atom has a stable set of eight valence electrons.

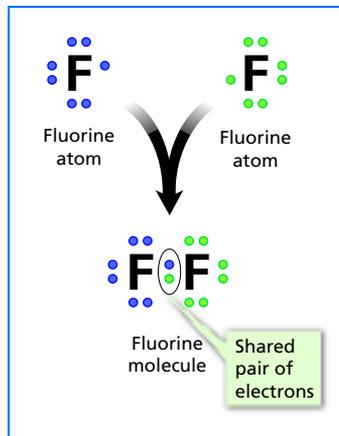


FIGURE 23
Covalent Bonds

The oxygen atom in water and the nitrogen atom in ammonia are each surrounded by eight electrons as a result of sharing electrons with hydrogen atoms.

Interpreting Diagrams How many electrons does each hydrogen atom have as a result of sharing?

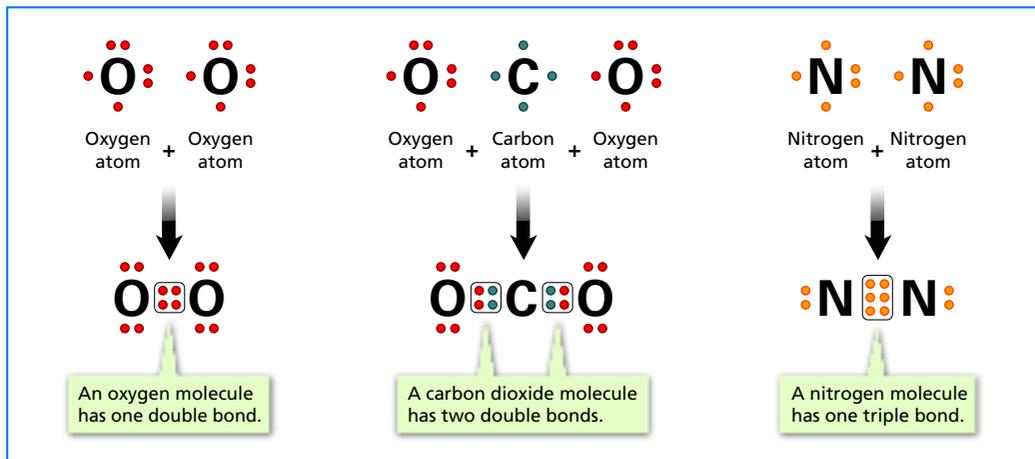


FIGURE 24

Double and Triple Bonds

An oxygen molecule contains one double bond, while a carbon dioxide molecule has two double bonds. A nitrogen molecule contains one triple bond.

Interpreting Diagrams In a nitrogen molecule, how many electrons does each nitrogen atom share with the other?

Double Bonds and Triple Bonds Look at the diagram of the oxygen molecule (O_2) in Figure 24. What do you see that's different? This time the two atoms share two pairs of electrons, forming a **double bond**. In a carbon dioxide molecule (CO_2), carbon forms a double bond with each of two oxygen atoms. Elements such as nitrogen and carbon can form **triple bonds** in which their atoms share three pairs of electrons.



Reading
Checkpoint

What is the difference between a double bond and a triple bond?

Molecular Compounds

A **molecular compound** is a compound that is composed of molecules. The molecules of a molecular compound contain atoms that are covalently bonded. Molecular compounds have very different properties than ionic compounds. **Compared to ionic compounds, molecular compounds generally have lower melting points and boiling points, and they do not conduct electricity when dissolved in water.**

Low Melting Points and Boiling Points Study the table in the Analyzing Data box on the next page. It lists the melting points and boiling points for a few molecular compounds and ionic compounds. In molecular solids, forces hold the molecules close to one another. But, the forces between molecules are much weaker than the forces between ions in an ionic solid. Compared with ionic solids, less heat must be added to molecular solids to separate the molecules and change the solid to a liquid. That is why most familiar compounds that are liquids or gases at room temperature are molecular compounds.



For: Links on molecular compounds
Visit: www.Scilinks.org
Web Code: scn-1214

Comparing Molecular and Ionic Compounds

The table compares the melting points and boiling points of a few molecular compounds and ionic compounds. Use the table to answer the following questions.

- Graphing** Create a bar graph of just the melting points of these compounds. Put the molecular compounds on the left and the ionic compounds on the right. Arrange the bars in order of increasing melting point. The y -axis should start at -200°C and go to 900°C .
- Interpreting Data** Describe what your graph reveals about the melting points of molecular compounds compared to those of ionic compounds.
- Inferring** How can you account for the differences in melting points between molecular compounds and ionic compounds?
- Interpreting Data** How do the boiling points of the molecular and ionic compounds compare?

Melting Points and Boiling Points of Molecular and Ionic Compounds

Substance	Formula	Melting Point ($^{\circ}\text{C}$)	Boiling Point ($^{\circ}\text{C}$)
Methane	CH_4	-182.4	-161.5
Rubbing alcohol	$\text{C}_3\text{H}_8\text{O}$	-89.5	82.4
Water	H_2O	0	100
Zinc chloride	ZnCl_2	290	732
Magnesium chloride	MgCl_2	714	$1,412$
Sodium chloride	NaCl	800.7	$1,465$

Molecular compound Ionic compound

- Predicting** Ammonia's melting point is -78°C and its boiling point is -34°C . Is ammonia a molecular compound or an ionic compound? Explain.

Poor Conductivity Most molecular compounds do not conduct electricity. No charged particles are available to move, so electricity cannot flow. Materials such as plastic and rubber are used to insulate wires because these materials are composed of molecular substances. Even as liquids, molecular compounds are poor conductors. Pure water, for example, does not conduct electricity. Neither does table sugar or alcohol when they are dissolved in pure water.

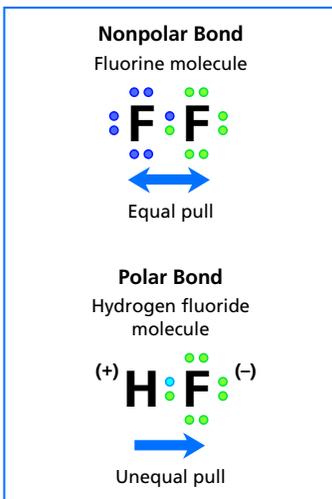
Unequal Sharing of Electrons

Have you ever played tug of war? If you have, you know that if both teams pull with equal force, the contest is a tie. But what if the teams pull on the rope with unequal force? Then the rope moves toward the side of the stronger team. The same is true of electrons in a covalent bond. **Atoms of some elements pull more strongly on shared electrons than do atoms of other elements. As a result, the electrons are pulled more toward one atom, causing the bonded atoms to have slight electrical charges.** These charges are not as strong as the charges on ions.

FIGURE 25

Nonpolar and Polar Bonds

Fluorine forms a nonpolar bond with another fluorine atom. In hydrogen fluoride, fluorine attracts electrons more strongly than hydrogen does, so the bond formed is polar.



Polar Bonds and Nonpolar Bonds The unequal sharing of electrons is enough to make the atom with the stronger pull slightly negative and the atom with the weaker pull slightly positive. A covalent bond in which electrons are shared unequally is called a **polar bond**. Of course, if two atoms pull equally on the electrons, neither atom becomes charged. A covalent bond in which electrons are shared equally is a **nonpolar bond**. Compare the bond in fluorine (F_2) with the bond in hydrogen fluoride (HF) in Figure 25.

Polar Bonds in Molecules It makes sense that a molecule with nonpolar bonds will itself be nonpolar. But a molecule may contain polar bonds and still be nonpolar overall. In carbon dioxide, the oxygen atoms attract electrons much more strongly than carbon does. So, the bonds between the oxygen and carbon atoms are polar. But, as you can see in Figure 26, a carbon dioxide molecule has a shape like a straight line. So, the two oxygen atoms pull with equal strength in opposite directions. In a sense, the attractions cancel out, and the molecule is nonpolar.

In contrast, other molecules that have polar covalent bonds are themselves polar. In a water molecule, the two hydrogen atoms are at one end of the molecule, while the oxygen atom is at the other end. The oxygen atom attracts electrons more strongly than do the hydrogen atoms. As a result, the oxygen end has a slight negative charge and the hydrogen end has a slight positive charge.

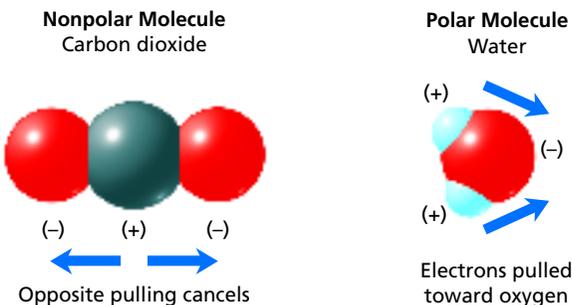
Attractions Between Molecules If you could shrink small enough to move among a bunch of water molecules, what would you find? The negatively charged oxygen ends of the polar water molecules attract the positively charged hydrogen ends of nearby water molecules. These attractions pull water molecules toward each other. In contrast, there is little attraction between nonpolar molecules, such as carbon dioxide molecules.

FIGURE 26

Nonpolar and Polar Molecules

A carbon dioxide molecule is a nonpolar molecule because of its straight-line shape. In contrast, a water molecule is a polar molecule because of its bent shape.

Interpreting Diagrams What do the arrows in the diagram show?



The properties of polar and nonpolar compounds differ because of differences in attractions between their molecules. For example, water and vegetable oil don't mix. The molecules in vegetable oil are nonpolar, and nonpolar molecules have little attraction for polar water molecules. On the other hand, the water molecules are attracted more strongly to one another than to the molecules of oil. Thus, water stays with water, and oil stays with oil.

If you did the Discover activity, you found that adding detergent helped oil and water to mix. This is because one end of a detergent molecule has nonpolar covalent bonds. The other end includes an ionic bond. The detergent's nonpolar end mixes easily with the oil. Meanwhile, the charged ionic end is attracted to polar water molecules, so the detergent dissolves in water.



Reading
Checkpoint

Why is water (H_2O) a polar molecule but a fluorine molecule (F_2) is not?



FIGURE 27

Getting Out the Dirt

Most laundry dirt is oily or greasy. Detergents can mix with both oil and water, so when the wash water goes down the drain, the soap and dirt go with it.

Section 4 Assessment

Target Reading Skill Asking Questions Use the answers to the questions you wrote about the headings to help you answer the questions below.

Reviewing Key Concepts

- Identifying** What is the attraction that holds two covalently bonded atoms together?
 - Inferring** A carbon atom can form four covalent bonds. How many valence electrons does it have?
 - Interpreting Diagrams** What is a double bond? Use Figure 24 to explain how carbon dioxide achieves a stable set of eight electrons for each atom.
- Reviewing** How are the properties of molecular compounds different from those of ionic compounds?
 - Relating Cause and Effect** Why are most molecular compounds poor conductors of electricity?
- Reviewing** How do some atoms in covalent bonds become slightly negative or slightly positive? What type of covalent bonds do these atoms form?

- Comparing and Contrasting** Both carbon dioxide molecules and water molecules have polar bonds. Why then is carbon dioxide a nonpolar molecule while water is a polar molecule?
- Predicting** Predict whether carbon dioxide or water would have a higher boiling point. Explain your prediction in terms of the attractions between molecules.

Lab
zone

At-Home Activity

Laundry Chemistry Demonstrate the action of soaps and detergents to your family. Pour some vegetable oil on a clean cloth and show how a detergent solution can wash the oil away better than water alone can. Explain to your family the features of soap and detergent molecules in terms of their chemical bonds.