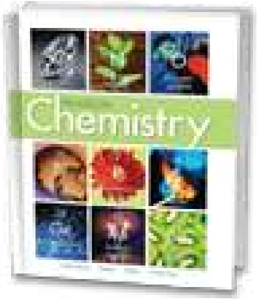


Chapter 8
Covalent Bonding

8.1 Molecular Compounds
8.2 The Nature of Covalent Bonding
8.3 Bonding Theories

8.4 Polar Bonds and Molecules

How does a snowflake get its shape?

The size and shape of each crystal depends mainly on the air temperature and amount of water vapor in the air at the time the snow crystal forms.

Bond Polarity

How do electronegativity values determine the charge distribution in a polar bond?

Bond Polarity

Covalent bonds differ in terms of how the bonded atoms share the electrons.

- The character of the molecule depends on the kind and number of atoms joined together.
- These features, in turn, determine the molecular properties.

The bonding pairs of electrons in covalent bonds are pulled between the nuclei of the atoms sharing the electrons.

- The nuclei of atoms pull on the shared electrons, much as the knot in the rope is pulled toward opposing sides in a tug-of-war.

Bond Polarity

The bonding pairs of electrons in covalent bonds are pulled between the nuclei of the atoms sharing the electrons.

- When the atoms in the bond pull equally (as occurs when identical atoms are bonded), the bonding electrons are shared equally, and each bond formed is a **nonpolar covalent bond**.

Bond Polarity

A **polar covalent bond**, known also as a **polar bond**, is a covalent bond between atoms in which the electrons are shared unequally.

Bond Polarity

A **polar covalent bond**, known also as a **polar bond**, is a covalent bond between atoms in which the electrons are shared unequally.

The more electronegative atom attracts more strongly and gains a slightly negative charge. The less electronegative atom has a slightly positive charge.

Bond Polarity

The higher the electronegativity value, the greater the ability of an atom to attract electrons to itself.

Describing Polar Covalent Bonds

Hydrogen has an electronegativity of 2.1, and chlorine has an electronegativity of 3.0.

- These values are significantly different, so the covalent bond in hydrogen chloride is polar.

Describing Polar Covalent Bonds

Hydrogen has an electronegativity of 2.1, and chlorine has an electronegativity of 3.0.

- The chlorine atom, with its higher electronegativity, acquires a slightly negative charge.
- The hydrogen atom acquires a slightly positive charge.

$$\overset{\delta+}{H}—\overset{\delta-}{Cl}$$

Describing Polar Covalent Bonds

The lowercase Greek letter **delta (δ) denotes that atoms in the covalent bond acquire only partial charges, less than 1+ or 1–.**

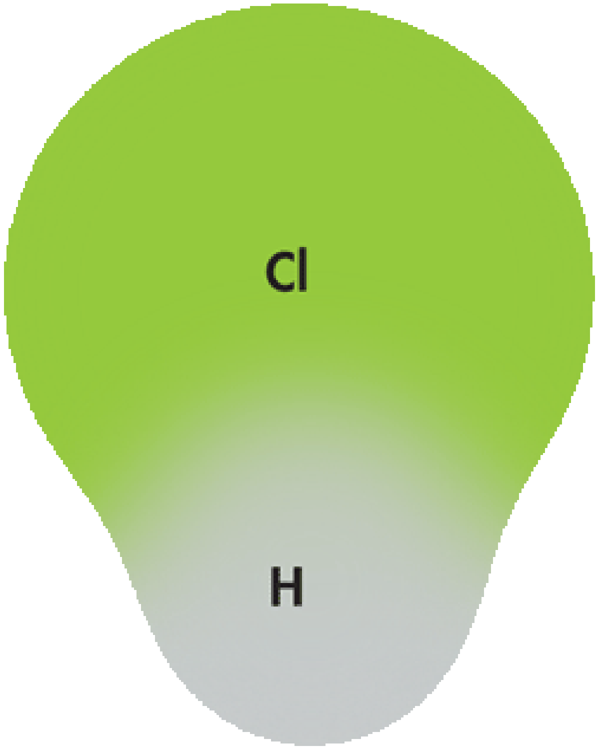
δ+ δ–
H—Cl

- The minus sign shows that chlorine has a slightly negative charge.
- The plus sign shows that hydrogen has acquired a slightly positive charge.

Describing Polar Covalent Bonds

These partial charges are shown as clouds of electron density.

- This electron-cloud picture of hydrogen chloride shows that the chlorine atom attracts the electron cloud more than the hydrogen atom does.



Describing Polar Covalent Bonds

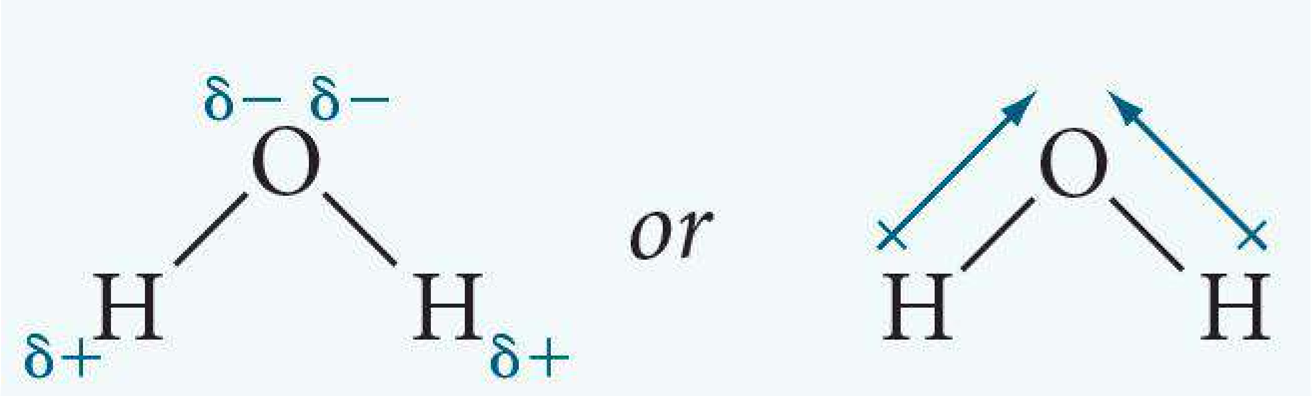
The polar nature of the bond may also be represented by an arrow pointing to the more electronegative atom.

$$\overset{+\!\!\!\longrightarrow}{\mathrm{H{-}Cl}}$$

Describing Polar Covalent Bonds

The O—H bonds in a water molecule are also polar.

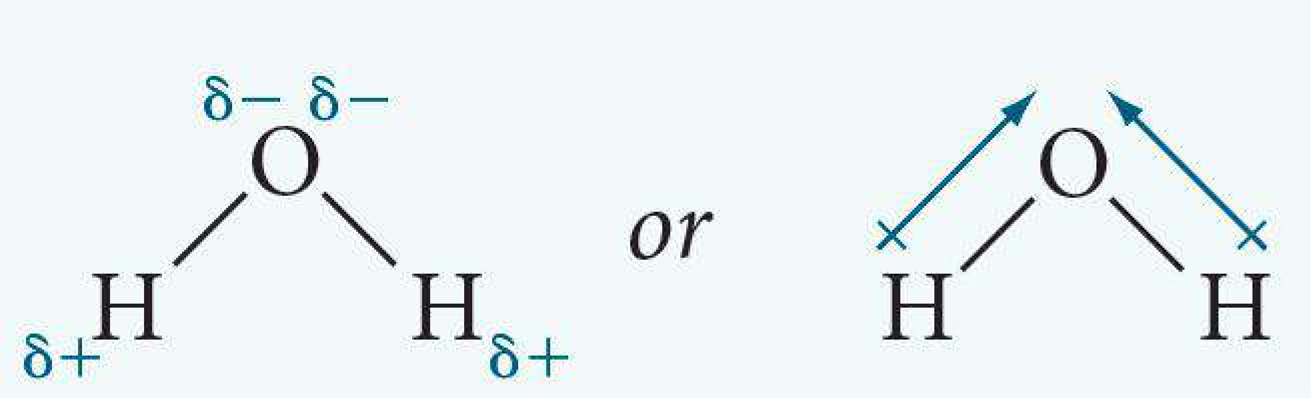
- The highly electronegative oxygen partially pulls the bonding electrons away from hydrogen.



Describing Polar Covalent Bonds

The O—H bonds in a water molecule are also polar.

- The oxygen acquires a slightly negative charge.
- The hydrogen is left with a slightly positive charge.



Describing Polar Covalent Bonds

The electronegativity difference between two atoms tells you what kind of bond is likely to form.

Electronegativity Differences and Bond Types		
Electronegativity difference range	**Most probable type of bond**	**Example**
0.0–0.4	Nonpolar covalent	H—H (0.0)
0.4–1.0	Moderately polar covalent	$\overset{\delta+}{H}$—$\overset{\delta-}{Cl}$ (0.9)
1.0–2.0	Very polar covalent	$\overset{\delta+}{H}$—$\overset{\delta-}{F}$ (1.9)
≥2.0	Ionic	Na^+Cl^- (2.1)

Describing Polar Covalent Bonds

There is no sharp boundary between ionic and covalent bonds.

- As the electronegativity difference between two atoms increases, the polarity of the bond increases.
- If the difference is more than 2.0, the electrons will likely be pulled away completely by one of the atoms.
  - In that case, an ionic bond will form.

Identifying Bond Type

Which type of bond (nonpolar covalent, moderately polar covalent, very polar covalent, or ionic) will form between each of the following pairs of atoms?

a. N and H

b. F and F

c. Ca and Cl

d. Al and Cl

1 Analyze **Identify the relevant concepts.**

- In each case, the pairs of atoms involved in the bonding pair are given.
- The types of bonds depend on the electronegativity differences between the bonding elements.

2 Solve Apply concepts to this problem.

Identify the electronegativities of each atom using Table 6.2.

a. N(3.0), H(2.1)

b. F(4.0), F(4.0)

c. Ca(1.0), Cl(3.0)

d. Al(1.5), Cl(3.0)

2 Solve Apply concepts to this problem.

Calculate the electronegativity difference between the two atoms.

a. N(3.0), H(2.1); 0.9

b. F(4.0), F(4.0); 0.0

c. Ca(1.0), Cl(3.0); 2.0

d. Al(1.5), Cl(3.0); 1.5

The electronegativity difference between two atoms is expressed as the absolute value. So, you will never express the difference as a negative number.

2 **Solve** **Apply concepts to this problem.**

Based on the electronegativity difference, determine the bond type using Table 8.4.

a. N(3.0), H(2.1); 0.9; moderately polar covalent

b. F(4.0), F(4.0); 0.0; nonpolar covalent

c. Ca(1.0), Cl(3.0); 2.0; ionic

d. Al(1.5), Cl(3.0); 1.5; very polar covalent

Describing Polar Covalent Molecules

The presence of a polar bond in a molecule often makes the entire molecule polar.

- In a **polar molecule**, one end of the molecule is slightly negative, and the other end is slightly positive.

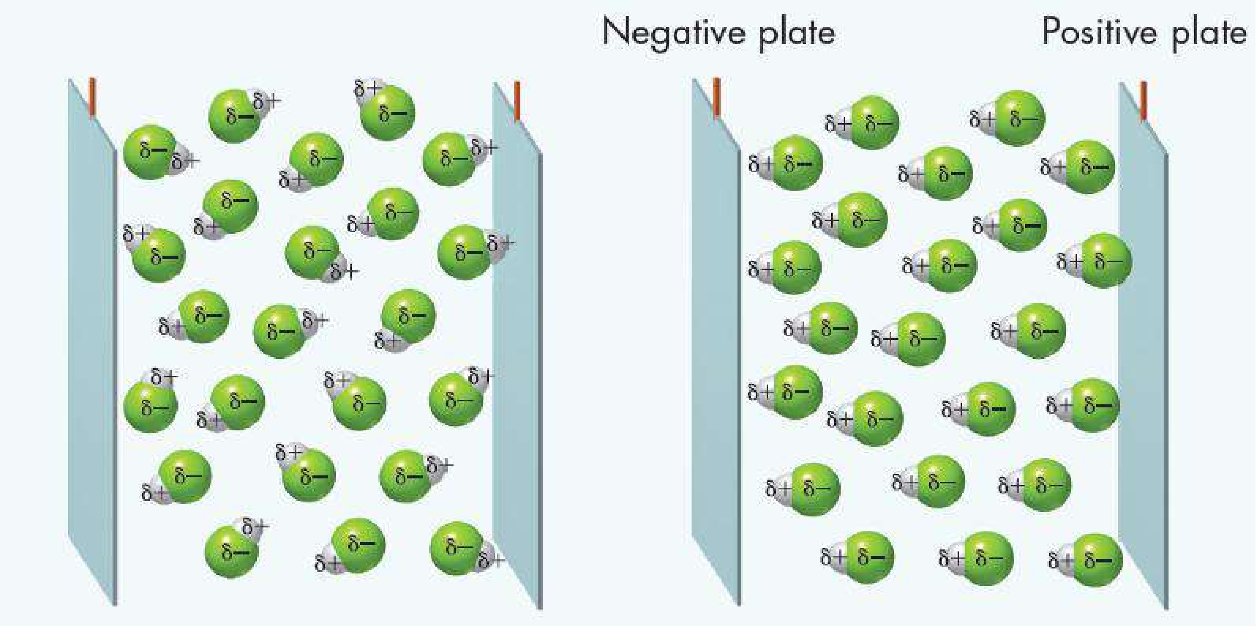
Describing Polar Covalent Molecules

In the hydrogen chloride molecule, for example, the partial charges on the hydrogen and chlorine atoms are electrically charged regions, or poles.

- A molecule that has two poles is called a dipolar molecule, or **dipole**.
  - The hydrogen chloride molecule is a dipole.

Describing Polar Covalent Molecules

When polar molecules are placed between oppositely charged plates, they tend to become oriented with respect to the positive and negative plates.

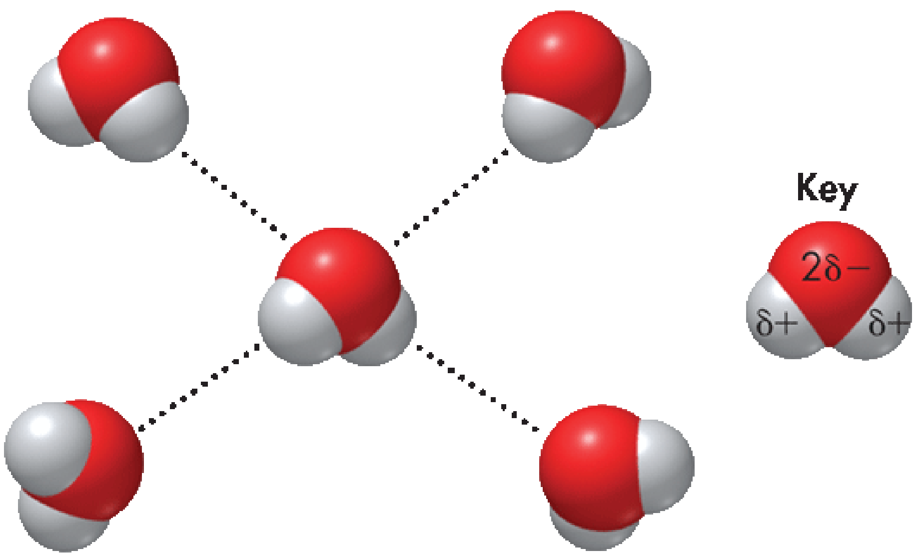


Electric field is absent.
Polar molecules orient randomly.

Electric field is on.
Polar molecules line up.

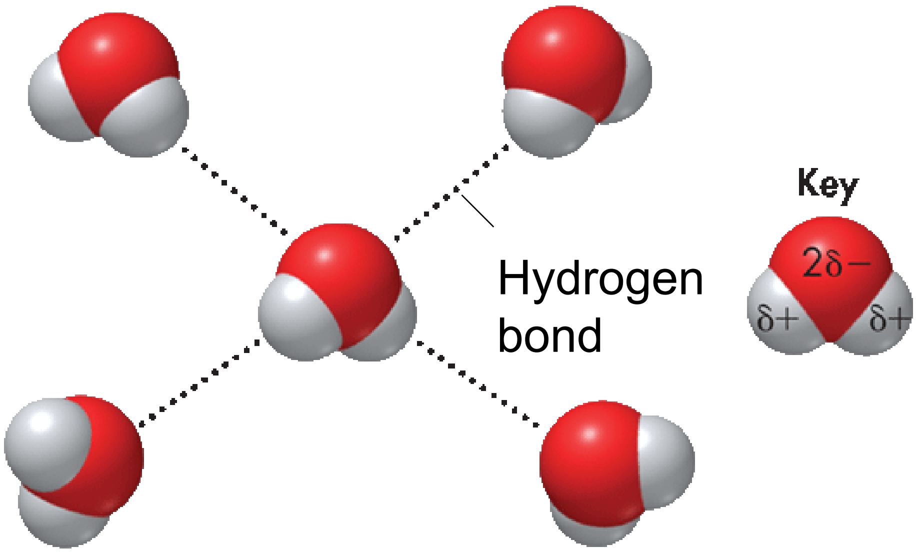
Hydrogen Bonds

The positive region of one water molecule attracts the negative region of another water molecule.



Hydrogen Bonds

This relatively strong attraction, which is also found in hydrogen-containing molecules other than water, is called a hydrogen bond.



Hydrogen Bonds

Hydrogen bonds are attractive forces in which a hydrogen covalently bonded to a very electronegative atom is also weakly bonded to an unshared electron pair of another electronegative atom.

- The other atom may be in the same molecule or in a nearby molecule.
- Hydrogen bonding always involves hydrogen.

How does a snowflake get its shape?

How does a snowflake get its shape?

A snowflake's shape is determined by the interactions of hydrogen bonds during its formation.

Intermolecular Attractions and Molecular Properties

Why are the properties of covalent compounds so diverse?

At room temperature, some compounds are gases, some are liquids, and some are solids.

- The physical properties of a compound depend on the type of bonding it displays—in particular, on whether it is ionic or covalent.

The diversity of physical properties among covalent compounds is mainly because of widely varying intermolecular attractions.

Intermolecular Attractions and Molecular Properties

The melting and boiling points of most compounds composed of molecules are low compared with those of ionic compounds.

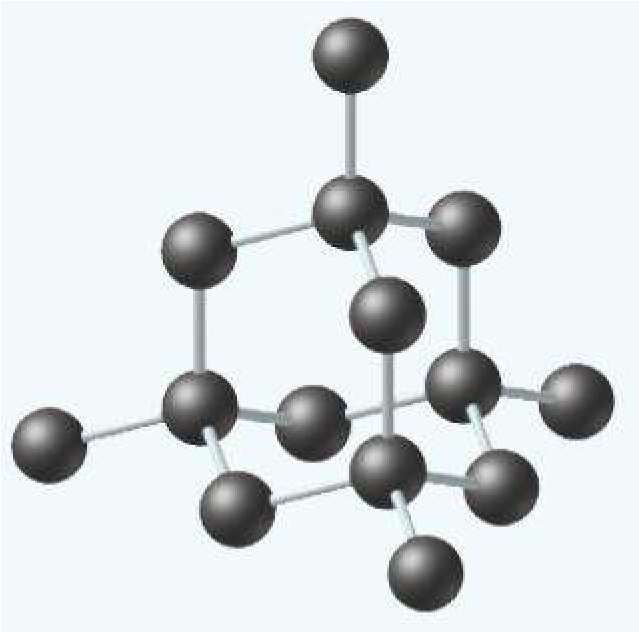
- In most solids formed by molecules, only the weak attractions between molecules need to be broken.

A few solids that consist of molecules do not melt until the temperature reaches 1000°C or higher.

- Most of these very stable substances are **network solids** (or network crystals), solids in which all of the atoms are covalently bonded to each other.
  - Melting a network solid would require breaking covalent bonds throughout the solid.

Diamond is an example of a network solid.

- Each carbon atom in a diamond is covalently bonded to four other carbons, interconnecting carbon atoms throughout the diamond.
- Diamond does not melt; rather, it vaporizes to a gas at 3500°C and above.



This table summarizes some of the characteristic differences between ionic and covalent (molecular) substances.

Characteristics of Ionic and Molecular Compounds

Characteristic	Ionic Compound	Molecular Compound
Representative unit	Formula unit	Molecule
Bond formation	Transfer of one or more electrons between atoms	Sharing of electron parts between atoms
Type of elements	Metallic and nonmetallic	Nonmetallic
Physical state	Solid	Solid, liquid, or gas
Melting point	High (usually above 300°C)	High (usually below 300°C)
Solubility in water	Usually high	High to low
Electrical conductivity of aqueous solution	Good conductor	Poor to nonconducting

Key Concepts

- **When different atoms bond, the more electronegative atom attracts electrons more strongly and acquires a slightly negative charge.**
- **Intermolecular attractions are weaker than either an ionic or a covalent bond.**
- **The diversity of physical properties among covalent compounds is mainly because of widely varying intermolecular attractions.**

- **nonpolar covalent bond**: a covalent bond in which the electrons are shared equally by the two atoms
- **polar covalent bond (polar bond)**: a covalent bond between atoms in which the electrons are shared unequally
- **polar molecule**: a molecule in which one side of the molecule is slightly negative and the opposite side is slightly positive

Glossary Terms

- **dipole**: a molecule that has two poles, or regions with opposite charges
- **van der Waals forces**: the two weakest intermolecular attractions—dispersion interactions and dipole forces
- **dipole interactions**: intermolecular forces resulting from the attraction of oppositely charged regions of polar molecules

Glossary Terms

- **dispersion forces**: attractions between molecules caused by the electron motion on one molecule affecting the electron motion on the other through electrical forces; these are the weakest interactions between molecules
- **hydrogen bonds**: attractive forces in which a hydrogen covalently bonded to a very electronegative atom is also weakly bonded to an unshared electron pair of another electronegative atom
- **network solid**: a solid in which all of the atoms are covalently bonded to each other

END OF 8.4