Covalent Bonds

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CHAPTER 1 Covalent Bonds

Lesson Objectives

- Describe how covalent bonds form.
- Compare properties of polar and nonpolar covalent compounds.

Lesson Vocabulary

- covalent bond
- covalent compound
- hydrogen bond
- nonpolar
- polar

Introduction

Covalent bonds are bonds in which atoms share rather than transfer electrons. Compounds with covalent bonds are called covalent compounds.

Formation of Covalent Bonds

A **covalent bond** is the force of attraction that holds together two atoms that share a pair of electrons. The shared electrons are attracted to the nuclei of both atoms. Covalent bonds form only between atoms of nonmetals. The two atoms may be the same or different elements. If the bonds form between atoms of different elements, a covalent compound forms. Covalent compounds are described in detail later in the lesson. To see a video about covalent bonding, go to this URL: http://www.youtube.com/watch?v=-Eh_0Dseg3E (6:20).

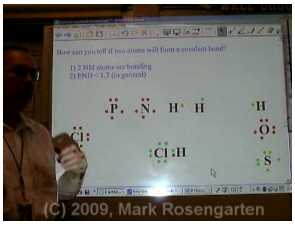

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Figure 1.1 shows an example of a covalent bond forming between two atoms of the same element, in this case two atoms of hydrogen. The two atoms share a pair of electrons. Hydrogen normally occurs in two-atom, or diatomic, molecules like this (*di-* means "two"). Several other elements also normally occur as diatomic molecules: nitrogen, oxygen, and all but one of the halogens (fluorine, chlorine, bromine, and iodine).

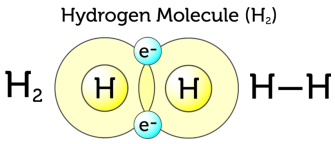

FIGURE 1.1

This figure shows three ways of representing a covalent bond. A dash (-) between two atoms represents one pair of shared electrons.

Why Covalent Bonds Form

Covalent bonds form because they give atoms a more stable arrangement of electrons. Look at the hydrogen atoms in **Figure** 1.1. Alone, each hydrogen atom has just one electron. By sharing electrons with another hydrogen atom, it has two electrons: its own and the one in the other hydrogen atom. The shared electrons are attracted to both hydrogen nuclei. This force of attraction holds the two atoms together as a molecule of hydrogen.

Some atoms need to share more than one pair of electrons to have a full outer energy level. For example, an oxygen atom has six valence electrons. It needs two more electrons to fill its outer energy level. Therefore, it must form two covalent bonds. This can happen in many different ways. One way is shown in **Figure** 1.2. The oxygen atom in the figure has covalent bonds with two hydrogen atoms. This forms the covalent compound water.

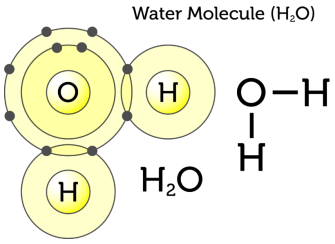

FIGURE 1.2

An oxygen atom has a more stable arrangement of electrons when it forms covalent bonds with two hydrogen atoms.

Polar and Nonpolar Covalent Bonds

In some covalent bonds, electrons are not shared equally between the two atoms. These are called **polar** bonds. **Figure** 1.3 shows this for water. The oxygen atom attracts the shared electrons more strongly because its nucleus has more positively charged protons. As a result, the oxygen atom becomes slightly negative in charge. The hydrogen atoms attract the electrons less strongly. They become slightly positive in charge. For another example of polar bonds, see the video at this URL: http://www.youtube.com/watch?v=1lnjg81daBs (0:52).

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In other covalent bonds, electrons are shared equally. These bonds are called **nonpolar** bonds. Neither atom attracts the shared electrons more strongly. As a result, the atoms remain neutral. **Figure** 1.4 shows an example of nonpolar bonds.

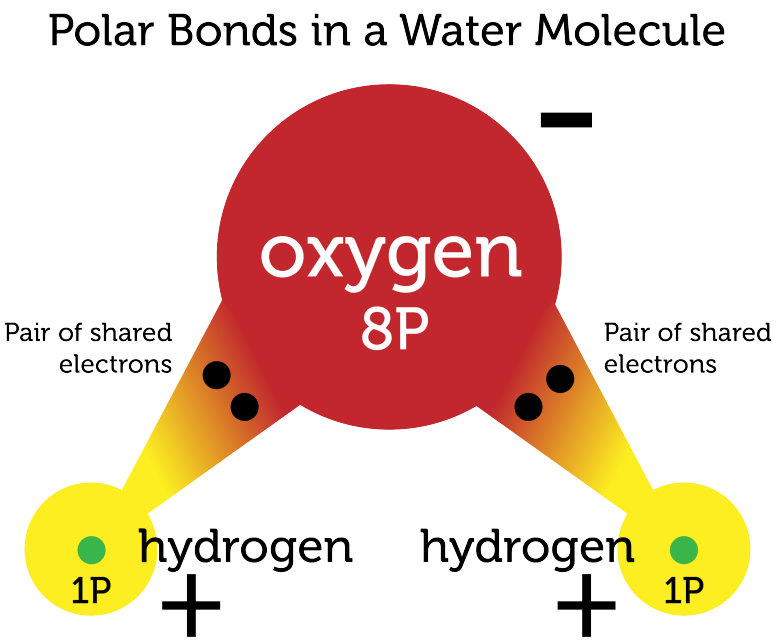


FIGURE 1.3
A water molecule has two polar bonds.

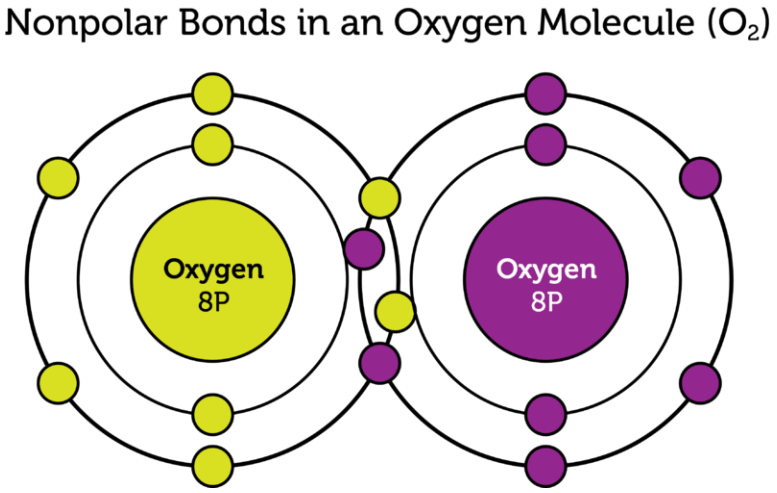


FIGURE 1.4
An oxygen molecule has two nonpolar bonds. This is called a double bond. The two oxygen atoms attract equally the four shared electrons.

Covalent Compounds

Covalent bonds between atoms of different elements form **covalent compounds**. The smallest, simplest covalent compounds have molecules with just two atoms. An example is hydrogen chloride (HCl). It consists of one hydrogen atom and one chlorine atom. The largest, most complex covalent molecules have thousands of atoms. Examples include proteins and carbohydrates. These are compounds in living things.

Helpful Hints

Naming Covalent Compounds Follow these rules in naming simple covalent compounds:

- The element closer to the left of the periodic table is named first.

- The second element gets the suffix *–ide*.
- Prefixes such as *di-* (2) and *tri-* (3) show the number of each atom in the compound. These are written with subscripts in the chemical formula.

Example: The gas that consists of one carbon atom and two oxygen atoms is named carbon dioxide. Its chemical formula is CO_2.

You Try It!

Problem: What is the name of the compound that contains three oxygen atoms and two nitrogen atoms? What is its chemical formula?

Properties of Covalent Compounds

Covalent compounds have different properties than ionic compounds because of their bonds. Covalent compounds exist as individual molecules rather than crystals. It takes less energy for individual molecules than ions in a crystal to pull apart. As a result, covalent compounds have lower melting and boiling points than ionic compounds. Many are gases or liquids at room temperature. Covalent compounds have shared electrons. These are not free to move like the transferred electrons of ionic compounds. This makes covalent compounds poor conductors of electricity. Many covalent compounds also do not dissolve in water as all ionic compounds do.

Polar and Nonpolar Covalent Compounds

Having polar bonds may make a covalent compound polar. A polar compound is one in which there is a slight difference in charge between opposite ends of the molecule. All polar compounds contain polar bonds. But having polar bonds does not necessarily result in a polar compound. It depends on how the atoms are arranged. This is illustrated in **Figure** 1.5. Both molecules in the figure contain polar bonds, but only formaldehyde is a polar compound. Why is carbon dioxide nonpolar?

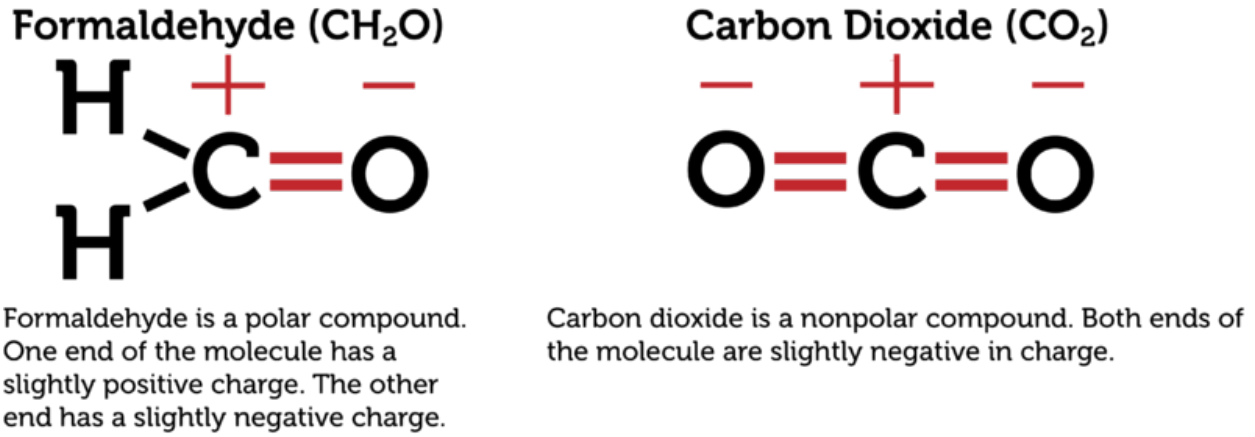
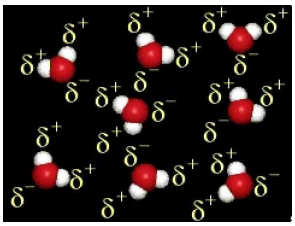


FIGURE 1.5

Covalent compounds may be polar or nonpolar, as these two examples show. In both molecules, the oxygen atoms attract electrons more strongly than the carbon or hydrogen atoms do.

The molecules of polar compounds are attracted to each other. You can see this in **Figure** 1.6 for water. A bond forms between the positive hydrogen end of one water molecule and the negative oxygen end of another water molecule.

This type of bond is called a **hydrogen bond**. Hydrogen bonds are weak, but they still must be overcome when a polar substance changes from a solid to a liquid or from a liquid to a gas. As a result, polar covalent compounds may have higher melting and boiling points than nonpolar covalent compounds. To learn more about hydrogen bonding and when it occurs, see the video at this URL: http://www.youtube.com/watch?v=lkl5cbfqFRM (0:58).



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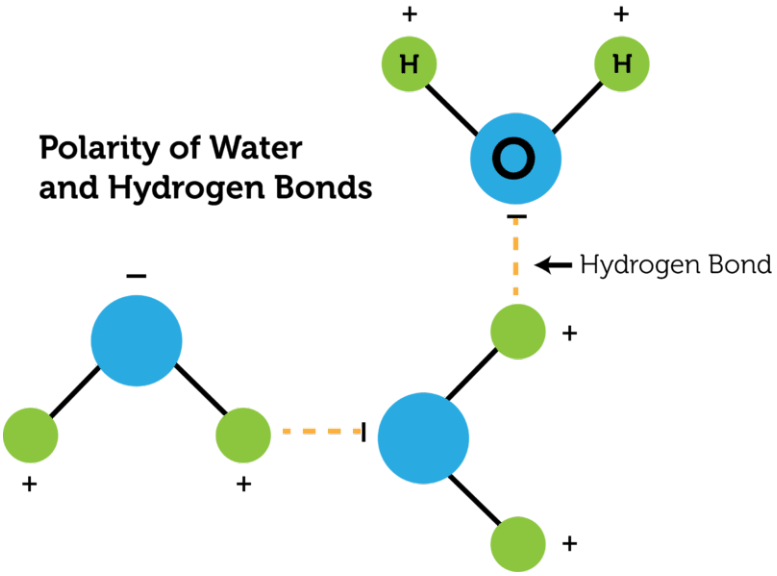


FIGURE 1.6

Water is a polar compound, so its molecules are attracted to each other and form hydrogen bonds.

Lesson Summary

- A covalent bond is the force of attraction that holds together two atoms that share a pair of electrons. It forms between atoms of the same or different nonmetals. In polar covalent bonds, one atom attracts the shared electrons more strongly and becomes slightly negative. The other atom becomes slightly positive.
- Covalent compounds form individual molecules rather than crystals. Compared with ionic compounds, they have low melting and boiling points. They are also poor conductors of electricity. In polar covalent compounds, oppositely charged ends of different molecules attract each other. This affects the properties of polar compounds.

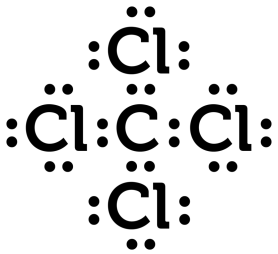
Lesson Review Questions

Recall

1. What is a covalent bond?
2. What is the difference between a polar and nonpolar covalent bond?
3. List general properties of covalent compounds.

Apply Concepts

4. The electron dot diagram below represents a covalent compound. Do you think it is a polar or nonpolar compound? Explain.



Think Critically

5. Explain why covalent bonds form.

Points to Consider

You read in this lesson that covalent bonds may form between atoms of the same nonmetal element. For example, hydrogen atoms (H) commonly form covalent bonds to form hydrogen molecules (H_2).

- Do you think bonds may also form between atoms of the same metallic element?
- Predict what these metallic bonds might be like.

References

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