16.1 Properties of Solutions

Connecting to Your World It was there one minute and gone the next! An entire house was swallowed up by Earth. A victim of moving groundwater, the house had disappeared into a sinkhole! Groundwater, the rain and melted snow that soaks into the ground, can dissolve huge amounts of rock over time and create beautiful limestone caves. A sinkhole forms when the roof of a cave weakens from being dissolved and suddenly collapses. One recorded sinkhole swallowed a house, several other buildings, five cars, and a swimming pool! In this section, you will learn how the solution process occurs and the factors that influence the process.

Guide for Reading

Key Concepts

- What factors determine the rate at which a substance dissolves?
- How is solubility usually expressed?
- What conditions determine the amount of solute that will dissolve in a given solvent?

Vocabulary

saturated solution
solubility
unsaturated solution
miscible
immiscible
supersaturated solution
Henry's law

Reading Strategy

Outlining As you read, make an outline of the most important ideas in this section. Use the red headings as the main topics and the blue headings as subtopics. Add a sentence or a note after each heading to provide key information about each topic.

Solution Formation

Have you noticed, when making tea, that granulated sugar dissolves faster than sugar cubes, and that both granulated sugar and sugar cubes dissolve faster in hot tea or when you stir? Figure 16.1 illustrates these observations. You will be able to explain these observations, as well as the formation of a sinkhole, once you have gained an understanding of the properties of solutions.

Recall that solutions are homogeneous mixtures that may be solid, liquid, or gaseous. **The compositions of the solvent and the solute determine whether a substance will dissolve. Stirring (agitation), temperature, and the surface area of the dissolving particles determine how fast the substance will dissolve.** These three factors involve the contact of the solute with the solvent.

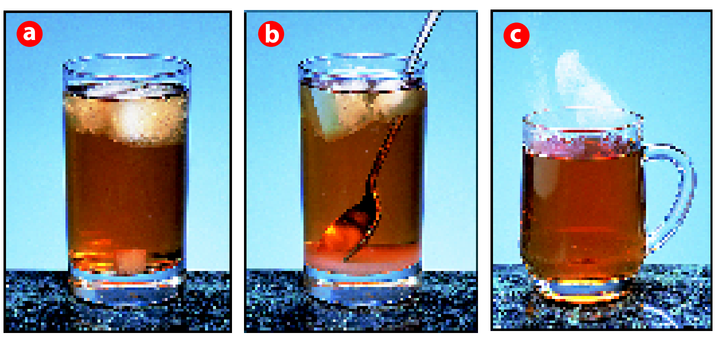


Figure 16.1 Stirring and heating increase the rate at which a solute dissolves. **a** A cube of sugar in cold tea dissolves slowly. **b** Granulated sugar dissolves in cold water more quickly than a sugar cube, especially with stirring. **c** Granulated sugar dissolves very quickly in hot tea.

16.1

1 FOCUS

Objectives

16.1.1 Identify the factors that determine the rate at which a solute dissolves.

16.1.2 Identify the units usually used to express the solubility of a solute.

16.1.3 Identify the factors that determine the mass of solute that will dissolve in a given mass of solute.

Guide for Reading

Build Vocabulary L2

Graphic Organizer Students can compare and contrast the three types of solutions—*saturated solution*, *unsaturated solution*, and *supersaturated solution*—using a table. Have them include definitions and examples of each solution type.

Reading Strategy L2

Relate Text and Visuals Have students study Figures 16.2 and 16.6. Have them make simple sketches that show how the three types of solutions differ.

2 INSTRUCT

Connecting to Your World

Ask, **What causes the formation of limestone caves?** *(groundwater, rain, and melted snow that soaks into the ground and dissolves a significant amount of limestone)*

Solution Formation

Relate L1

Prepare a bulletin board display using pictures that illustrate the importance of solution processes in nature. Examples include a farmer applying fertilizer to a field, a close-up of a plant, a person eating food, fish swimming, a volcanic eruption, and natural crystals. Encourage students to contribute to the display by posting pictures they find.

Section Resources

Print

- **Guided Reading and Study Workbook,** Section 16.1
- **Core Teaching Resources,** Section 16.1 Review, *Interpreting Graphics*
- **Small–Scale Chemistry Laboratory Manual,** Lab 26
- **Laboratory Manual,** Labs 30, 31
- **Transparencies,** T169–T170

Technology

- **Interactive Textbook with ChemASAP,** Simulation 20, Problem-Solving 16.2, Assessment 16.1
- **Go Online,** Section 16.1

Go Online NSTA SciLinks

Download a worksheet on **Solubility** for students to complete, and find additional teacher support from NSTA SciLinks.

Solubility

Relate L2

Explain that solubility is somewhat like population density. Both terms express the concentration of objects. With solubility, the objects are molecules or ions dissolved in a given quantity of solvent. With population density, the objects are organisms per unit area. However, point out that the precise amount of solute that a particular solvent holds under given conditions is fixed. Population density is not limited in the same way.

Go Online NSTA SciLinks

For: Links on Solubility
Visit: www.SciLinks.org
Web Code: cdn-1161

Stirring and Solution Formation If a teaspoon of granulated sugar (sucrose) is placed in a glass of tea, the crystals dissolve slowly. If the contents of the glass are stirred, however, the crystals dissolve more quickly. The dissolving process occurs at the surface of the sugar crystals. Stirring speeds up the process because fresh solvent (the water in tea) is continually brought into contact with the surface of the solute (sugar). It's important to realize, however, that agitation (stirring or shaking) affects only the rate at which a solid solute dissolves. It does not influence the amount of solute that will dissolve. An insoluble substance remains undissolved regardless of how vigorously or for how long the solvent/solute system is agitated.

Temperature and Solution Formation Temperature also influences the rate at which a solute dissolves. Sugar dissolves much more rapidly in hot tea than in iced tea. At higher temperatures, the kinetic energy of water molecules is greater than at lower temperatures so they move faster. The more rapid motion of the solvent molecules leads to an increase in the frequency and the force of the collisions between water molecules and the surfaces of the sugar crystals.

Particle Size and Solution Formation The rate at which a solute dissolves also depends upon the size of the solute particles. A spoonful of granulated sugar dissolves more quickly than a sugar cube because the smaller particles in granulated sugar expose a much greater surface area to the colliding water molecules. Remember, the dissolving process is a surface phenomenon. The more surface of the solute that is exposed, the faster the rate of dissolving.

Solubility

If you add 36.0 g of sodium chloride to 100 g of water at 25°C, all of the 36.0 g of salt dissolves. But if you add one more gram of salt and stir, no matter how vigorously or for how long, only 0.2 g of the last portion will dissolve. Why does the remaining 0.8 g of salt remain undissolved? According to the kinetic theory, water molecules are in continuous motion. Therefore, they should continue to bombard the excess solid, removing and solvating the ions. As ions are solvated, they dissolve in the water. Based on this information, you might expect all of the sodium chloride to dissolve eventually. That does not happen, however, because an exchange process is occurring. New particles from the solid are solvated and enter into solution, as shown in Figure 16.2. At the same time an equal number of already dissolved particles crystalize. These particles come out of solution and are deposited as a solid. The mass of undissolved crystals remains constant.

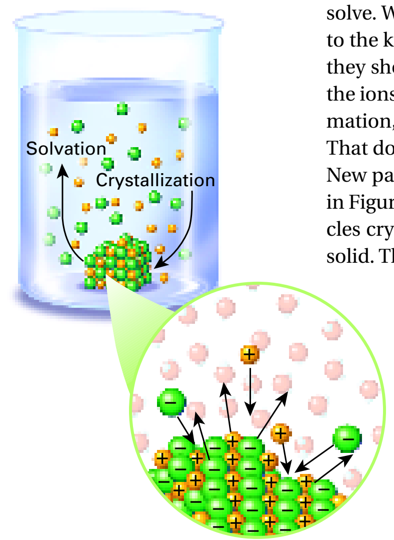


Figure 16.2 In a saturated solution, a state of dynamic equilibrium exists between the solution and the excess solute. The rate of solvation (dissolving) equals the rate of crystallization, so the total amount of dissolved solute remains constant.
Inferring ***What would happen if you added more solute?***

Facts and Figures

Fertilizer Runoff

Most farmers use fertilizers that contain salts of one or more of three elements essential to plant growth: potassium, nitrogen, and phosphorus. When more fertilizer is applied than the soil can absorb, rain washes off the excess salts. Not only is this economically wasteful, it is hazardous to the environment. The water containing these dissolved salts flows into streams and rivers, where the salts contribute to the eutrophication of the water. Eutrophied waters are rich in nutrients but deficient in dissolved oxygen. Signs of eutrophication include overgrowth of water plants, algal blooms, and bad odors resulting from the growth of bacteria that do not need oxygen. In recent years, the problem of fertilizer runoff has lessened with the introduction of slow-release nitrogenous fertilizers. Many farmers have also adopted new methods to reduce runoff.

Figure 16.3 Liquids that are insoluble in one another are immiscible. **a** A thin film of oil spreads over a water surface. Light rays, bent by the film, create patterns of color. **b** Vinegar, which is water-based, and oil are immiscible.

What is happening? Particles move from the solid into the solution. Other dissolved particles move from the solution back to the solid. Because these two processes occur at the same rate, no net change occurs in the overall system. As Figure 16.2 illustrates, a state of dynamic equilibrium exists between the solution and the undissolved solute. The system will remain the same as long as the temperature remains constant. Such a solution is said to be saturated. A **saturated solution** contains the maximum amount of solute for a given quantity of solvent at a constant temperature and pressure. For example, 36.2 g of sodium chloride dissolved in 100 g of water is a saturated solution at 25°C. If additional solute is added to this solution, it will not dissolve. The **solubility** of a substance is the amount of solute that dissolves in a given quantity of a solvent at a specified temperature and pressure to produce a saturated solution. **Solubility is often expressed in grams of solute per 100 g of solvent.** Sometimes the solubility of a gas is expressed in grams per liter of solution (g/L). A solution that contains less solute than a saturated solution at a given temperature and pressure is an **unsaturated solution.** If additional solute is added to an unsaturated solution, the solute will dissolve until the solution is saturated.

Some liquids—for example, water and ethanol—are infinitely soluble in each other. Any amount of ethanol will dissolve in a given volume of water, and vice versa. Similarly, ethylene glycol and water mix in all proportions. Pairs of liquids such as these are said to be completely miscible. Two liquids are **miscible** if they dissolve in each other in all proportions. In such a solution, the liquid that is present in the larger amount is usually considered the solvent. Liquids that are slightly soluble in each other—for example, water and diethyl ether—are partially miscible. Liquids that are insoluble in one another are **immiscible.** As you can see in Figure 16.3, oil and vinegar are immiscible, as are oil and water.

Checkpoint ***What is a saturated solution?***

Word *Origins*

Miscible comes from the Latin word *miscere,* meaning "to mix." Completely miscible liquids dissolve in each other in all proportions. **If the prefix *im-* means "not," what would you call two liquids that are insoluble in each other?**

Word *Origins* L2

Two liquids that are insoluble in each other are called immiscible. Similarly, the word *immense* means transcending ordinary means of measurement, or not capable of measurement. The word *immobile* means incapable of being moved.

Use Visuals L1

Figure 16.3 Have students study the photographs. Ask, **Why do the two liquids not mix?** *(For nonpolar liquids to mix with water, hydrogen bonds must be broken and replaced by much weaker forces between water and the nonpolar compound. In the cases shown, the forces of attraction between molecules are maximized if the liquids remain unmixed.)*

Differentiated Instruction

English Learners L1

Equilibrium may be a difficult concept for some students. Emphasize the dynamic nature of saturation. Initially, salt readily dissolves in water because the ions can be solvated by available water molecules. However, the number of solvated ion-complexes that can inhabit a given volume of water is limited. If more ions are to join in the solvation, some ions must give up their places. Use substitutions in a basketball game as an analogy for the dynamic nature of saturation. Tell students that only five players from each team can be on the court at one time. Players on the bench must wait until a player comes off the court. In this analogy, the players on the sidelines represent ions in a crystal; and those on the court represent dissolved ions.

Answers to...

Figure 16.2 nothing

Checkpoint a solution that contains the maximum amount of solute for a given quantity of solvent at a constant temperature and pressure

Factors Affecting Solubility

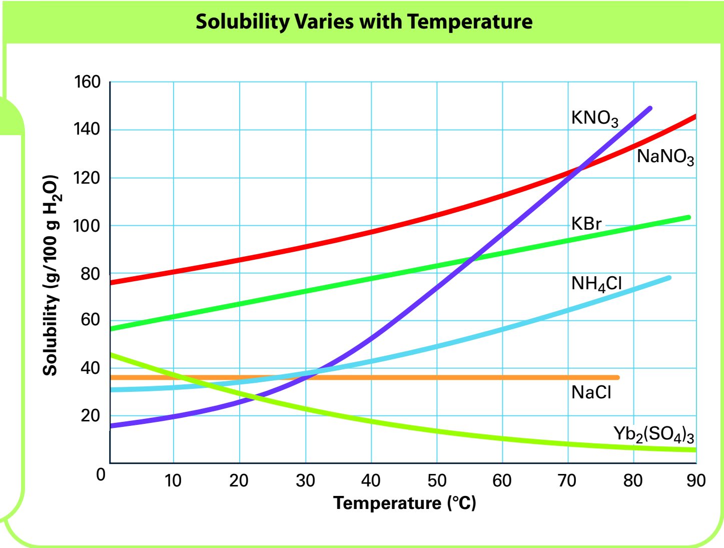
Interpreting Graphs L2

a. The solubility of KNO_3 increases as the temperature increases.
b. $Yb_2(SO_4)_3$ shows a decrease in solubility as temperature increases. NaCl shows the least change in solubility.
c. Only a negligible amount of NaCl would go into solution, if any.

Enrichment Question L3

Ask students which of the compounds in Figure 16.4 they would predict would have negative molar heats of solution. Have students look up the ΔH_{soln} for each compound in the graph (*CRC Handbook of Chemistry and Physics*). Students should state how the solubility curve for a compound is related to its ΔH_{soln}. *(Students should find that with the exception of $Yb_2(SO_4)_3$, for which data is not given, all of the compounds in the graph have positive ΔH_{soln} values at 25°C. Thus, heat is absorbed in the solution process for these compounds. Students may predict, then, that providing more heat by raising the temperature of a solution will increase solubility. Students may also note that NaCl, which shows the least increase in solubility with temperature, has the lowest positive ΔH_{soln} among the compounds discussed.)*

Figure 16.4 Changing the temperature usually affects the solubility of a substance.



INTERPRETING GRAPHS

a. Describe What happens to the solubility of KNO_3 as the temperature increases?
b. Identify Which substance shows a decrease in solubility as temperature increases? Which substance exhibits the least change in solubility?
c. Apply Concepts Suppose you added some solid sodium chloride (NaCl) to a saturated solution of sodium chloride at 20°C and warmed the mixture to 40°C. What would happen to the added sodium chloride?

Factors Affecting Solubility

You have read that solubility is defined as the mass of solute that dissolves in a given mass of a solvent at a specified temperature. **Temperature affects the solubility of solid, liquid, and gaseous solutes in a solvent; both temperature and pressure affect the solubility of gaseous solutes.**

Temperature The solubility of most solid substances increases as the temperature of the solvent increases. Figure 16.4 shows how the solubility of several substances changes as temperature increases. The mineral deposits around hot springs, such as the one shown in Figure 16.5, result from the cooling of the hot, saturated solution of minerals emerging from the spring. As the solution cools in air, it cannot contain the same concentration of minerals as it did at a higher temperature, so some of the minerals precipitate.

For a few substances, solubility decreases with temperature. For example, the solubility of ytterbium sulfate ($Yb_2(SO_4)_3$) in water drops from 44.2 g per 100 g of water at 0°C to 5.8 g per 100 g of water at 90°C. Table 16.1 lists the solubilities of some common substances at various temperatures.

Suppose you make a saturated solution of sodium ethanoate (sodium acetate) at 30°C and let the solution stand undisturbed as it cools to 25°C. Because the solubility of this compound is greater at 30°C than at 25°C, you expect that solid sodium ethanoate will crystallize from the solution as the temperature drops. But no crystals form. You have made a supersaturated solution. A **supersaturated solution** contains more solute than it can theoretically hold at a given temperature. The crystallization of a supersaturated solution can be initiated if a very small crystal, called a seed crystal, of the solute is added. The rate at which excess solute deposits upon the surface of a seed crystal can be very rapid, as shown in Figure 16.6. Crystallization can also occur if the inside of the container is scratched.

Figure 16.5 Mineral deposits form around the edges of this hot spring because the hot water is saturated with minerals. As the water cools, some of the minerals crystallize because they are less soluble at the lower temperature.

Differentiated Instruction

English Learners and Less Proficient Readers L1

Have students draw and label a diagram illustrating the dynamic equilibrium of a saturated solution with arrows describing the motion of particles between the crystalline and solvated states.

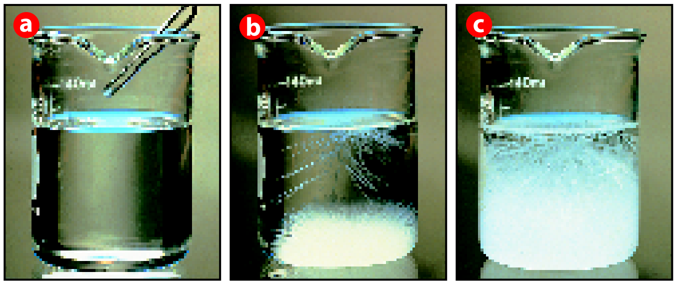


Figure 16.6 A supersaturated solution crystallizes rapidly when disturbed. **a** The solution is clear before a seed crystal is added. **b** Crystals begin to form in the solution immediately after the addition of a seed crystal. **c** Excess solute crystallizes rapidly. **Applying Concepts** ***When the crystallization has ceased, will the solution be saturated or unsaturated?***

Another example of crystallization in a supersaturated solution is the production of rock candy. A solution is supersaturated with sugar. Seed crystals cause the sugar to crystallize out of solution onto a string for you to enjoy!

The effect of temperature on the solubility of gases in liquid solvents is opposite that of solids. The solubilities of most gases are greater in cold water than in hot. For example, Table 16.1 shows that the most important component of air for living beings—oxygen—becomes less soluble in water as the temperature of the solution rises. This fact has some important consequences. When an industrial plant takes water from a lake to use for cooling and then dumps the resulting heated water back into the lake, the temperature of the entire lake increases. Such a change in temperature is known as thermal pollution. Aquatic animal and plant life can be severely affected because the increase in temperature lowers the concentration of dissolved oxygen in the lake water.

Interactive Textbook

Simulation 20 Observe the effect of temperature on the solubility of solids and gases in water.

with **ChemASAP**

Table 16.1

Solubilities of Some Substances in Water at Various Temperatures

		Solubility (g/100 g H_2O)			
Substance	**Formula**	**0°C**	**20°C**	**50°C**	**100°C**
Barium hydroxide	$Ba(OH)_2$	1.67	31.89	—	—
Barium sulfate	$BaSO_4$	0.00019	0.00025	0.00034	—
Calcium hydroxide	$Ca(OH)_2$	0.189	0.173	—	0.07
Lead(II) chloride	$PbCl_2$	0.60	0.99	1.70	—
Lithium carbonate	Li_2CO_3	1.5	1.3	1.1	0.70
Potassium chlorate	$KClO_3$	4.0	7.4	19.3	56.0
Potassium chloride	KCl	27.6	34.0	42.6	57.6
Sodium chloride	NaCl	35.7	36.0	37.0	39.2
Sodium nitrate	$NaNO_3$	74	88.0	114.0	182
Aluminum chloride	$AlCl_3$	30.84	31.03	31.60	33.32
Silver nitrate	$AgNO_3$	122	222.0	455.0	733
Lithium bromide	LiBr	143.0	166	203	266.0
Sucrose (cane sugar)	$C_{12}H_{22}O_{11}$	179	230.9	260.4	487
Hydrogen*	H_2	0.00019	0.00016	0.00013	0.0
Oxygen*	O_2	0.0070	0.0043	0.0026	0.0
Carbon dioxide*	CO_2	0.335	0.169	0.076	0.0

*Gas at 101 kPa (one atmosphere) total pressure

TEACHER Demo

Solubility of Gases L1

Purpose Students observe the effects of pressure and agitation on the solubility of gases.

Materials bottle of warm soda, bottle of cold soda, 2 other bottles of soda

Procedure Open a bottle of warm soda and a bottle of cold soda. Ask students to observe and compare the results. *(Carbon dioxide gas comes out of solution much more quickly in the warm soda.)* The rush of bubbles in a warm bottle of soda can be a model for the "bends," a malady that afflicts divers when dissolved nitrogen forms bubbles in the bloodstream. The model also shows how the escape of carbon dioxide from rising magma can trigger a volcanic eruption. In each case, high pressure keeps a gas in solution; reduced pressure allows it to escape. Repeat the demonstration, this time using a shaken and unshaken bottle of soda. Have students compare and contrast the effect of agitation on the solubility of gases and solids. **CAUTION:** *Be sure to open the shaken bottle in a sink or other partially enclosed area, to avoid spilling.*

Facts and Figures

Rainmakers

U.S. scientists Vincent Schaefer, Irving Langmuir, and Bernard Vonnegut carried out the first successful rainmaking experiments. They knew that water vapor in the atmosphere condenses around tiny nuclei, such as particles of soot. In 1946, Schaefer produced snow by dropping dry ice (solid carbon dioxide) pellets into clouds. A year later, Vonnegut discovered that silver iodide particles also serve as "precipitation nuclei." Since that time, seeding clouds with silver iodide has been the standard method.

Answers to...

Figure 16.6 saturated

Relate

L2

Explain that the action of a gas pressing down on the surface of a liquid and increasing the solubility of the gas in the liquid is like the action of a hammer driving a nail into a piece of wood. When you hit the nail harder, more of the nail is driven into the wood. The hammer is analogous to pressure, the nail to solute gas, and the wood to solvent liquid.

Sample Problem 16.1

Answers

1. $S_2 = S_1 \times P_2 / P_1 = 0.16$ g/L $\times$ 288 kPa/ 104 kPa $= 4.4 \times 10^{-1}$ g/ L
2. $P_2 = P_1 \times S_2 / S_1 = 1.0$ atm $\times$ 9.5 g/L /3.6 g/L = 2.6 atm

Practice Problems Plus

L2

The solubility of a gas is 1.04 g/L at 98.0 kPa and 25°C. **What is the solubility of the same gas at 125 kPa and 25°C?** *(1.33 g/L)*

Math Handbook

For a math refresher and practice, direct students to algebraic equations, page R69.

Pressure Changes in pressure have little affect on the solubility of solids and liquids, but pressure strongly influences the solubility of gases. Gas solubility increases as the partial pressure of the gas above the solution increases. Carbonated beverages are a good example. These drinks contain large amounts of carbon dioxide (CO_2) dissolved in water. Dissolved CO_2 makes the liquid fizz and your mouth tingle. The drinks are bottled under a high pressure of CO_2 gas, which forces large amounts of the gas into solution. When a carbonated-beverage container is opened, the partial pressure of CO_2 above the liquid decreases. Immediately, bubbles of CO_2 form in the liquid and escape from the open bottle, as shown in Figure 16.7. As a result, the concentration of dissolved CO_2 decreases. If the bottle is left open, the drink becomes "flat" as the solution loses its CO_2.

How is the partial pressure of carbon dioxide gas related to the solubility of CO_2 in a carbonated beverage? The relationship is described by **Henry's law,** which states that at a given temperature, the solubility (S) of a gas in a liquid is directly proportional to the pressure (P) of the gas above the liquid. In other words, as the pressure of the gas above the liquid increases, the solubility of the gas increases. Similarly, as the pressure of the gas decreases, the solubility of the gas decreases. You can write the relationship in the form of an equation.

$$\frac{S_1}{P_1} = \frac{S_2}{P_2}$$

S_1 is the solubility of a gas at one pressure, P_1; S_2 is the solubility at another pressure, P_2.

Checkpoint ***How is the solubility of a gas affected by pressure?***

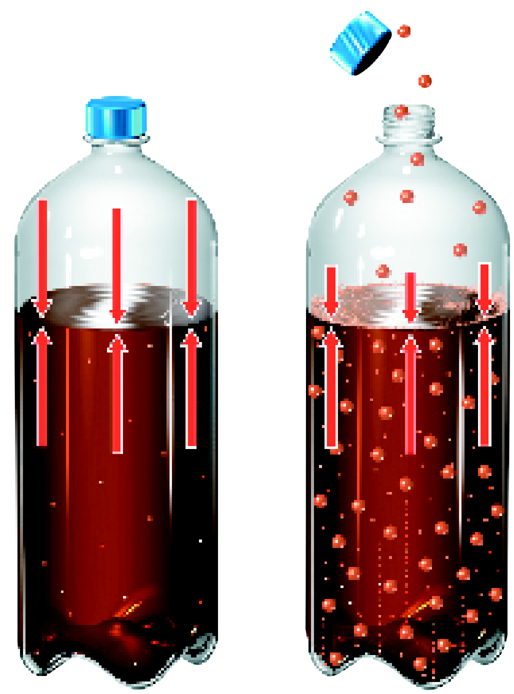


Figure 16.7 Pressure is a factor in the solubility of a gas. **a** In a sealed bottle, both the pressure of CO_2 above the liquid and the concentration of CO_2 in the liquid are high and equal. **b** When the cap is removed, the equilibrium is disturbed; the pressure of CO_2 gas above the liquid decreases and carbon dioxide bubbles out of the liquid.

476 Chapter 16

SAMPLE PROBLEM 16.1

Calculating the Solubility of a Gas

If the solubility of a gas in water is 0.77 g/L at 3.5 atm of pressure, what is its solubility (in g/L) at 1.0 atm of pressure? (The temperature is held constant at 25°C.)

1 Analyze ***List the knowns and the unknown.***

Knowns
- $P_1 = 3.5$ atm
- $S_1 = 0.77$ g/L
- $P_2 = 1.0$ atm
- Henry's law: $\frac{S_1}{P_1} = \frac{S_2}{P_2}$

Unknown
- $S_2 = ?$ g/L

2 Calculate ***Solve for the unknown.***

Solve Henry's law for S_2. Substitute the known values and calculate.

$$S_2 = \frac{S_1 \times P_2}{P_1} = \frac{0.77\ \text{g/L} \times 1.0\ \cancel{\text{atm}}}{3.5\ \cancel{\text{atm}}} = 0.22\ \text{g/L}$$

3 Evaluate ***Does the result make sense?***

The new pressure is approximately one-third of the original pressure, so the new solubility should be approximately one-third of the original. The answer is correctly expressed to two significant figures.

Practice Problems

1. The solubility of a gas in water is 0.16 g/L at 104 kPa. What is the solubility when the pressure of the gas is increased to 288 kPa? Assume the temperature remains constant.
2. A gas has a solubility in water at 0°C of 3.6 g/L at a pressure of 1.0 atm. What pressure is needed to produce an aqueous solution containing 9.5 g/L of the same gas at 0°C?

Math Handbook

For help with algebraic equations, go to page R69.

Interactive Textbook

Problem-Solving 16.2 Solve Problem 2 with the help of an interactive guided tutorial.

with ChemASAP

16.1 Section Assessment

3. **Key Concept** What determines whether a substance will dissolve? What determines how fast a substance will dissolve?
4. **Key Concept** What units are usually used to express the solubility of a solute?
5. **Key Concept** What are two conditions that determine the mass of solute that will dissolve in a given mass of solvent?
6. What would you do to change
   a. a saturated solid/liquid solution to an unsaturated solution?
   b. a saturated gas/liquid solution to an unsaturated solution?
7. The solubility of a gas is 0.58 g/L at a pressure of 104 kPa. What is its solubility if the pressure increases to 250 kPa at the same temperature?

Writing Activity

Procedure Research how to grow crystals. Then write a stepwise procedure for growing rock candy, which is crystallized sugar, or sucrose ($C_{12}H_{22}O_{11}$).

Interactive Textbook

Assessment 16.1 Test yourself on the concepts in Section 16.1.

with ChemASAP

Section 16.1 Assessment

3. chemical composition of the solute and solvent; agitation, temperature, particle size of the solute
4. grams of solute per 100 g of solvent
5. temperature and pressure (if the solute is a gas)
6. **a.** Add solvent.
   b. Increase the pressure.
7. 1.4 g/L

3 ASSESS

Evaluate Understanding L2

Have students use the concept of solvation to explain how agitation, temperature, and particle size affect the rate of solution formation. Ask, **Which of these factors affect the solubility of a substance?** *(temperature only)* **How is the solubility of a gas affected by the pressure of the gas above the liquid?** *(The solubility of the gas increases with increasing pressure.)*

Reteach L1

Review the factors that affect the aqueous solubilities of solid and gaseous substances. *(temperature and pressure)* Make sure that students are able to distinguish between the factors that affect the solubility and those that affect the rate of solution, such as agitation and particle size. Tell students that solubility is the amount of a substance that will dissolve in a given amount of solvent, whereas rate of solution is the amount of solute entering a solution per unit time. Temperature is the only factor discussed that affects both the rate of solution and the solubility.

Writing Activity

Student procedures should include making a saturated aqueous solution of table sugar, heating it, and suspending a thread or string in the solution. The loosely covered solution is allowed to stand undisturbed for about a week.

Interactive Textbook

If your class subscribes to the Interactive Textbook use it to review key concepts in Section 16.1.

with ChemASAP

Answers to...

Checkpoint The solubility of a gas increases with increasing pressure.

Technology & Society

A Solution for Kidney Failure

Comparing and Contrasting

Both kidneys and hemodialysis "clean" blood by removing waste products using semipermeable membranes for filtering. Kidneys undergo this internal process continually, filtering the body's entire blood supply approximately every 45 minutes. Hemodialysis must be performed three times a week and takes several hours to complete a session.

Kidney Function

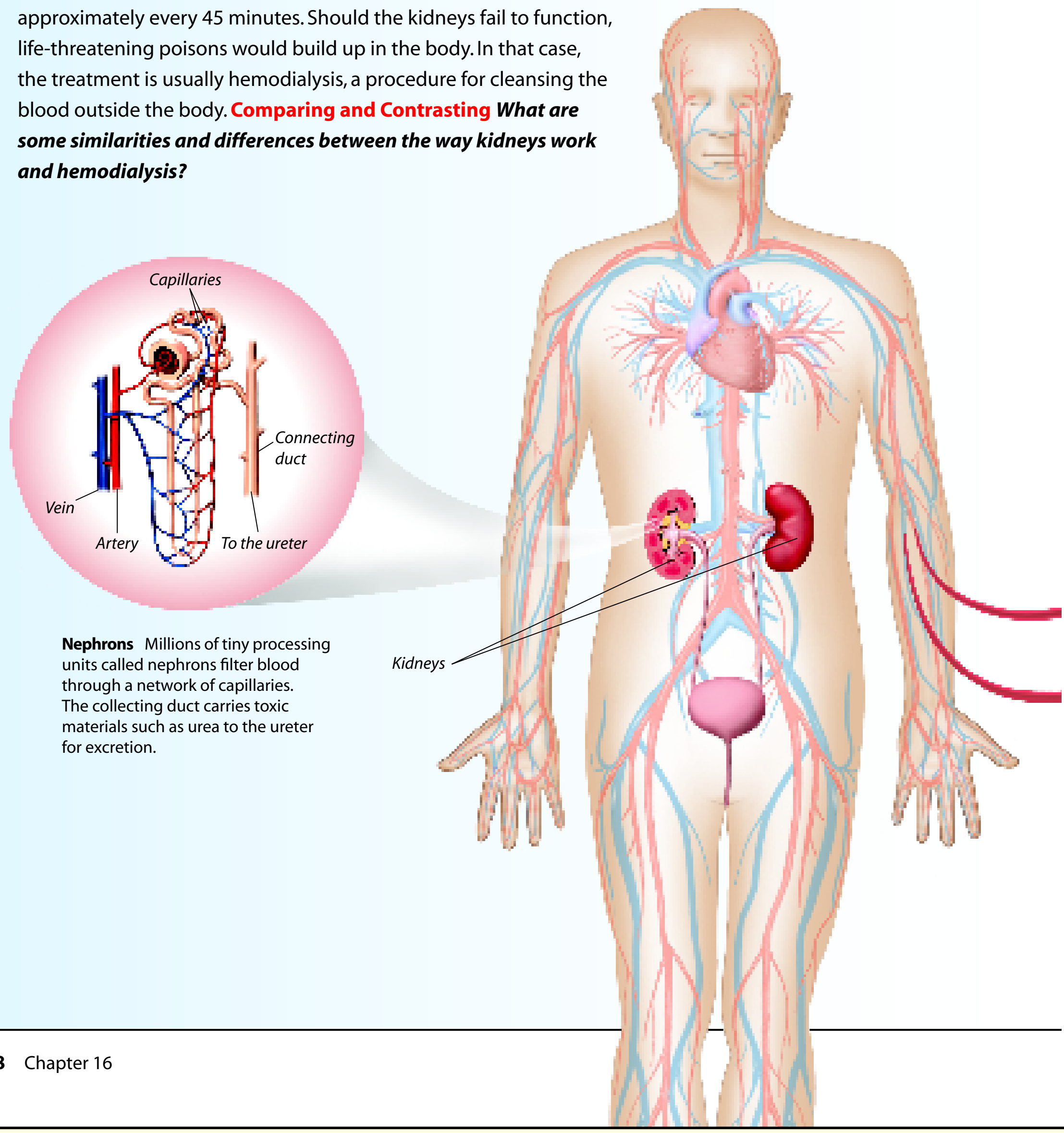
As part of their normal functioning, the body's cells continually produce waste products and dump these wastes into the blood. If they are not removed from the blood, the dissolved waste products build up and become toxic to the body. The work of filtering waste products from blood is done by thousands of small nephrons within the kidneys. Blood enters a nephron through a tiny blood vessel. Everything except blood cells and very large molecules can then pass out of the blood through a semipermeable membrane into a long collecting duct. As the fluid travels through this tube, all the necessary components of your blood—water, ions, and other solutes—pass through the walls of the tube and back into the blood. Waste products, however, remain in the tube. By the time the tube exits the nephron, it contains only urine. Blood that leaves the nephron has all its necessary components—minus the waste products in the urine.

Technology & Society

A Solution for Kidney Failure

Your blood transports oxygen and other nutrients to cells throughout your body. It also picks up discarded waste materials from cells and carries them to your kidneys. Kidneys have the important job of filtering potentially toxic materials from blood and excreting them in urine. The body's entire blood supply passes through its two kidneys approximately every 45 minutes. Should the kidneys fail to function, life-threatening poisons would build up in the body. In that case, the treatment is usually hemodialysis, a procedure for cleansing the blood outside the body. **Comparing and Contrasting** ***What are some similarities and differences between the way kidneys work and hemodialysis?***

A A tube connects a patient to a dialysis machine. The machine pumps blood from a vein, circulates it through a dialyzing bath, and returns it to another vein.



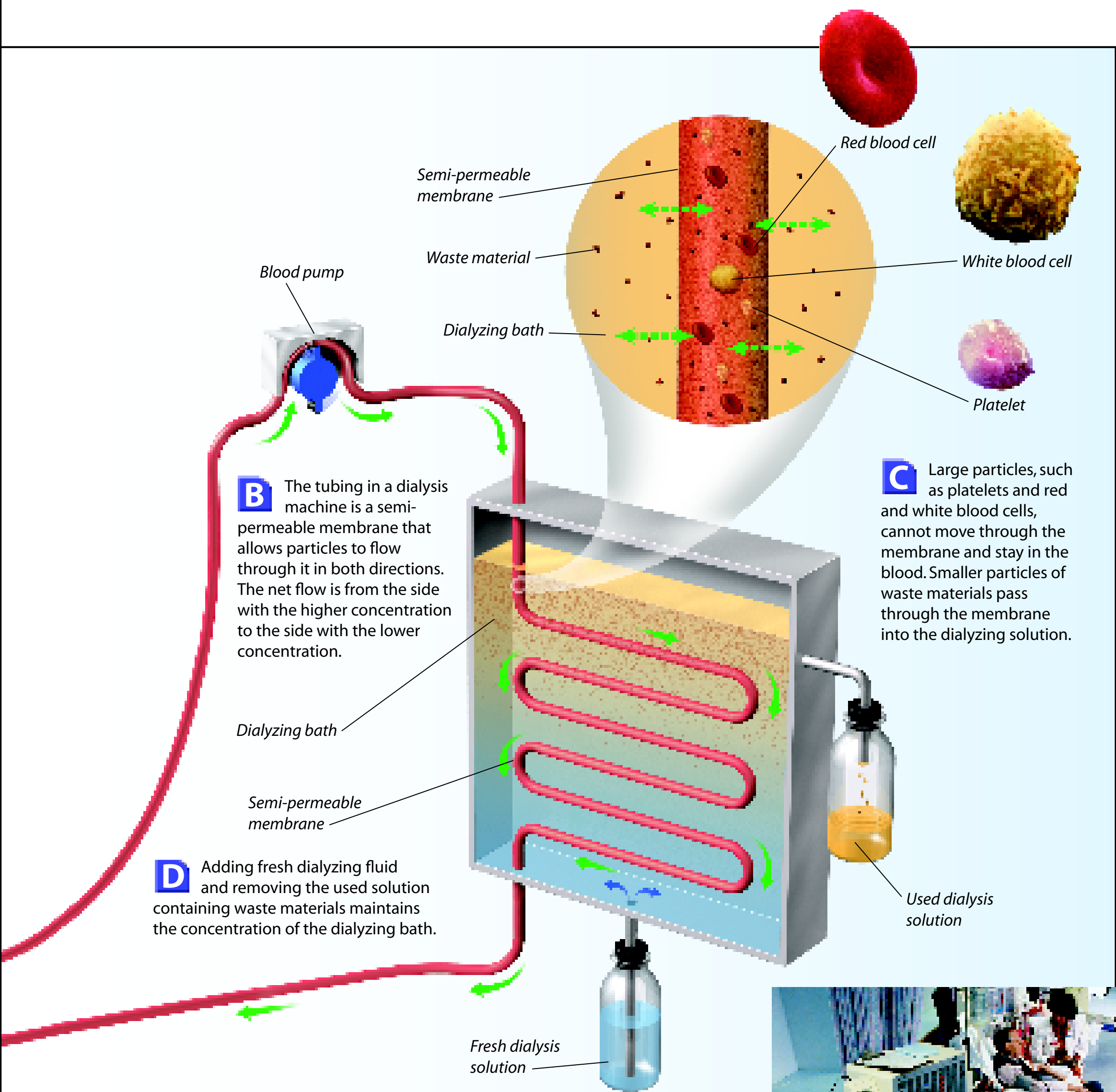
Nephrons Millions of tiny processing units called nephrons filter blood through a network of capillaries. The collecting duct carries toxic materials such as urea to the ureter for excretion.

Facts and Figures

The Makeup of Blood

Blood is a solution, a colloid, and a suspension all at the same time. Blood contains gases, ions, and nutrient molecules in solution. It also contains biologically important particles—protein molecules—in colloidal dispersion, and cells in suspension.

For your body to function properly, solutes in blood must be kept at the right concentrations. Many of your organs participate in this process. The liver and pancreas are responsible for regulating the concentration of sugar in your body, while kidneys keep the concentration of dissolved waste products in your blood at a minimum.



Hemodialysis takes several hours and must happen three times a week. It helps keep people with kidney failure alive and allows them to lead normal lives.

Blood Composition and Health

After students have had a chance to read the article, ask them to name some of the molecular and ionic solutes found in the bloodstream. Create a table on the chalkboard that lists the different components in the bloodstream, including water, proteins, Na^+, K^+, Mg^{2+}, Ca^{2+}, Cl^-, HCO_3^-, SO_4^{2-}, HPO_4^{2-}, O_2, CO_2, red and white blood cells, and platelets. Create additional columns with the headings *concentration, possible causes of elevated levels,* and *possible causes of depressed levels.* Explain that changes in the composition of blood, for example in the concentration of one or more of the ions, can be an indication of a disease or disorder. Doctors frequently use blood tests to check on patients' health. Have students do research to find the concentrations of each of the components in "normal" blood and to find out what types of diseases are linked to changes in the concentrations of certain ions. For example, elevated levels of Na^+ are associated with overactive adrenal glands. Ask students which components of blood are suspended and which are dissolved.

Answers to...

Comparing and Contrasting

Both use a semipermeable membrane to filter waste products from the blood. The process must occur at regular intervals—every 45 minutes in the kidneys and three times a week with hemodialysis. In hemodialysis, the cleansing of the blood takes place outside the body