8.3 The Key Role of Hydrogen Bonding

Consider what happens when two water molecules approach each other. Because opposite charges attract, a H atom (δ^+) on one of the water molecules is attracted to the O atom (δ^-) on the neighboring water molecule. This is an example of an **intermolecular force**; that is, a force that occurs *between* molecules.

With more than two water molecules, the story gets more complicated. Examine each H_2O molecule in Figure 8.7 and note the two H atoms and two nonbonding pairs of electrons on the O atom. These allow for multiple intermolecular attractions. This set of attractions among molecules is called "hydrogen bonding." A **hydrogen bond** is an electrostatic attraction between a H atom, which is bonded to a highly electronegative atom (O, N, or F), and a neighboring O, N, or F atom—either in another molecule, or in a different part of the same molecule. Do not confuse hydrogen "bonds" with covalent bonds. Typically, hydrogen bonds are only about one-tenth as strong as the covalent bonds connecting atoms *within* molecules. Also, the atoms involved in hydrogen bonding are farther apart than they are in covalent bonds. In liquid water, there may be up to four hydrogen bonds per water molecule, as shown in Figure 8.7.

Compare:

- *Intermolecular* forces are *between* molecules, whereas *intramolecular* forces are *within* a single molecule.
- *Intercollegiate* sports are played *between* colleges, whereas *intracollegiate* (or *intramural*) sports are played *within* colleges.

The relative strengths of interactions are (typically): ionic bonds > covalent bonds ≫ hydrogen bonds > London dispersion forces

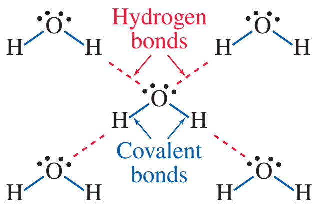

Figure 8.7

The inter- and intramolecular forces within and among water molecules (distances not to scale).

An interactive illustration of hydrogen bonding is found on **Figures Alive!** in **Connect**

Your Turn 8.9 Skill Building Hydrogen Bonding

a. Explain what the dashed lines between water molecules in **Figure 8.7** represent.

b. In the same figure, label the atoms on two adjacent water molecules with δ^+ or δ^-. How do these partial charges help explain the orientation of the molecules?

c. Illustrate hydrogen bonding in four molecules of NH_3.

Although hydrogen bonds are not as strong as covalent bonds, hydrogen bonds are still quite strong compared with other types of intermolecular forces. The boiling point of water gives us evidence for this assertion. For example, consider hydrogen sulfide, H_2S, a molecule that has the same shape as water but does not contain hydrogen bonds. Due to its relatively weak intermolecular forces, H_2S boils at about −60 °C and so is a gas at room temperature. In contrast, water boils at 100 °C. Because of hydrogen bonding, water is a liquid at room temperature, as well as at body temperature (about 37 °C). In fact, life's very existence on our planet depends on this fact!

Sulfur is less electronegative than oxygen and nitrogen. Although N–H or O–H groups can form hydrogen bonds with other molecules, S–H groups are unable to do so.

Your Turn 8.10 Scientific Practices Bonds Within and Among Water Molecules

Are covalent bonds broken when water boils? Explain with drawings.

Hint: Start with molecules of water in the liquid state, as shown in Figure 8.7. Make a second drawing to show water in the vapor phase.

Hydrogen bonding can also help you understand why ice cubes and icebergs float. Ice is composed of a regular array of water molecules in which every H_2O molecule is