Chemistry St 6 K1: Through systems thinking, people can recognize the commonalities that exist among all systems and how parts of a systems interrelate and combine to perform specific functions.
Also covers: St 4 3.1oo, 3.1rr, 3.4h, 4.1b

Objectives

- **Describe** how intermolecular forces affect solvation.
- **Define** solubility.
- **Understand** what factors affect solubility.

Review Vocabulary

exothermic: a chemical reaction in which more energy is released than is required to break bonds in the initial reactants

New Vocabulary

solvation
heat of solution
unsaturated solution
saturated solution
supersaturated solution
Henry's law

Factors Affecting Solvation

MAIN Idea **Factors such as temperature, pressure, and polarity affect the formation of solutions.**

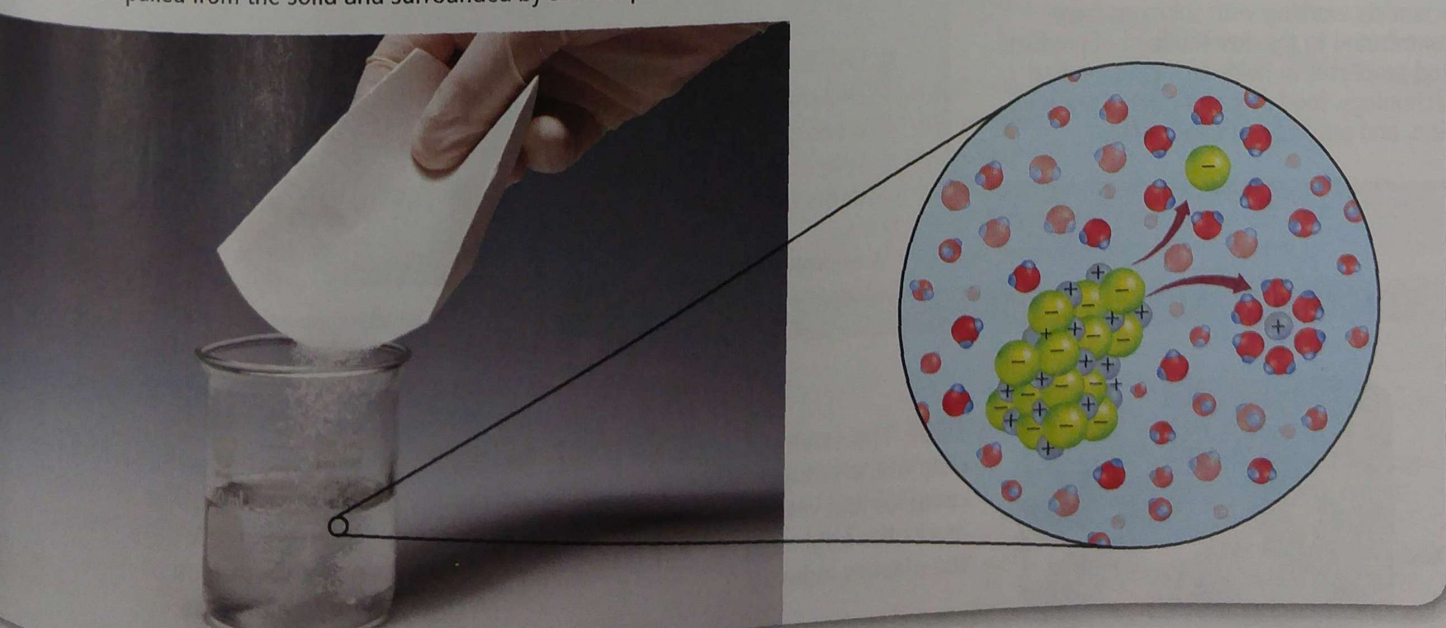
Real-World Reading Link If you have ever made microwavable soup from a dry mix, you added cold water to the dry mix and stirred. At first, only a small amount of the powdered mix dissolves in the cold water. After heating it in the microwave and stirring again, all of the powdered mix dissolves and you have soup.

The Solvation Process

Why are some substances soluble in each other, while others are not? To form a solution, solute particles must separate from one another and the solute and solvent particles must mix. Recall from Chapter 12 that attractive forces exist among the particles of all substances. Attractive forces exist between the pure solute particles, between the pure solvent particles, and between the solute and solvent particles. When a solid solute is placed in a solvent, the solvent particles completely surround the surface of the solid solute. If the attractive forces between the solvent and solute particles are greater than the attractive forces holding the solute particles together, the solvent particles pull the solute particles apart and surround them. These surrounded solute particles then move away from the solid solute and out into the solution.

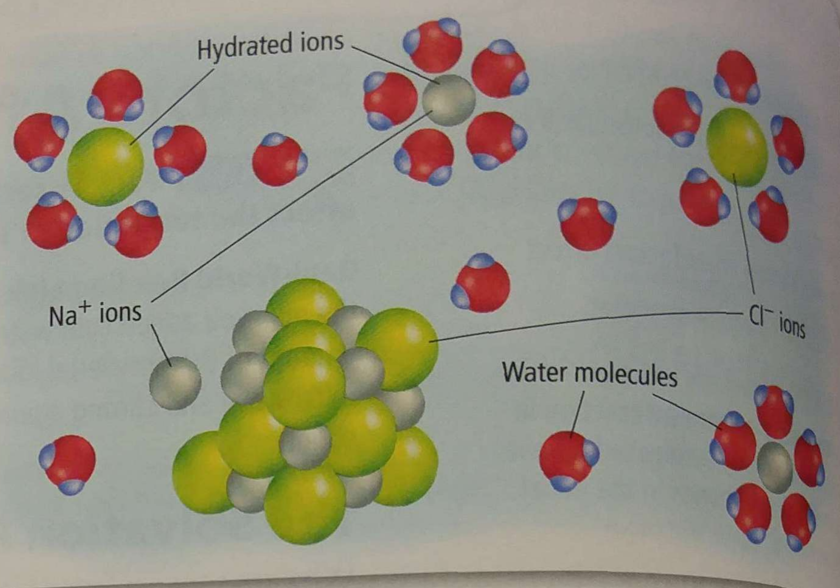
The process of surrounding solute particles with solvent particles to form a solution is called **solvation,** as shown in **Figure 14.9.** Solvation in water is called hydration. "Like dissolves like" is the general rule used to determine whether solvation will occur in a specific solvent. To determine whether a solvent and solute are alike, you must examine the bonding and polarity of the particles and the intermolecular forces among particles.

Figure 14.9 Salt begins to separate when it is dropped into water. The solute particles are pulled from the solid and surrounded by solvent particles.



■ **Figure 14.10** Sodium chloride dissolves in water as the water molecules surround the sodium and chloride ions. Note how the polar water molecules orient themselves differently around the positive and negative ions.

Solvation Process of NaCl



Concepts In Motion

Interactive Figure To see an animation of the dissolution of compounds, visit glencoe.com.

Aqueous solutions of ionic compounds Recall that water molecules are polar molecules and are in constant motion, as described by the kinetic-molecular theory. When a crystal of an ionic compound, such as sodium chloride (NaCl), is placed in water, the water molecules collide with the surface of the crystal. The charged ends of the water molecules attract the positive sodium ions and negative chloride ions. This attraction between the dipoles and the ions is greater than the attraction among the ions in the crystal, so the ions break away from the surface. The water molecules surround the ions, and the solvated ions move into the solution, shown in **Figure 14.10,** exposing more ions on the surface of the crystal. Solvation continues until the entire crystal has dissolved.

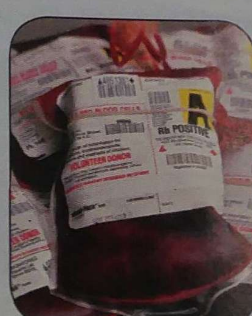
Not all ionic substances are solvated by water molecules. Gypsum is insoluble in water because the attractive forces between the ions in gypsum are so strong that they cannot be overcome by the attractive forces of the water molecules. As shown in **Figure 14.11,** the discoveries of specific solutions and mixtures, such as plaster made out of gypsum, have contributed to the development of many products and processes.

■ **Figure 14.11**

Milestones in Solution Chemistry

Scientists working with solutions have contributed to the development of products and processes in fields including medical technology, food preparation and preservation, and public health and safety.

1883 The first successful centrifuge uses the force created by a high rate of spin to separate components of a mixture.

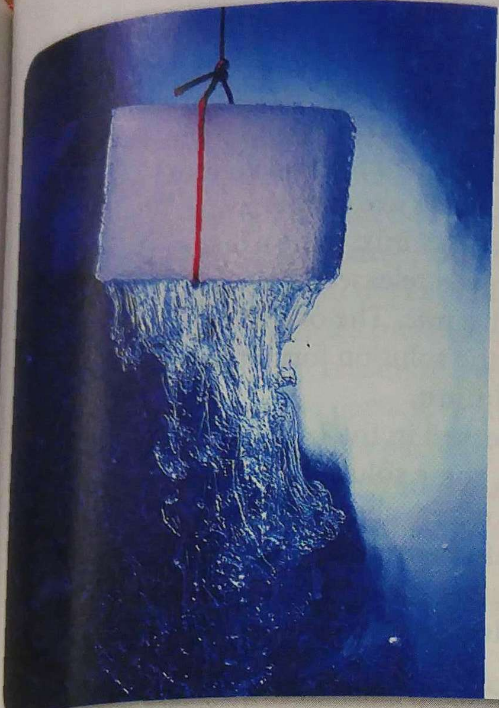


1916 Doctors develop a glycerol solution that allows blood to be stored for up to several weeks after collection for use in transfusions.

1870 1890 1910

1866 The invention of celluloid, a solution of camphor and cellulose, marks the beginning of the plastics industry.

1899 Newly patented technology reduces the size of fat globules dispersed in raw milk, preventing formation of a cream layer in a process called homogenization.



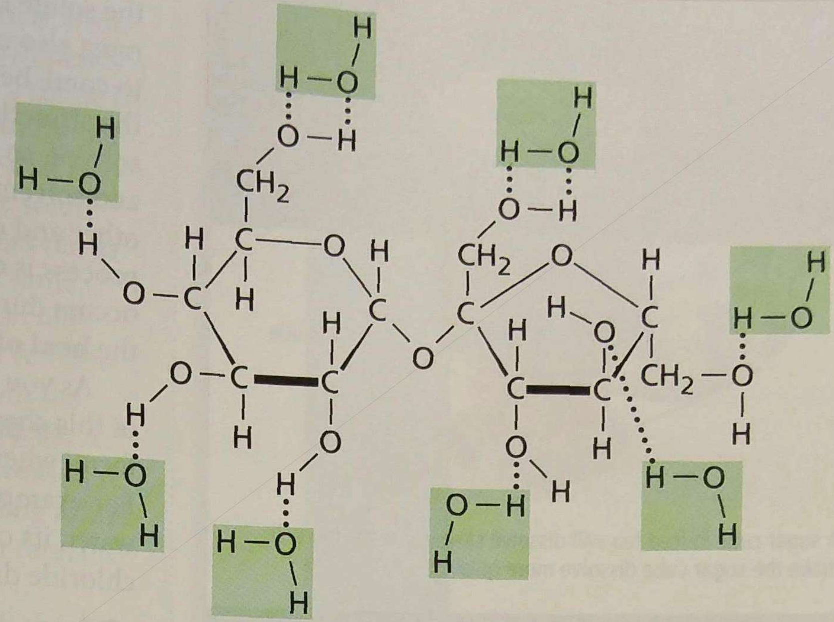


Figure 14.12 Sucrose molecules contain eight O–H bonds and are polar. Polar water molecules form hydrogen bonds with the O–H bonds, which pulls the sucrose into solution.

Aqueous solutions of molecular compounds Water is also a good solvent for many molecular compounds. Table sugar is the molecular compound sucrose. As shown in **Figure 14.12,** sucrose molecules are polar and have several O–H bonds. As soon as the sugar crystals contact the water, water molecules collide with the outer surface of the crystal. Each O–H bond becomes a site for hydrogen bonding with water. The attractive forces among sucrose molecules are overcome by the attractive forces between polar water molecules and polar sucrose molecules. Sucrose molecules leave the crystal and become solvated by water molecules.

Oil is a substance made up primarily of carbon and hydrogen. It does not form a solution with water. There is little attraction between the polar water molecules and the nonpolar oil molecules. However, oil spills can be cleaned up with a nonpolar solvent because nonpolar solutes are more readily dissolved in nonpolar solvents.

1964 Stephanie Kwolek discovers a synthetic fiber, formed from liquid crystals in solution, that is stronger than steel and lighter than fiberglass.

2003 Scientists develop chemical packets that remove toxic metals and pesticides and kill pathogens in drinking water. They can be distributed to survivors of natural disasters.

1950 · 1970 · 1990 · 2010

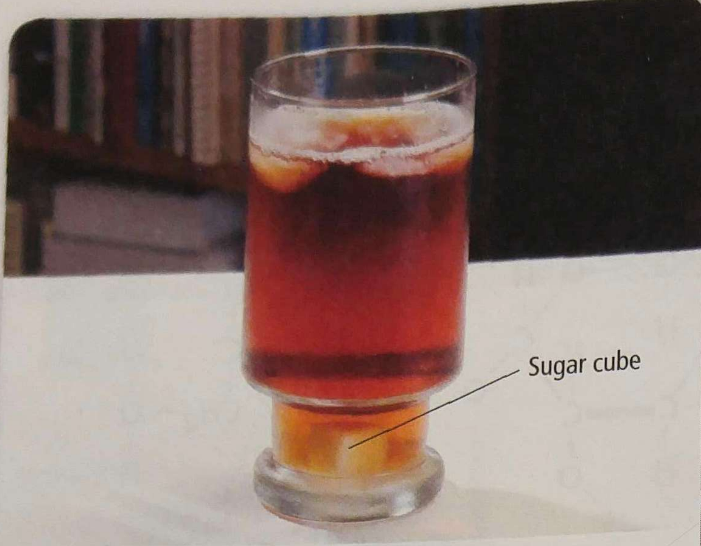
1943 The first artificial kidney removes toxins dissolved in a patient's blood.

1980 A type of gypsum board is developed as a firewall system to separate townhome and condominium units.

Concepts In Motion

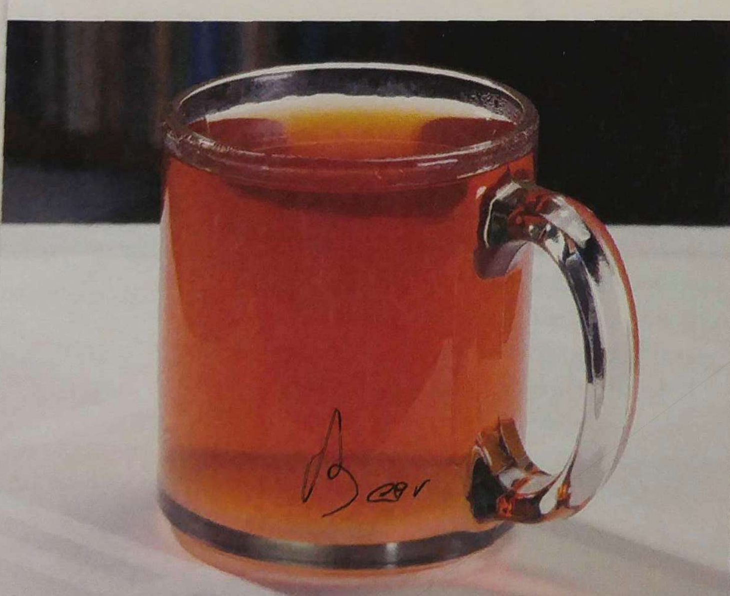
Interactive Time Line To learn more about these discoveries and others, visit glencoe.com.

Chemistry Online



A sugar cube in iced tea will dissolve slowly, but stirring will make the sugar cube dissolve more quickly.

Granulated sugar dissolves more quickly in iced tea than a sugar cube, and stirring will make the granulated sugar dissolve even more quickly.



Granulated sugar dissolves very quickly in hot tea.

■ **Figure 14.13** Agitation, surface area, and temperature affect the rate of solvation.

Heat of solution During the process of solvation, the solute must separate into particles. Solvent particles must also move apart in order to allow solute particles to come between them. Energy is required to overcome the attractive forces within the solute and within the solvent, so both steps are endothermic. When solute and solvent particles mix, the particles attract each other and energy is released. This step in the solvation process is exothermic. The overall energy change that occurs during the solution formation process is called the **heat of solution.**

As you observed in the Launch Lab at the beginning of this chapter, some solutions release energy as they form, whereas others absorb energy during formation. For example, after ammonium nitrate dissolves in water, its container feels cool. In contrast, after calcium chloride dissolves in water, its container feels warm.

Reading Check **Explain** why some solutions absorb energy during formation, while others release energy during formation.

Factors That Affect Solvation

Solvation occurs only when the solute and solvent particles come in contact with each other. There are three common ways, shown in **Figure 14.13,** to increase the collisions between solute and solvent particles and thus increase the rate at which the solute dissolves: agitation, increasing the surface area of the solute, and increasing the temperature of the solvent.

Agitation Stirring or shaking—agitation of the mixture—moves dissolved solute particles away from the contact surfaces more quickly and thereby allows new collisions between solute and solvent particles to occur. Without agitation, solvated particles move away from the contact areas slowly.

Surface area Breaking the solute into small pieces increases its surface area. A greater surface area allows more collisions to occur. This is why a teaspoon of granulated sugar dissolves more quickly than an equal amount of sugar in cube form.

Temperature The rate of solvation is affected by temperature. For example, sugar dissolves more quickly in hot tea, shown in **Figure 14.13,** than it does in iced tea. Additionally, hotter solvents generally can dissolve more solid solute. Hot tea can hold more dissolved sugar than the iced tea. Most solids act in the same way as sugar—as temperature increases, the rate of solvation also increases. Solvation of other substances, such as gases, decreases at higher temperatures. For example, a carbonated soft drink will lose its fizz (carbon dioxide) faster at room temperature than when cold.