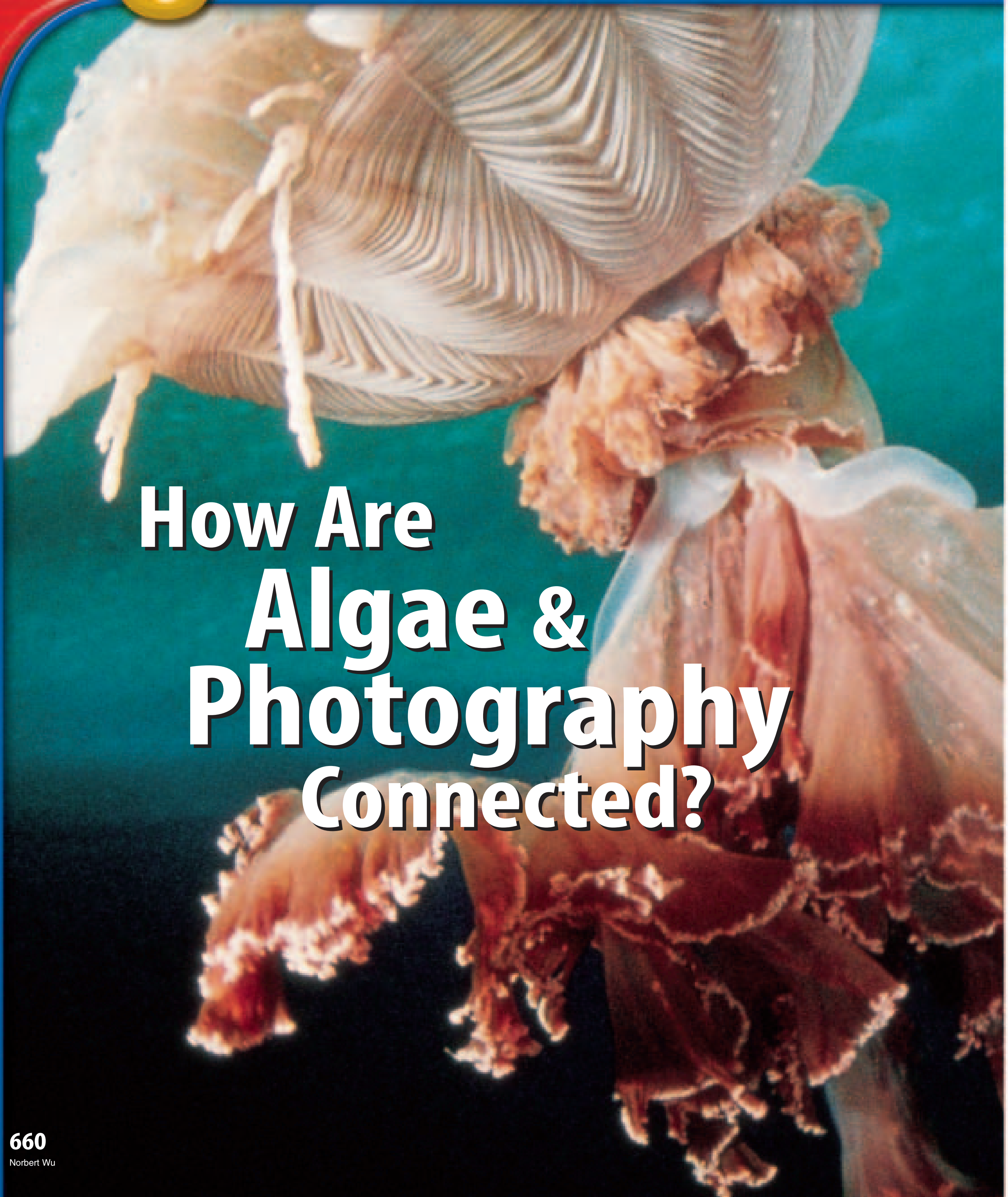


How Are Algae & Photography Connected?

Norbert Wu

NATIONAL GEOGRAPHIC

In the mid-1800s, scientists experimented with light-sensitive chemicals. They found that when paper was treated with such chemicals and then exposed to light, the resulting reaction changed the paper's color. If an object blocked some of the light, a silhouette of the object was created. One set of chemicals produced prints—called cyanotypes—of white images on a blue background. A botanist named Anna Atkins saw the potential of this process. Until that time, the only way to create pictures of plants had been to draw them. Atkins used cyanotypes to create impressions of the plants. In 1843, she published a book of cyanotype images of algae, including the two seen at lower right. It was the first book ever to be illustrated by photography. Since Atkins' time, photography has gone through many changes. But it is still a powerful tool for making images of the natural world—which includes this giant jellyfish, whose image is being captured by an underwater photographer.

unit projects

Visit **gpscience.com/unit_project** to find project ideas and resources.
Projects include:

- **Career** Explore the field of pharmaceutical research. Develop a list of questions, interview a professional, and compile class data.
- **Technology** Discover what elements are used to make salts, how they are made, where they can be found, and where they are used. Create a formula for personal bath salts or salt scrubs.
- **Model** Design a creative review game—board game, card game, or quiz game—to offer practice with chemical elements and their properties.

WebQuest *Chemistry of Fireworks* explores the chemical compounds of fireworks, what chemicals are used, and how firework displays are created.

(bkgd.)Norbert Wu, (inset)Spencer Collection, New York Public Library, Astor, Lenox & Tilden Foundation chapter 22

Solutions

BIG Idea A solution is a homogeneous mixture of a solvent and a solute.

22.1 How Solutions Form

MAIN Idea A solution forms when particles of solute become evenly mixed among particles of solute.

22.2 Solubility and Concentration

MAIN Idea Solubility is the maximum amount of solute that can dissolve and concentration is the amount of solute actually dissolved in a given amount of solute.

22.3 Particles in Solution

MAIN Idea Dissolved particles can both lower the freezing point and raise the boiling point of a solution.

22.4 Dissolving Without Water

MAIN Idea Nonpolar solvents can dissolve many nonpolar solutes.

Mixed-Up Chemistry

Seawater, lemonade, and suntan lotion are liquids. They have something else in common, too—they are all solutions. In this chapter, you will learn about solutions.

Science Journal

Are all liquids necessarily solutions, and are all solutions liquids? Check your answer later and revise it if you've learned differently.

Start-Up Activities

Launch LAB

Solution Identification by Solvent Subtraction

What do you like to drink when you're thirsty? Do you prefer water from the faucet, bottled water, or a sports drink that contains substances added to replace those lost during sweating? What do these thirst quenchers contain? Try the following lab to find out.

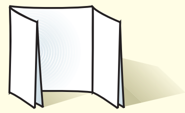
1. Obtain three solution samples from your teacher and place equal amounts of each in separate, marked, 100-mL beakers.
2. Carefully, boil each solution on a hot plate. As soon as the liquid is gone, remove each beaker to a heat-proof surface using a thermal mitt. Let cool.
3. Examine the inside of your cooled beakers. What do you see? Guess the identity of each solution.
4. **Think Critically** Describe in your Science Journal what remained in each of the three containers and explain how solutions may look alike but contain different substances.

FOLDABLES™ Study Organizer

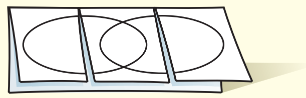
Solvent-Solute Comparison Make the following Foldable to compare and contrast the characteristics of solvents and solutes.

STEP 1 **Fold** one sheet of paper lengthwise.

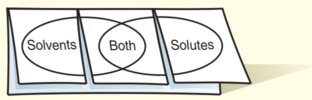
STEP 2 **Fold** into thirds.



STEP 3 **Unfold and draw** overlapping ovals. **Cut** the top sheet along the folds.



STEP 4 **Label** the ovals as shown.



Construct a Venn Diagram As you read the chapter, list characteristics that are unique to solvents under the left tab, those unique to solutes under the right tab, and characteristics common to both under the middle tab.

Science Online

Preview this chapter's content and activities at gpscience.com

Stephen Frink/Index Stock Imagery

section 1

How Solutions Form

Reading Guide

What You'll Learn

- **Determine** how things dissolve.
- **Examine** the factors that affect the rates at which solids and gases dissolve in liquids.

Why It's Important

Many chemical reactions take place in solution—the food you eat is digested, or chemically changed, by the solution that is in your stomach.

Review Vocabulary

alloy: a mixture of elements that has metallic properties

New Vocabulary

- solution
- solute
- solvent
- polar

What is a solution?

Hummingbirds are fascinating creatures. They can hover for long periods while they sip nectar from flowers through their long beaks. To attract hummingbirds, many people use feeder bottles containing a red liquid, as shown in **Figure 1.** The liquid is a solution of sugar and red food coloring in water.

Suppose you are making some hummingbird food. When you add sugar to water and stir, the sugar crystals disappear. When you add a few drops of red food coloring and stir, the color spreads evenly throughout the sugar water. Why does this happen?

Hummingbird food is one of many solutions. A **solution** is a mixture that has the same composition, color, density, and even taste throughout. The reason you no longer see the sugar crystals and the reason the red dye spreads out evenly is that they have formed a completely homogeneous mixture. The sugar crystals broke up into sugar molecules, the red dye into its molecules, and both mixed evenly among the water molecules.

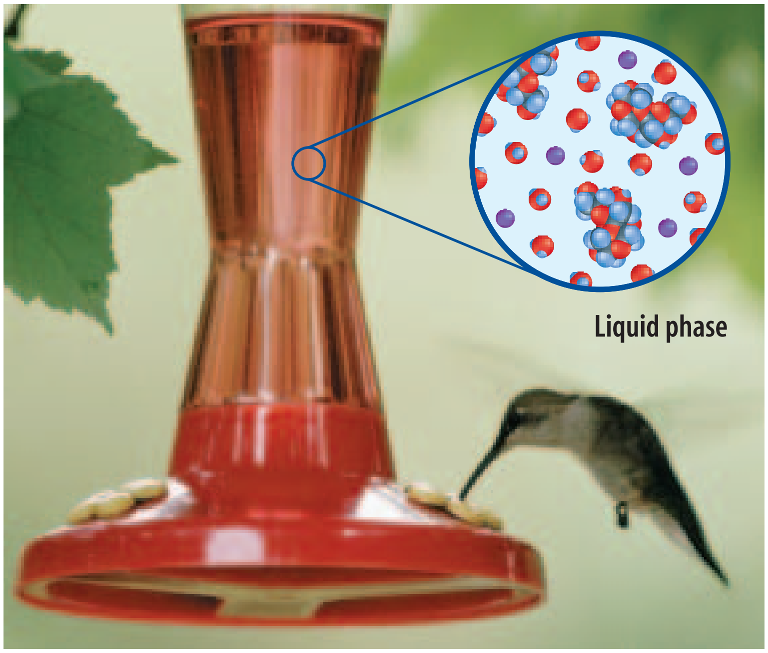


Figure 1 Liquid solutions, like this hummingbird food, which has sugar and food coloring, may contain gases, other liquids, or solids.

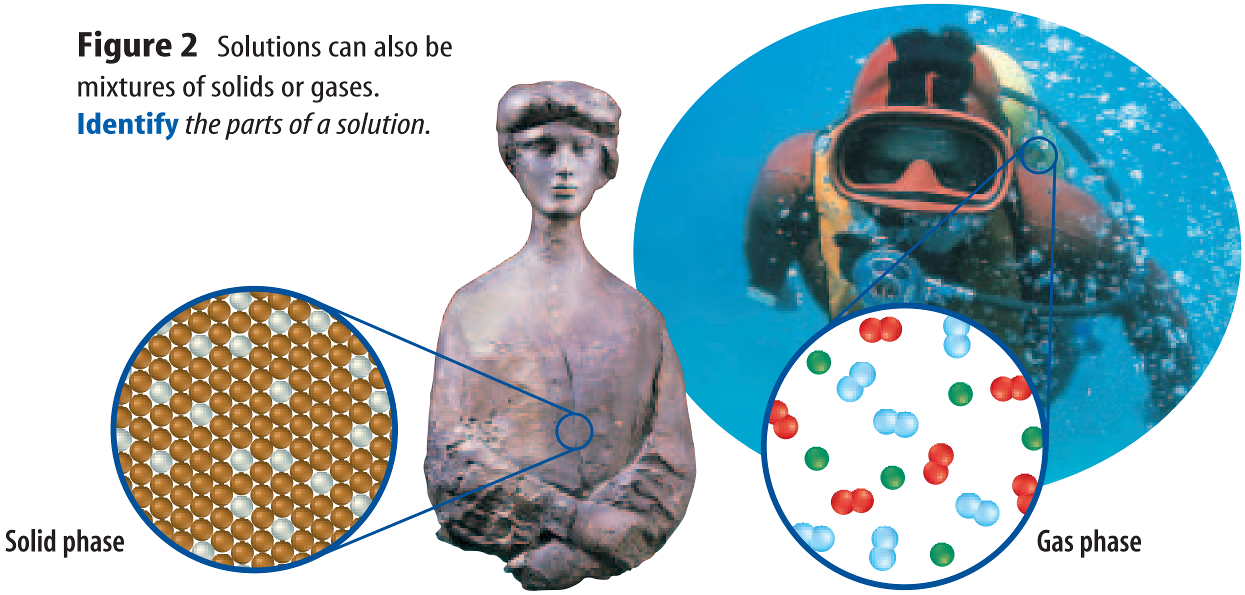
Solutes and Solvents

To describe a solution, you may say that one substance is dissolved in another. The substance being dissolved is the **solute,** and the substance doing the dissolving is the **solvent.** When a solid dissolves in a liquid, the solid is the solute and the liquid is the solvent. Thus, in salt water, salt is the solute and water is the solvent. In carbonated soft drinks, carbon dioxide gas is one of the solutes and water is the solvent. When a liquid dissolves in another liquid, the substance present in the larger amount is usually called the solvent.

Reading Check *How do you know which substance is the solute in a solution?*

Nonliquid Solutions Solutions can also be gaseous or even solid. Examples of all three solution phases are shown in **Figure 1** and **Figure 2.** Did you know that the air you breathe is a solution? In fact, all mixtures of gases are solutions. Air is a solution of 78 percent nitrogen, 21 percent oxygen, and small amounts of other gases such as argon, carbon dioxide and hydrogen. The sterling silver and brass used in musical instruments is an example of a solid solution. The sterling silver contains 92.5 percent silver and 7.5 percent copper. The brass is a solution of copper and zinc metals. Solid solutions are known as alloys. They are made by melting the metal solute and solvent together. Most coins, as shown in **Figure 3,** are alloys.

Figure 2 Solutions can also be mixtures of solids or gases.
Identify *the parts of a solution.*



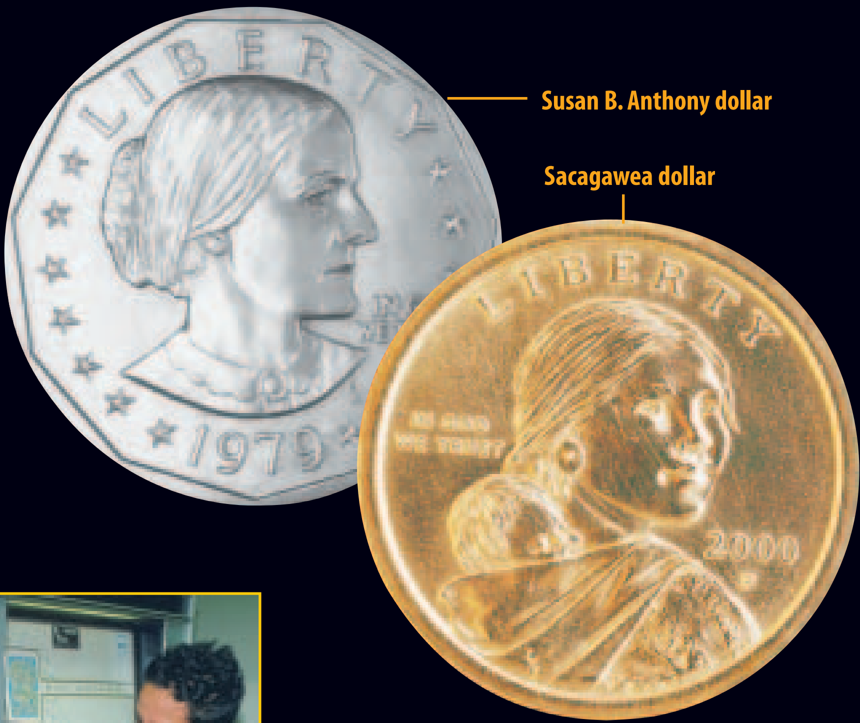
Bronze is a solid solution of copper and tin.

A diver breathes a gas solution containing compressed air.

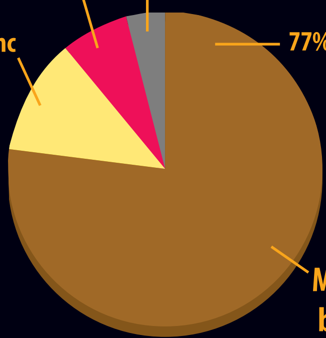
NATIONAL GEOGRAPHIC VISUALIZING METAL ALLOYS

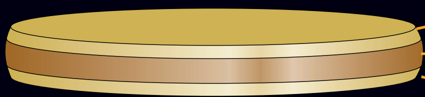
Figure 3

Have you ever accidentally put a non-United States coin into a vending machine? Of course, the vending machine didn't accept it. If a vending machine is that selective, how can it be fooled by two coins that look and feel very different? This is exactly the case with the silver Susan B. Anthony dollar and the new golden Sacagawea dollar. Vending machines can't tell them apart.



▶ Vending machines recognize coins by size, weight, and electrical conductivity. The size and weight of the Susan B. Anthony coin were easy to copy. Copying the coin's electrical conductivity was more difficult.





▲ The dollar's copper core is half the coin's thickness. It is sandwiched between two layers of manganese brass alloy.

▲ Over 30,000 samples of coin coatings were tested to find an alloy and thickness that would copy the conductivity of the Susan B. Anthony dollar. The final composition of the alloy is shown in the graph above. The key ingredient? Manganese.

(t)Bettmann/CORBIS, (c)Brian Gordon Green, (b)Michael Newman/PhotoEdit, Inc./PictureQuest

How Substances Dissolve

Fruit drinks and sports drinks are examples of solutions made by dissolving solids in liquids. Like hummingbird food, both contain sugar as well as other substances that add color and flavor. How do solids such as sugar dissolve in water?

The dissolving of a solid in a liquid occurs at the surface of the solid. To understand how water solutions form, keep in mind two things you have learned about water. Like the particles of any substance, water molecules are constantly moving. Also, water molecules are **polar**, which means they have a positive area and a negative area. Molecules of sugar are also polar.

How It Happens **Figure 4** shows molecules of sugar dissolving in water. First, water molecules cluster around sugar molecules with their negative ends attracted to the positive ends of the sugar. Then, the water molecules pull the sugar molecules into solution. Finally, the water molecules and the sugar molecules mix evenly, forming a solution.

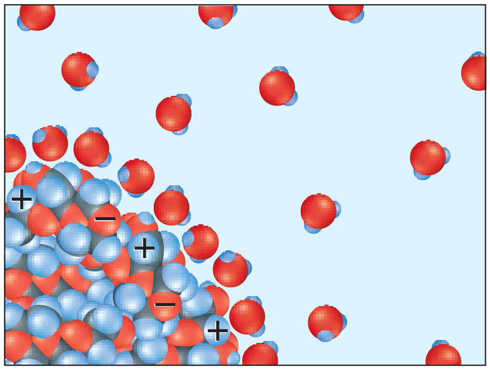
Reading Check *How do water molecules help sugar molecules dissolve?*

The process described in **Figure 4** repeats as layer after layer of sugar molecules moves away from the crystal, until all the molecules are evenly spread out. The same three steps occur for any solid solute dissolving in a liquid solvent.

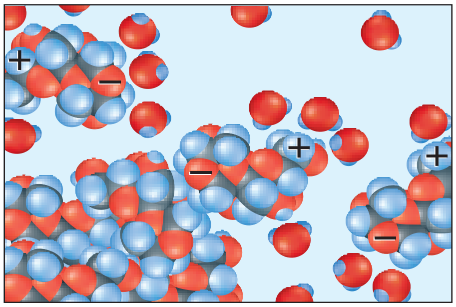
Dissolving Liquids and Gases A similar but more complex process takes place when a gas dissolves in a liquid. Particles of liquids and gases move much more freely than do particles of solids. When gases dissolve in gases or when liquids dissolve in liquids, this movement spreads solutes evenly throughout the solvent, resulting in a homogenous solution.

Dissolving Solids in Solids How can you mix solids to make alloys? Although solid particles do move a little, this movement is not enough to spread them evenly throughout the mixture. The solid metals are first melted and then mixed together. In this liquid state, the metal atoms can spread out evenly and will remain mixed when cooled.

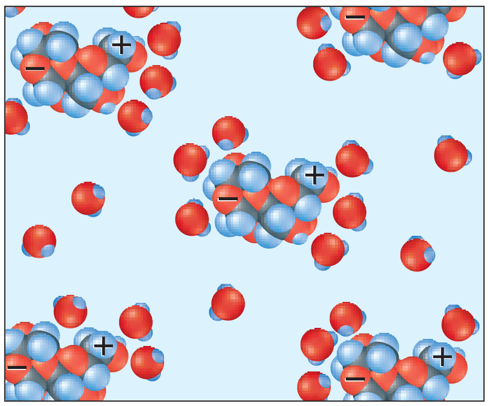
Figure 4 Dissolving sugar in water can be thought of as a three-step process.



Step 1 Moving water molecules cluster around the sugar molecules as their negative ends are attracted to the positive ends of the sugar molecules.



Step 2 Water molecules pull the sugar molecules into solution.



Step 3 Water molecules and sugar molecules spread out to form a homogeneous mixture.

Mini LAB

Observing the Effect of Surface Area

Procedure

1. Grind up two **sugar cubes.**
2. Place the ground sugar particles into a **medium-sized glass** and place two **unground sugar cubes** into a similar glass.
3. Add an equal amount of **distilled water** at room temperature to each glass.

Analysis

1. Compare the times required to dissolve each.
2. What do you conclude about the dissolving rate and surface area?

Try at Home

Figure 5 Crystal size affects solubility. Large crystals dissolve in water slowly because the amount of surface area is limited. Increasing the amount of surface area by creating smaller particles increases the rate of dissolving.

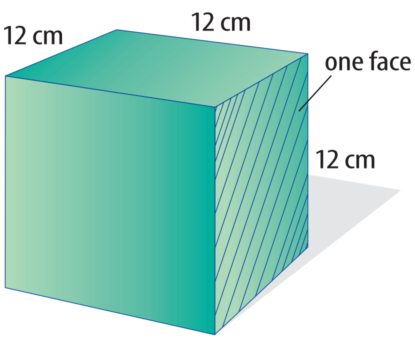
Rate of Dissolving

If two substances will form a solution, they will do so at a particular rate. Sometimes the rate at which a solute dissolves into a solvent is fast and other times slow. There are several things you can do to speed up the rate of dissolving—stirring, reducing crystal size, and increasing temperature are three of the most effective techniques.

Stirring How can you speed up the dissolving process? Think about how you make a drink from a powdered mix. After you add the mix to water, you stir it. Stirring a solution speeds up dissolving because it brings more fresh solvent into contact with more solute. The fresh solvent attracts the particles of solute, causing the solid solute to dissolve faster.

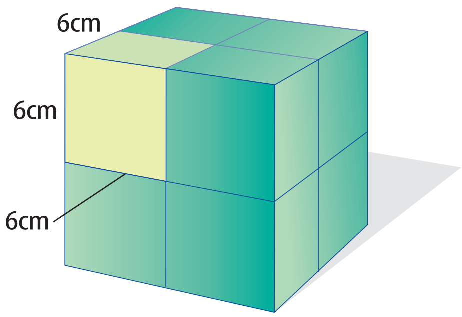
Crystal Size Another way to speed the dissolving of a solid in a liquid is to grind large crystals into smaller ones. Suppose you want to use a 5-g crystal of rock candy to sweeten your water. If you put the whole crystal into a glass of water, it might take several minutes to dissolve, even with stirring. However, if you first grind the crystal of rock candy into a powder, it will dissolve in the same amount of water in a few seconds.

Why does breaking up a solid cause it to dissolve faster? Breaking the solid into smaller pieces greatly increases its surface area, as you can see in **Figure 5.** Because dissolving takes place at the surface of the solid, increasing the surface area allows more solvent to come into contact with more solid solute. Therefore, the speed of the dissolving process increases.



Surface area = 864 cm^2

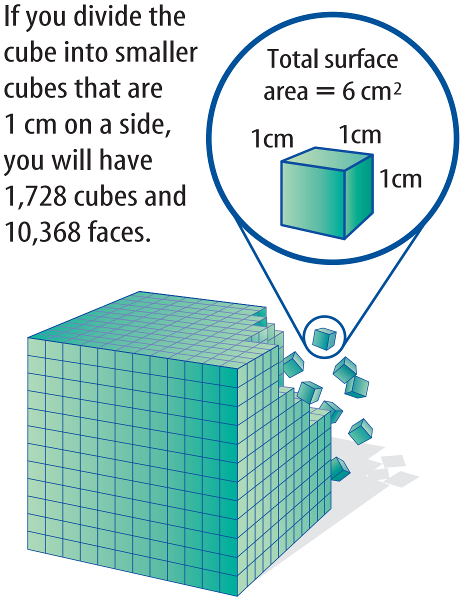
A face of a cube is the outer surface that has four edges.



Surface area = 1,728 cm^2

Pull apart the cube into smaller cubes of equal size. You now have eight cubes and forty-eight faces.

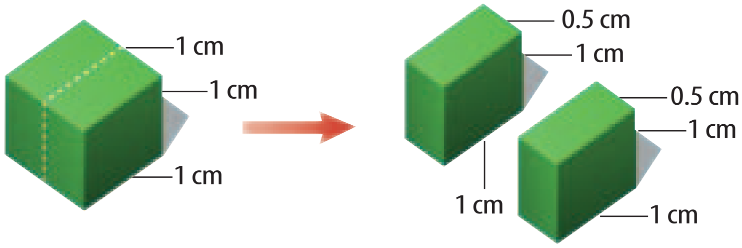
If you divide the cube into smaller cubes that are 1 cm on a side, you will have 1,728 cubes and 10,368 faces.



Surface area = 10,368 cm^2

Surface Area Equation

Calculating Surface Area The length, height, and width of a cube are each 1 cm. If the cube is cut in half to form two rectangles, what is the total surface area of the new pieces?



1. **This is what you know:** Each new piece has the dimensions:
l = 1 cm h = 1 cm w = 0.5 cm

2. **This is what you need to find:** Total surface area of the two new pieces

3. **Use this formula:** The rectangular solids each have six faces:
SA front and back = $2(h \times w)$
SA left and right = $2(h \times l)$
SA top and bottom = $2(w \times l)$
Total *SA* of one piece:
Total $SA = 2(h \times w) + 2(h \times l) + 2(w \times l)$

4. **Substitute:** $2(1\text{ cm} \times 0.5\text{ cm}) + 2(1\text{ cm} \times 1\text{ cm}) + 2(0.5\text{ cm} \times 1\text{ cm})$
$= 4\text{ cm}^2$

Because there are two identical pieces,
their total surface area: $2\,(4\text{ cm}^2) = 8\text{ cm}^2$

5. **Determine the units:** units of *SA* = (cm × cm) + (cm × cm) + (cm × cm)
units of *SA* = $\text{cm}^2 + \text{cm}^2 + \text{cm}^2$
units of *SA* = cm^2

Answer: The total surface area of the two rectangles is 8 cm^2

Science Online
For more practice problems, go to page 834, and visit gpscience.com/extra_problems.

Practice Problems

1. A cube of salt with a length, height, and width of 5 cm is attached along a face to another cube of salt with the same dimensions. What is the combined surface area of the new rectangular solid?

2. **Challenge** How much surface area was lost by combining cubes?

Temperature In addition to stirring and decreasing particle size, a third way to increase the rate at which most solids dissolve is to increase the temperature of the solvent. Think about making hot chocolate from a mix. You can make the sugar in the chocolate mix dissolve faster by putting it in hot water instead of cold water. Increasing the temperature of a solvent speeds up the movement of its particles. This increase causes more solvent particles to bump into the solute. As a result, solute particles break loose and dissolve faster.

Controlling the Process Think about how the three factors you just learned affect the rate of dissolving. Can these factors combine to further increase the rate or perhaps control the rate of dissolving? Each technique, stirring, crushing, and heating, is known to speed up the rate of dissolving by itself. However, when two or more techniques are combined, the rate of dissolving is even faster. Consider a sugar cube placed in cold water. You know that the sugar cube will eventually dissolve. You can predict that heating the water will increase the rate by some amount. You can also predict that heat and stirring will increase the rate further. Finally, you can predict that crushing the cube combined with heating and stirring will result in the fastest rate of dissolving. Knowing how much each technique affects the rate will allow you to control the rate of dissolving more precisely.

section 1 review

Summary

What is a solution?

- A solution is a uniform mixture.
- Solutions have the same composition, color, density, and taste throughout.

Solutes and Solvents

- In a solution, the solute is the substance that is being dissolved; the solvent is the substance that is doing the dissolving.

How Substances Dissolve

- The process of dissolving happens at the surface and is aided by polarity and molecular movement.

Rate of Dissolving

- Stirring, surface area, and temperature affect the rate of dissolving.

Self Check

1. **List** possible ways that phases of matter could combine to form a solution.
2. **Describe** how temperature affects the rate of dissolving.
3. **Describe** how the metal atoms in an alloy are mixed.
4. **Think Critically** Amalgrams, which are sometimes used in tooth fillings, are alloys of mercury with other metals. Is an amalgam a solution? Explain.

Applying Math

5. **Find Surface Area** Calculate the surface area of a rectangular solid with dimensions $l = 2$ cm, $w = 1$ cm, and $h = 0.5$ cm.
6. **Calculate Percent Increase** If the length of the rectangle in question 5 is increased by 10%, by how much will the surface area increase?

Science Online gpscience.com/self_check_quiz

Section 2 Solubility and Concentration

Reading Guide

What You'll Learn

- **Define** the concept of solubility.
- **Identify** how to express the concentration of solutions.
- **List** and define three types of solutions.
- **Describe** the effects of pressure and temperature on the solubility of gases.

Why It's Important

Solutions such as medicine and lemonade work and taste a particular way because of the specific solution concentrations

Review Vocabulary

concentration: describes how much solute is present in a solution compared to the amount of solvent

New Vocabulary

- solubility
- saturated solution
- unsaturated solution
- supersaturated solution

How much can dissolve?

You can stir several teaspoons of sugar into lemonade, and the sugar will dissolve. However, if you continue adding sugar, eventually the point is reached when no more sugar dissolves and the excess granules sink to the bottom of the glass. This indicates how soluble sugar is in water. **Solubility** (sol yuh BIH luh tee) is the maximum amount of a solute that can be dissolved in a given amount of solvent at a given temperature.

Reading Check *What is solubility?*

Comparing Solubilities The amount of a substance that can dissolve in a solvent depends on the nature of these substances. **Figure 6** shows two beakers with the same volume of water and two different solutes. In one beaker, 1 g of solute A dissolves completely, but additional solute does not dissolve and falls to the bottom of the beaker. On the other hand, 1 g of solute B dissolves completely, and two more grams also dissolve before solute begins to fall to the bottom. If the temperature of the water is the same in both beakers, you can conclude that substance B is more soluble than substance A. **Table 1** shows how the solubility of several substances varies at 20°C. For solutes that are gases, the pressure also must be given.

Figure 6 Substance B is more soluble in water than substance A at the same temperature.

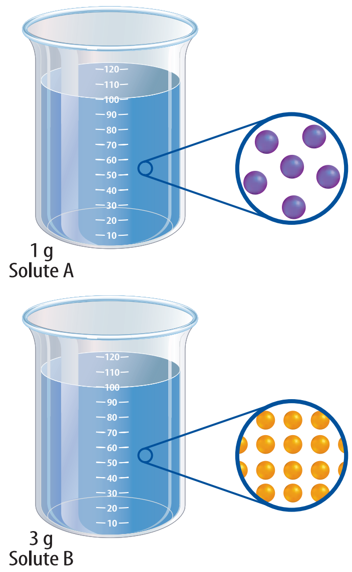


Table 1 Solubility of Substances in Water at 20°C

Substance	Solubility in g/100 g of Water
Solid Substances	
Salt (sodium chloride)	35.9
Baking soda (sodium bicarbonate)	9.6
Washing soda (sodium carbonate)	21.4
Lye (sodium hydroxide)	109.0
Sugar (sucrose)	203.9
Gaseous Substances*	
Hydrogen	0.00017
Oxygen	0.005
Carbon dioxide	0.16

*at normal atmospheric pressure

Concentration

Suppose you add one teaspoon of lemon juice to a glass of water to make lemonade. Your friend adds four teaspoons of lemon juice to another glass of water the same size. You could say that your glass of lemonade is dilute and your friend's lemonade is concentrated, because your friend's drink now has more lemon flavor than yours. A concentrated solution is one in which a large amount of solute is dissolved in the solvent. A dilute solution is one that has a small amount of solute in the solvent.

Precise Concentrations How much real fruit juice is there in one of those boxed fruit drinks? You can read the label to find out. *Concentrated* and *dilute* are not precise terms. However, concentrations of solutions can be described precisely. One way is to state the percentage by volume of the solute. The percentage by volume of the juice in the drink shown in **Figure 7** is 10 percent. Adding 10 mL of juice to 90 mL of water makes 100 mL of this drink. Commonly, fruit-flavored drinks can contain from ten percent to 100 percent fruit juice. Generally, if two or more liquids are being mixed, the concentration is given in percentage by volume. To be certain of the concentration of your beverage, chose a product that is 100% juice.

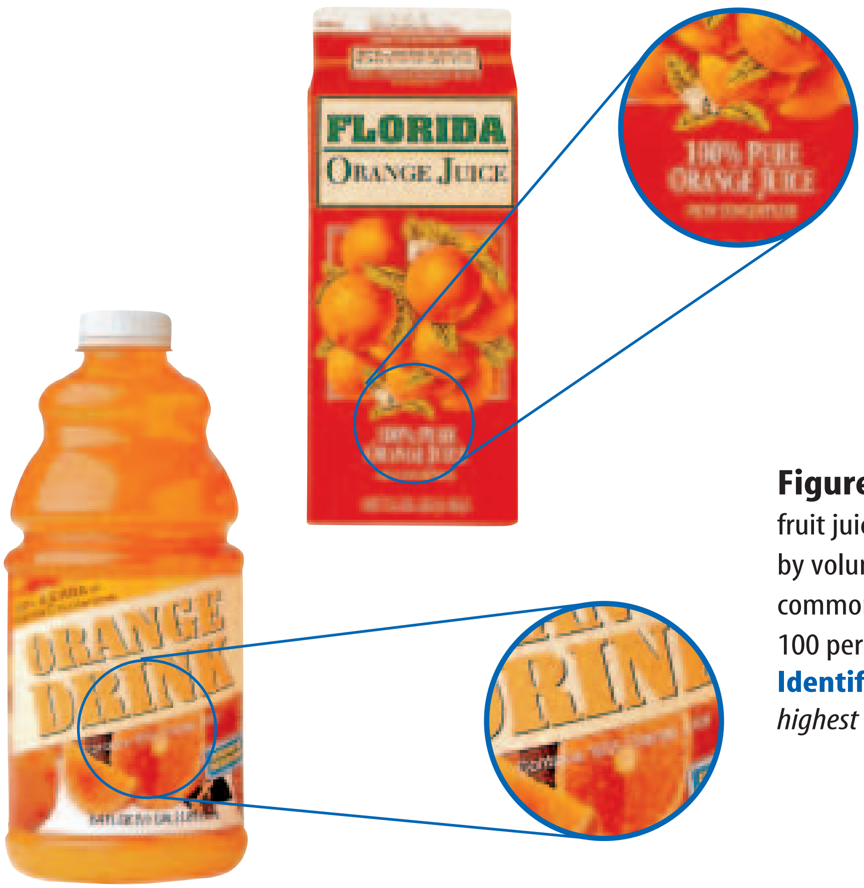


Figure 7 The concentrations of fruit juices often are given in percent by volume like these. Concentrations commonly range from 10 percent to 100 percent juice.
Identify *the product that has the highest concentration.*

Mark Thayer Photography, Inc.

Types of Solutions

How much solute can dissolve in a given amount of solvent? That depends on a number of factors, including the solubility of the solute. Here you will examine the types of solutions based on the amount of a solute dissolved.

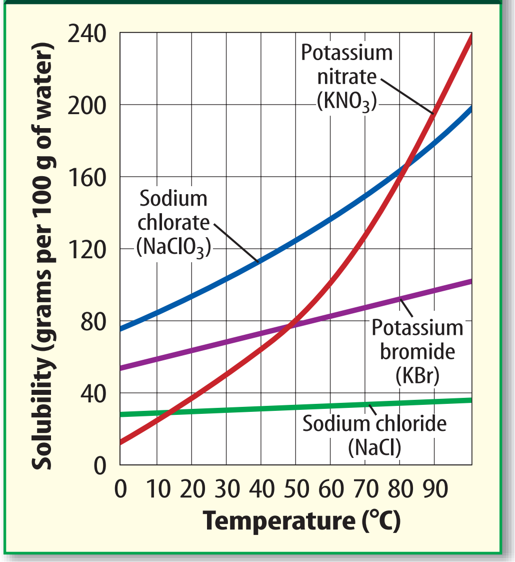
Saturated Solutions If you add 35 g of copper(II) sulfate, $CuSO_4$, to 100 g of water at 20°C, only 32 g will dissolve. You have a saturated solution because no more copper(II) sulfate can dissolve. A **saturated solution** is a solution that contains all the solute it can hold at a given temperature. However, if you heat the mixture to a higher temperature, more copper(II) sulfate can dissolve. Generally, as the temperature of a liquid solvent increases, the amount of solid solute that can dissolve in it also increases. **Table 2** shows the amounts of a few solutes that can dissolve in 100 g of water at different temperatures, forming saturated solutions. Some of these data also are shown on the accompanying graph.

Table 2 Solubility of Compounds in g/100 g of Water

Compound	0°C	20°C	100°C
Copper(II) sulfate	23.1	32.0	114
Potassium bromide	53.6	65.3	104
Potassium chloride	28.0	34.0	56.3
Potassium nitrate	13.9	31.6	245
Sodium chlorate	79.6	95.9	204
Sodium chloride	35.7	35.9	39.2
Sucrose (sugar)	179.2	203.9	487.2

Solubility Curves Each line on the graph from **Table 2** is called a solubility curve for a particular substance. You can use a solubility curve to figure out how much solute will dissolve at any temperature given on the graph. For example, about 78 g of KBr (potassium bromide) will form a saturated solution in 100 g of water at 47°C. How much NaCl (sodium chloride) will form a saturated solution with 100 g of water at the same temperature?

Temperature Effects on Solubility



Unsaturated Solutions An **unsaturated solution** is any solution that can dissolve more solute at a given temperature. Each time a saturated solution is heated to a higher temperature, it becomes unsaturated. The term *unsaturated* isn't precise. If you look at **Table 2,** you'll see that at 20°C, 35.9 g of NaCl (sodium chloride) forms a saturated solution in 100 g of water. However, an unsaturated solution of NaCl could be any amount less than 35.9 g in 100 g of water at 20°C.

Reading Check ***What happens to a saturated solution if it is heated?***

Supersaturated Solutions If you make a saturated solution of potassium nitrate at 100°C and then let it cool to 20°C, part of the solute comes out of solution. This is because, at the lower temperature, the solvent cannot hold as much solute. Most other saturated solutions behave in a similar way when cooled. However, if you cool a saturated solution of sodium acetate from 100°C to 20°C without disturbing it, no solute comes out. At this point, the solution is supersaturated. A **supersaturated solution** is one that contains more solute than a saturated solution at the same temperature. Supersaturated solutions are unstable. For example, if a seed crystal of sodium acetate is dropped into the supersaturated solution, excess sodium acetate crystallizes out, as shown in **Figure 8.**

Solution Energy As the supersaturated solution of sodium acetate crystallizes, the solution becomes hot. Energy is given off as new bonds form between the ions and the water molecules. Some portable heat packs use crystallization from supersaturated solutions to produce heat. After crystallization, the heat pack can be reused by heating it to again dissolve all the solute.

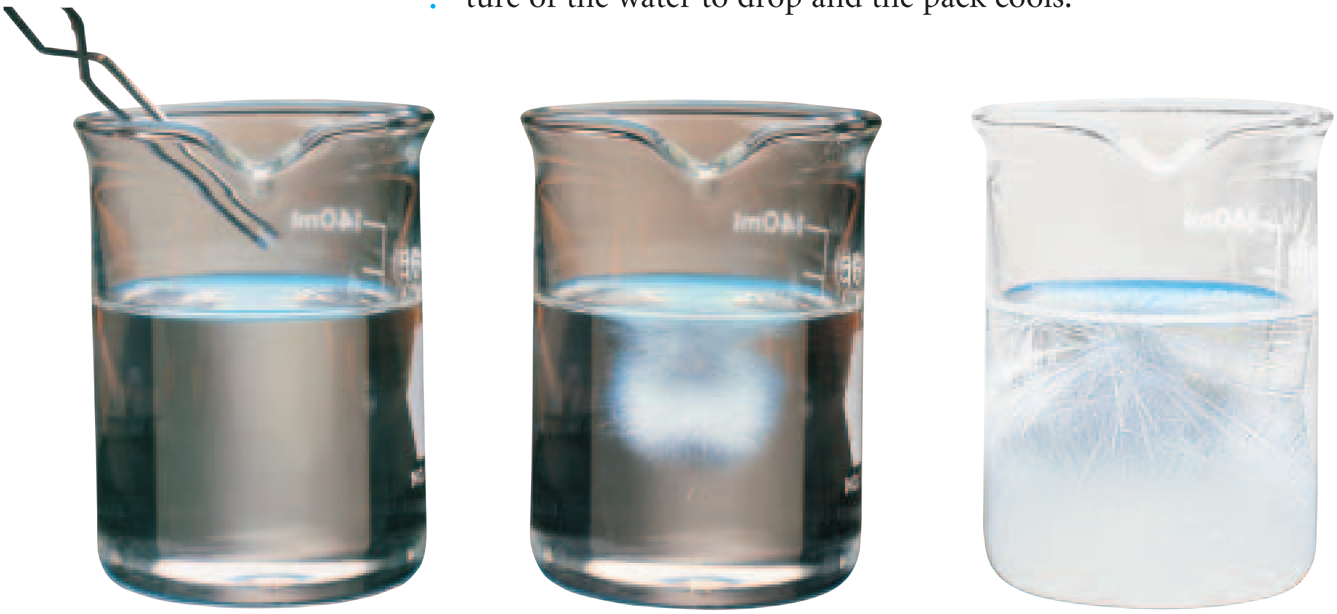
Another result of solution energy is to reduce the temperature of the solution. Some substances, such as ammonium nitrate, must draw energy from the surroundings to dissolve. This is what happens when a cold pack is activated to treat minor injuries or to reduce swelling. When the inner bags of ammonium nitrate and water are broken, the ammonium nitrate draws energy from the water, which causes the temperature of the water to drop and the pack cools.

Science Online

Topic: Crystallization
Visit gpscience.com for Web links to information about crystals and crystallization.

Activity Find instructions for a safe "do-it-yourself" home crystallization experiment. Grow the crystals as directed and share the results with the class.

Figure 8 A supersaturated solution is unstable.
Explain *why this is so.*



A seed crystal of sodium acetate is added to a supersaturated solution of sodium acetate.

Excess solute immediately crystallizes from solution.

The crystallization reaction continues to draw solute from the solution.

Solubility of Gases

When you shake an opened bottle of soda, it bubbles up and may squirt out. Shaking or pouring a solution of a gas in a liquid causes gas to come out of solution. Agitating the solution exposes more gas molecules to the surface, where they escape from the liquid.

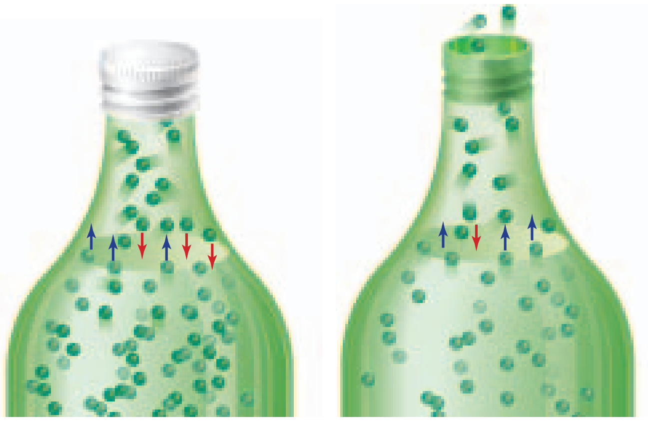


Figure 9 Solutions of gases behave differently from those of solids or liquids. This soda is bottled under pressure to keep carbon dioxide in solution. When the bottle is opened, pressure is released and carbon dioxide bubbles out of solution.

Pressure Effects What might you do if you want to dissolve more gas in a liquid? One thing you can do is increase the pressure of that gas over the liquid. Soft drinks are bottled under increased pressure. This increases the amount of carbon dioxide that dissolves in the liquid. When the pressure is released, the carbon dioxide bubbles out.

Temperature Effects Another way to increase the amount of gas that dissolves in a liquid is to cool the liquid. This is just the opposite of what you do to increase the speed at which most solids dissolve in a liquid. Imagine what happens to the carbon dioxide when a bottle of soft drink is opened. Even more carbon dioxide will bubble out of a soft drink as it gets warmer.

section 2 review

Summary

How much can dissolve?

- Solubility tells how much solute can dissolve in a solvent at a particular temperature.

Concentration

- A concentrated solution has a large amount of dissolved solute. A dilute solution has a small amount of dissolved solute.

Types of Solutions

- Saturated, unsaturated, and supersaturated solutions are defined by how much solute is dissolved.
- Solubility curves help predict how much solute can dissolve at a particular temperature.
- Some supersaturated solutions absorb or give off energy.

Gases in Solution

- Pressure and temperature affect gases in solution. High pressure and low temperature allow more gas to dissolve.

Self Check

1. **Explain** Do all solutes dissolve to the same extent in the same solvent? How do you know?
2. **Interpret** from **Table 2** the mass of sugar that would have to be dissolved in 100 g of water to form a saturated solution at 20°C.
3. **Determine** which is more soluble in water: 17 g of solute X dissolved in 100 mL of water at 23°C or 26 g of solute Z dissolved in 100 mL of water at 23°C.
4. **Identify** the type of solution you have if, at 35°C, solute continues to dissolve as you add more.
5. **Think Critically** Explain how keeping a carbonated beverage capped helps keep it from going "flat."

Applying Math

6. **Calculate Cost** By volume, orange drink is ten percent each of orange juice and corn syrup. A 1.5-L can of the drink costs $0.95. A 1.5-L can of orange juice is $1.49, and 1.5 L of corn syrup is $1.69. Per serving, does it cost less to make your own orange drink or buy it ?

section 3

Particles in Solution

Reading Guide

What You'll Learn

- **Examine** how some solutes break apart in water solutions to form positively and negatively charged particles.
- **Determine** how some solutions conduct electricity.
- **Describe** how antifreeze works.

Why It's Important

Many of the products we use every day rely on the effects of solutes in solution.The name and the formula convey information about the compound.

Review Vocabulary

conductivity: property of metals and alloys that allows them to be good conductors of heat and electricity

New Vocabulary

- ion
- electrolyte
- nonelectrolyte
- ionization
- dissociation

Particles with a Charge

Did you know that there are charged particles in your body that conduct electricity? In fact, you could not live without them. Some help nerve cells transmit messages. Each time you blink your eyes or wave your hand nerves control how muscles will respond. These charged particles, called **ions,** are in the fluids that are in and around all the cells in your body. The compounds that produce solutions of ions that conduct electricity in water are known as **electrolytes.** Some substances, like sodium chloride, are strong electrolytes and conduct a strong current. Strong electrolytes exist completely in the form of ions in solution. Other substances, like acetic acid in vinegar, remain mainly in the form of molecules when they dissolve in water. They produce few ions and conduct current only weakly. They are called weak electrolytes. Substances that form no ions in water and cannot conduct electricity are called **nonelectrolytes.** Among these are organic molecules like ethyl alcohol and sucrose.

Ionization Ionic solutions form in two ways. Electrolytes, such as hydrogen chloride, are molecules made up of neutral atoms. To form ions, the molecules must be broken apart in such a way that the atoms take on a charge. This process of forming ions is called **ionization.** The process is shown in **Figure 10,** using hydrogen chloride as a model.

Figure 10 Both hydrogen chloride and water are polar molecules. Water surrounds the hydrogen chloride molecules and pulls them apart, forming positive hydrogen ions and negative chloride ions. Hydrogen ions are often shown as H_3O^+ to emphasize the role water plays in ionization.

$HCl + H_2O \rightarrow H_3O^+ + Cl^-$

Dissociation The second way that ionic solutions form is by the separation of ionic compounds. The ions already exist in the ionic compound and are attracted into the solution by the surrounding polar water molecules. **Dissociation** is the process in which an ionic solid, such as sodium chloride, separates into its positive and negative ions. A model of a sodium chloride crystal is shown in **Figure 11.** In the crystal, each positive sodium ion is attracted to six negative chloride ions. Each of the negative chloride ions is attracted to six sodium ions, a pattern that exists throughout the crystal.

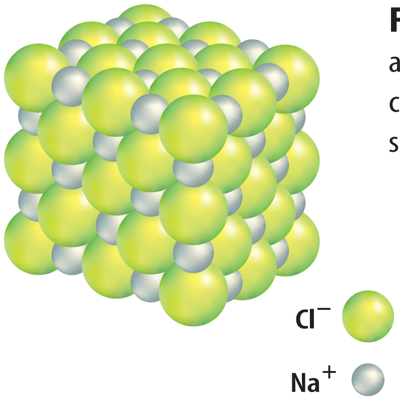


Figure 11 This is a model of a sodium chloride crystal. Each chloride ion is surrounded by six sodium ions and vice versa.

When placed in water, the crystal begins to break apart under the influence of water molecules. Remember that water is polar, which means that the positive areas of the water molecules are attracted to the negative chloride ions. Likewise the negative oxygen part of the water molecules is attracted to the sodium ions.

In **Figure 12,** water molecules are approaching the sodium and chloride ions in the crystal. The water molecules surround the sodium and chloride ions, having pulled them away from the crystal and into solution. The sodium and chloride ions have dissociated from one another. The solution now consists of sodium and chloride ions mixed with water. The ions move freely through the solution and are capable of conducting an electric current.

Reading Check ***What are the differences and similarities between dissociation and ionization?***

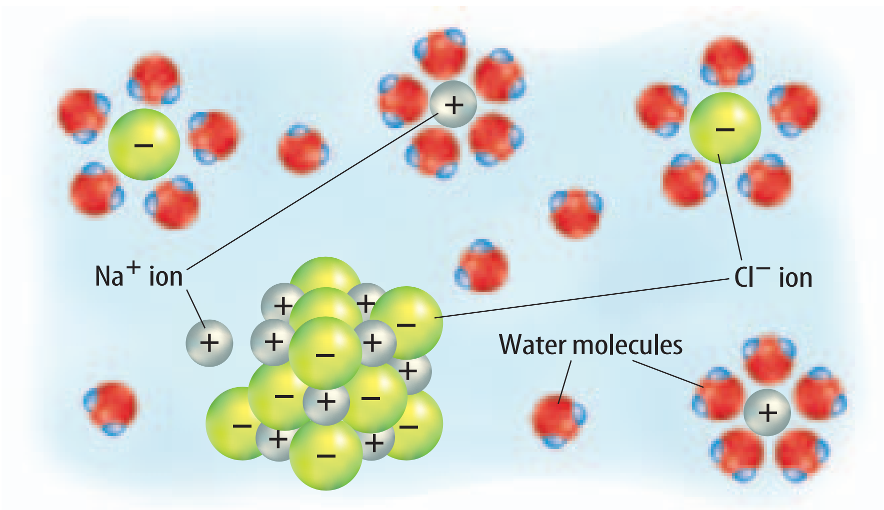


Figure 12 Sodium chloride dissociates as water molecules attract and pull the sodium and chloride ions from the crystal. Water molecules then surround and separate the Na^+ and Cl^- ions.
Predict *Will sodium chloride in solution conduct electricity?*

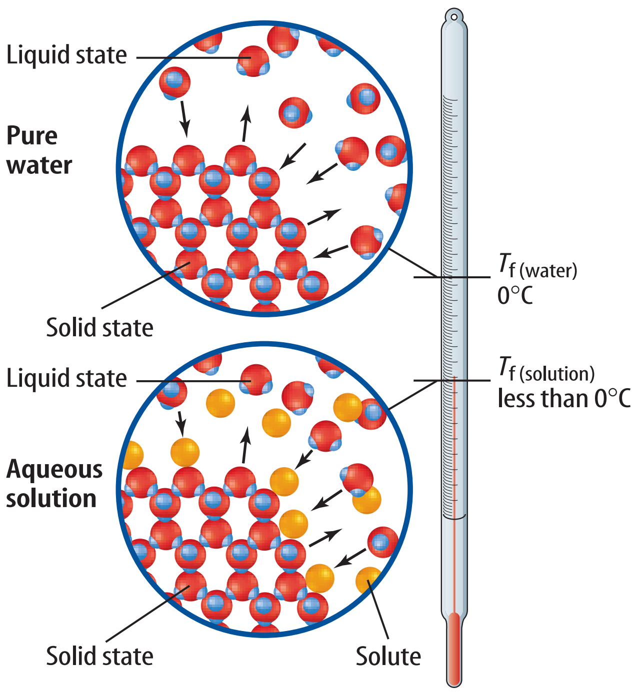
Effects of Solute Particles

All solute particles—polar and nonpolar, electrolyte and nonelectrolyte—affect the physical properties of the solvent, such as its freezing point and its boiling point. These effects can be useful. For example, adding antifreeze to water in a car radiator lowers the freezing point of the radiator fluid. Sugar and salt also would do the same thing, however, both would damage the cooling system. The effect that a solute has on the freezing point or boiling point of a solvent depends on the number of solute particles in solution, not on the chemical nature of the particles.

Lowering Freezing Point Adding a solute such as antifreeze to a solvent lowers the freezing point of the solvent. How much the freezing point goes down depends upon how many solute particles you add. How does this work?

As a substance freezes, its particles arrange themselves in an orderly pattern. The added solute particles interfere with the formation of this pattern, making it harder for the solvent to freeze as shown in **Figure 13.** To overcome this interference, a lower temperature is needed to freeze the solvent.

Figure 13 Solute molecules interfere with the freezing process by blocking molecules of solvent as they try to join the growing crystal lattice. For example, antifreeze molecules added to water block the formation of ice crystals.



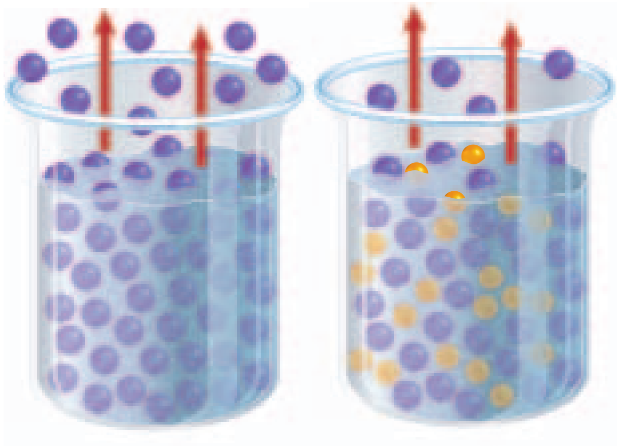
INTEGRATE Life Science

Animal Antifreeze Certain animals that live in extremely cold climates have their own kind of antifreeze. Caribou, for example, contain substances in the lower section of their legs that prevent freezing in subzero temperatures. The caribou can stand for long periods of time in snow and ice with no harm to their legs. Fish that live in polar waters also have a natural chemical antifreeze called glycoprotein in their bodies. Glycoprotein prevents ice crystals from forming in the moist tissues. Many insects also have a similar antifreeze chemical to protect them from freezing temperatures.

Raising Boiling Point Surprisingly, antifreeze also raises the boiling point of the water. How can it do this? The amount the boiling point is raised depends upon the number of solute molecules present. Solute particles interfere with the evaporation of solvent particles. Thus, more energy is needed for the solvent particles to escape from the liquid surface, and so the boiling point of the solution will be higher than the boiling point of solvent alone.

Car Radiators The beaker in **Figure 14** represents a car radiator when it contains water molecules only—no antifreeze. Some of those molecules on the surface will vaporize, and the number of molecules that do vaporize depends upon the temperature of the solvent. As temperature increases, water molecules move faster, and more molecules vaporize. Finally, when the pressure of the water vapor equals atmospheric pressure, the water boils. Have you ever seen a vehicle at the side of the road with vapors rising from the radiator?

The result of adding antifreeze is shown in **Figure 14.** Particles of solute are distributed evenly throughout the solution, including the surface area. Now fewer water molecules can reach the surface and evaporate, making the vapor pressure of the solution lower than that of the solvent. This means that it will take a higher temperature to make the car's radiator boil over.



Solvent particles vaporize freely from the surface.

Solute particles block part of the surface, making it more difficult for solvent to vaporize.

Figure 14 Solute particles raise the boiling point of a solution.
Describe *how antifreeze works in a car.*

section 3 review

Summary

Particles with a Charge

- Ions, charged particles, are formed from neutral compounds in such a way that the atoms take on a charge.
- Electrolytes can conduct electricity.
- Dissociation is the process of breaking an ionic compound into its positive and negative ions.
- Ions are found in the fluids that are in and around the cells in your body.

Effects of Solute Particles

- Solutes affect the physical properties of a solution by the number of solute particles, not by the chemical nature of the solute.
- Solute particles change the freezing and boiling points of solutions.
- Fish that live in polar waters have a natural chemical antifreeze called glycoprotein.
- When a substance freezes, its particles arrange themselves in an orderly pattern.

Self Check

1. **Determine** what has taken place, ionization or dissociation, if calcium phosphate ($Ca_3(PO_4)_2$) breaks into Ca^{2+} and PO_4^{3-}.
2. **Identify** what kinds of solute particles are present in water solutions of electrolytes and nonelectrolytes.
3. **Describe** how an ionic substance dissociates in water.
4. **Describe** how the concentration of a solution influences its boiling point.
5. **Think Critically** In cold weather, people often put salt on ice that forms on sidewalks and driveways. The salt helps melt the ice, forming a saltwater solution. Explain why this solution may not refreeze.

Applying Math

6. **Graph Data** Use the following data points (0,12), (10,8),(20,4), and (30,0), to graph the effect of a solute on the freezing point of a solvent. Label the *x*-axis *Grams solute* and the *y*-axis *Freezing point.*
7. **Calculate Slope** Find the slope of the line you graphed in question 6.

LAB

Boiling Points of Solutions

Adding small amounts of salt to water that is being boiled and adding antifreeze to a radiator have a common result—increasing the boiling point.

Real-World Question

How much can the boiling point of a solution be changed?

Goals

- **Determine** how adding salt affects the boiling point of water.

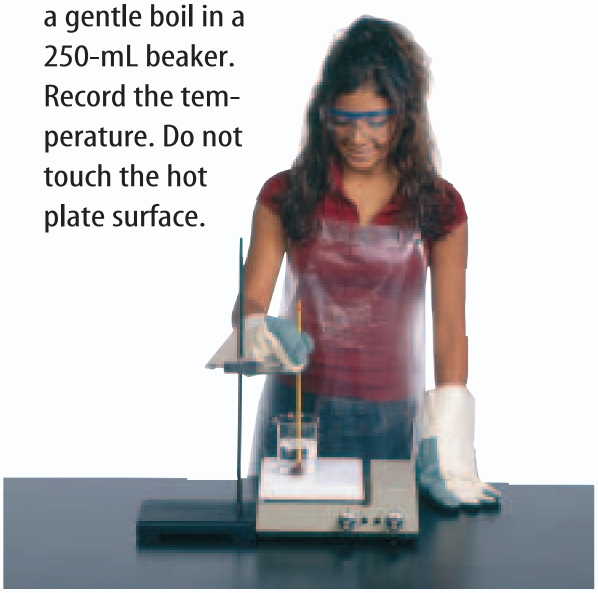
Possible Materials

distilled water (400 mL)
Celsius thermometer
table salt, NaCl (72 g)
ring stand
hot plate
250-mL beaker

Safety Precautions

Procedure

1. Copy the data table as shown in the next column. Bring 100 mL of distilled water to a gentle boil in a 250-mL beaker. Record the temperature. Do not touch the hot plate surface.



2. Dissolve 12 g of NaCl in 100 mL of distilled water. Bring this solution to a gentle boil and record its boiling point.
3. Repeat step 2, using 24 g of NaCl, then 36 g.
4. Make a graph of your results. Put boiling point on the *x*-axis and grams of NaCl on the *y*-axis.

Effects of Solute on Boiling Point

Grams of NaCl Solute	Boiling Point (°C)
0	
12	Do not write in this book.
24	
36	

Conclude and Apply

1. **Explain** the difference between the boiling points of pure water and a water solution.
2. **Predict** what would have been the effect of doubling the amount of water instead of the amount of NaCl in step 3.
3. **Predict** what would happen if you continued to add more salt. Would your graph continue in the same pattern or eventually level off? Explain your prediction.

Communicating Your Data

Compare your results with those of other groups and discuss any differences in the results obtained. **For more help, refer to the Science Skill Handbook.**

section 4

Dissolving Without Water

Reading Guide

What You'll Learn

- **Identify** several kinds of solutes that do not dissolve well in water.
- **Explain** how solvents work in terms of polarity.
- **Determine** how to choose the right solvent for the job.

Why It's Important

Many solutes do not dissolve in water, yet there are useful applications for solutions that make use of these solutes.

Review Vocabulary

hydrocarbon: Saturated or unsaturated compound that contains only carbon and hydrogen atoms.

New Vocabulary

- nonpolar

When Water Won't Work

Water often is referred to as the universal solvent because it can dissolve so many things. However, there are some things, such as oil, that it can't dissolve. Why?

As you learned in the first section, water has positive and negative areas that allow it to attract polar solutes. However, **nonpolar** materials have no separated positive and negative areas. Because of this, they are not attracted to polar materials, which means they are not attracted to water molecules. Nonpolar materials do not dissolve in water except to a small extent, if at all.

Nonpolar Solutes An example of a nonpolar substance that does not dissolve in water can be seen on many dinner tables. The vinegar-and-oil salad dressing shown in **Figure 15** has two distinct layers—the bottom layer is vinegar, which is a solution of acetic acid in water, and the top layer is salad oil.

Most salad oils contain large molecules made of carbon and hydrogen atoms, which are called hydrocarbons. In hydrocarbons, carbon and hydrogen atoms share electrons in a nearly equal manner. This equal distribution of electrons means that the molecule has no separate positive and negative areas. Therefore, the nonpolar oil molecule is not attracted to the polar water molecules in the vinegar solution. That's why you must shake this kind of dressing to mix it just before you pour it on your salad.

Figure 15 Oil and vinegar do not form a solution.
Infer *How do the particles in this substance disperse so it is tasteful to eat?*

Icon Images

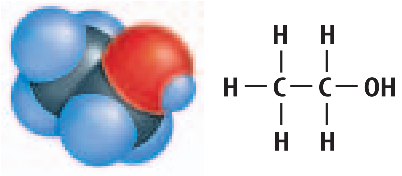


Figure 16 Ethanol, C_2H_5OH, has a polar –OH group at one end but the $-C_2H_5$ section is nonpolar. **Determine** *the molecular weight for ethanol.*

Versatile Alcohol Some substances form solutions with polar as well as nonpolar solutes because their molecules have a polar and a nonpolar end. Ethanol, shown in **Figure 16,** is such a molecule. The polar end dissolves polar substances, and the nonpolar end dissolves nonpolar substances. For example, ethanol dissolves iodine, which is nonpolar, as well as water, which is polar.

Reading Check *How can alcohol dissolve both polar and nonpolar substances?*

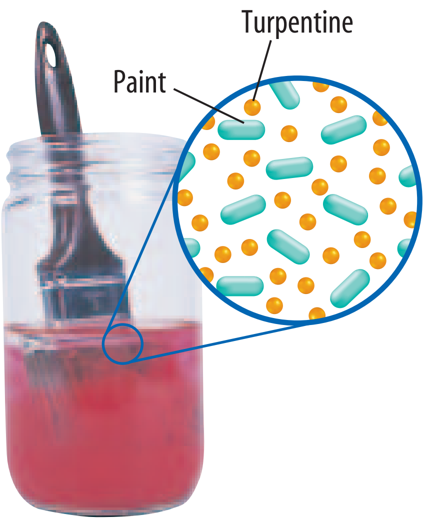
Useful Nonpolar Molecules

Some materials around your house may be useful as nonpolar solvents. For example, mineral oil may be used as a solvent to remove candle wax from glass or metal candleholders. Both the mineral oil and the candle wax are nonpolar materials. Mineral oil can also aid in removing bubble gum from some surfaces for the same reason. Oil-based paints contain pigments that are dissolved in oils. In order to thin or remove such paints, a nonpolar solvent must be used. The gasoline you use in your car and lawnmower is a solution of hydrocarbons, which are nonpolar substances.

Dry cleaners use nonpolar solvents when removing oily stains. The word *dry* refers to the fact that no water is used in the process. Molecules of a nonpolar solute can slip easily among molecules of a nonpolar solvent. That is why dry cleaning can remove stains of grease and oil that you cannot clean easily yourself. A general statement that describes which substance dissolves which is the phrase "like dissolves like."

Many nonpolar solvents are connected with specific jobs. People who paint pictures using oil-based paints probably use the solvent turpentine. It comes from the sap of a pine tree. **Figure 17** shows how well turpentine dissolves non-polar paint.

Figure 17 With no polarity to interfere, paint molecules slide smoothly among molecules of turpentine.



Drawbacks of Nonpolar Solvents Although nonpolar solvents have many uses, they have some drawbacks, too. First, many nonpolar solvents are flammable. Also, some are toxic, which means they are dangerous if they come into contact with the skin or if their vapors are inhaled. For these reasons, you must always be careful when handling these materials and never use them in a closed area. Good ventilation is critical, because nonpolar solvents tend to evaporate more readily than water, and even small amounts of a nonpolar liquid can produce high concentrations of harmful vapor in the air.

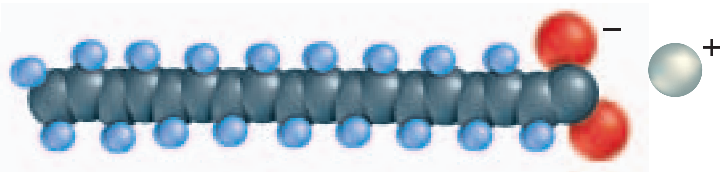


Figure 18 The long hydrocarbon tail of sodium stearate is nonpolar. The head is ionic.

How Soap Works The oils on human skin and hair keep them from drying out, but the oils can also attract and hold dirt. The oily dirt is a nonpolar mixture, so washing with water alone won't clean away the dirt. This is where soap comes in. Soaps, you might say, have a split personality. They are substances that have polar and nonpolar properties. Soaps are salts of fatty acids, which are long hydrocarbon molecules with a carboxylic acid group –COOH at one end. When a soap is made, the hydrogen atom of the acid group is removed, leaving a negative charge behind, and a positive ion of sodium or potassium is attached. This is shown in **Figure 18.**

Thus, soap has an ionic end that will dissolve in water and a long hydrocarbon portion that will dissolve in oily dirt. In this way, the dirt is removed from your skin, hair, or a fabric, suspended in the wash water, and washed away, as shown in **Figure 19.**

Reading Check *Why doesn't water alone clean oily dirt?*

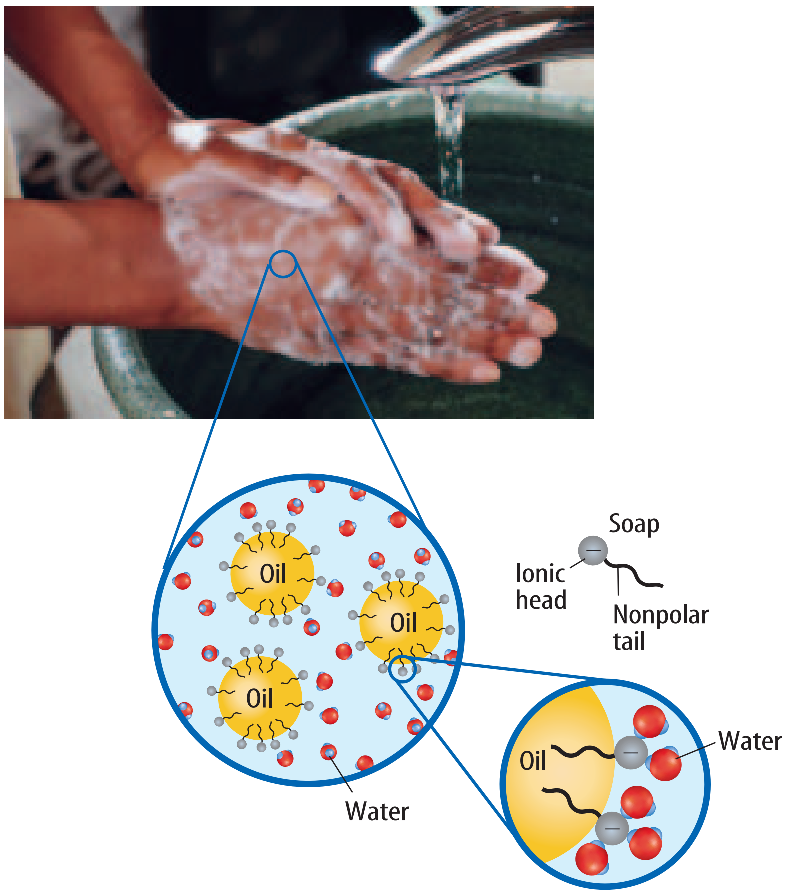


Figure 19 Soap cleans because its nonpolar hydrocarbon part dissolves in oily dirt and its ionic part interacts strongly with water. The oil and water mix and the dirt is washed away.

Mini LAB

Observing Clinging Molecules

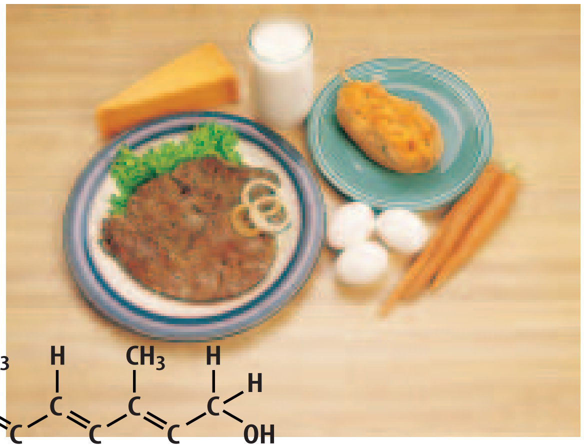
Procedure

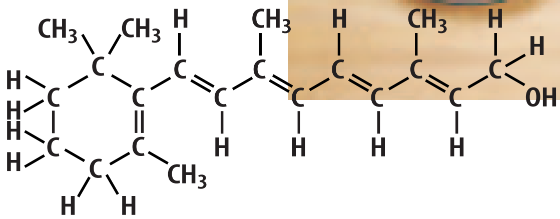
1. Lay **two clean pennies** side by side and heads up on a **paper towel.**
2. Slowly place drops of **water** from a **dropper** onto the head of one penny. Count each drop and continue until the accumulated water spills off the edge of the penny.
3. With adult supervision, repeat step 2 using **rubbing alcohol,** which is approximately 30 percent isopropyl alcohol, and the other penny.

Analysis

1. Which penny held the most drops before liquid spilled over the edge of the penny?
2. Isopropyl alcohol has the formula C_3H_7OH. How polar do you think it is?
3. How do the results of the experiment support the concept of polarity and molecules sticking to each other?

Figure 20 The structural formula of vitamin A shows a long hydrocarbon chain that makes it nonpolar. Foods such as liver, lettuce, cheese, eggs, carrots, sweet potatoes, and milk are good sources of this fat-soluble vitamin. Vitamins D, E, and K are also fat-soluble vitamins.





Science Online

Topic: Vitamins
Visit gpscience.com for Web links to information about vitamins.

Activity Copy the ingredients list from a container of multivitamins and use the links at gpscience.com to research those listed. Make a chart that categorizes each as either a water-soluble vitamin or a fat-soluble vitamin.

Polarity and Vitamins

Having the right kinds and amounts of vitamins is important for your health. Some of the vitamins you need, such as vitamin A, shown in **Figure 20,** are nonpolar and can dissolve in fat, which is another nonpolar substance. Because fat and fat-soluble vitamins do not wash away with the water that is present in the cells throughout your body, the vitamins can accumulate in your tissues. Some fat-soluble vitamins are toxic in high concentrations, so taking large doses or taking doses that are not recommended by your physician can be dangerous.

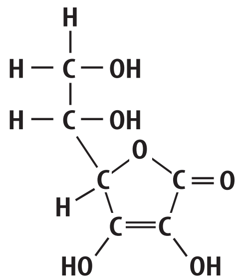


Figure 21 Although vitamin C has carbon-to-carbon bonds, it also has polar groups and is water soluble. Foods such as those shown here are good sources of vitamin C, which helps heal wounds and helps the body absorb iron.

Table 3 Sources of Vitamin C

Food	Amount	mg
Orange juice, fresh	1 cup	124
Green peppers, raw	1/2 cup	96
Broccoli, raw	1/2 cup	70
Cantaloupe	1/4 melon	70
Strawberries	1/2 cup	42

Other vitamins, such as vitamins B and C, are polar compounds. When you look at the structure of vitamin C, shown in **Figure 21,** you will see that it has several carbon-to-carbon bonds. This might make you think that it is nonpolar. But, if you look again, you will see that it also has several oxygen-to-hydrogen bonds that resemble those found in water. This makes vitamin C polar.

Polar vitamins dissolve readily in the water that is in your body. These vitamins do not accumulate in tissue because any excess vitamin is washed away with the water in the body. For this reason, you must replace water-soluble vitamins by eating enough of the foods that contain them or by taking vitamin supplements. **Table 3** lists some good sources of vitamin C. In general, the best way to stay healthy is to eat a variety of healthy foods. Such a diet will supply the vitamins you need with no risk of overdoses.

Reading Check *Why do you need to replace some of the vitamins used in your body?*

INTEGRATE Health

Vitamins in Excess
Drinking too much carrot juice, which is rich in beta carotene, a substance related to vitamin A, can cause the palms of your hands and soles of your feet to turn orange. Though this condition is not serious and the color fades in time, taking too much of some vitamins can be dangerous. Research what might result from taking too much vitamin B-6, vitamin D, and niacin.

section 4 review

Summary

When Water Won't Work

- Water cannot dissolve all substances.
- Nonpolar molecules are not attracted to polar molecules.

Useful Nonpolar Molecules

- Nonpolar solvents have many household and industrial uses.
- Nonpolar solvents may have drawbacks including flammability and toxicity.
- Some molecules have both polar and nonpolar properties. Solvents made from these kinds of substances can dissolve things that water alone cannot.

Polarity and Vitamins

- Nonpolar vitamins may dissolve in fat and accumulate to sometimes dangerous levels in your body.
- Polar vitamins dissolve readily in water and can be flushed from the body before absorption.

Self Check

1. **Explain** how a solute can dissolve in polar and nonpolar solvents.
2. **Explain** the phrase "like dissolves like" and give an example of two polar "like" substances.
3. **Describe** how soap cleans greasy dirt from your hands.
4. **Infer** Some small engines require a mixture of oil and gasoline. Gasoline evaporates easily. What conclusion can be drawn about the polarity of the engine oil?
5. **Think Critically** What might happen to your skin if you washed with soap too often?

Applying Math

6. **Calculate Mass** If 60 mg of vitamin C in a multivitamin provides only 75 percent of the recommended daily dosage for children, how much is recommended?
7. **Interpret Data** To get the recommended 80 mg of vitamin C, refer to **Table 3** to determine approximately how much fresh orange juice you must drink.

LAB

Saturated Solutions

Goals

- **Observe** the effects of temperature on the amount of solute that dissolves.

Materials

distilled water at room temperature
large test tubes
Celsius thermometer
table sugar
copper wire stirrer, bent into a spiral as shown on the next page
test-tube holder
graduated cylinder (25-mL)
beaker (250-mL) with 150 mL of water
electric hot plate
test-tube rack
ring stand

Safety Precautions

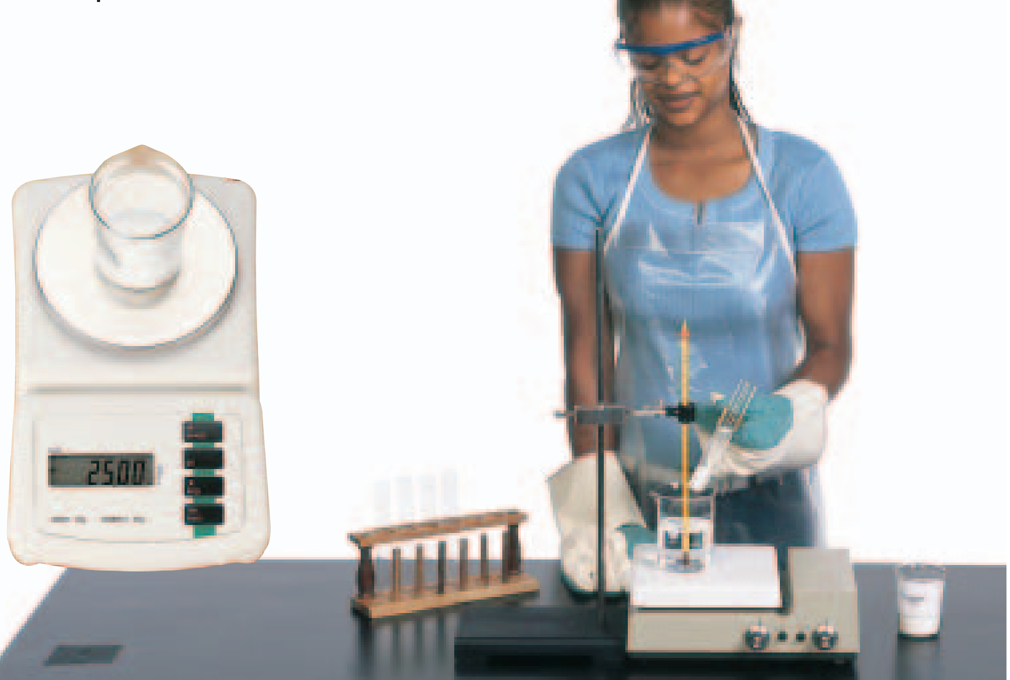
WARNING: *Do NOT touch the test tubes or hot plate surface when hot plate is turned on or cooling down. When heating a solution in a test tube, keep it pointed away from yourself and others. Do NOT remove goggles until clean up including washing hands is completed.*

Real-World Question

Two major factors to consider when you are dissolving a solute in water are temperature and the ratio of solute to solvent. What happens to a solution as the temperature changes? To be able to draw conclusions about the effect of temperature, you must keep other variables constant. For example, you must be sure to stir each solution in a similar manner. How does solubility change as temperature is increased?

Procedure

1. Place 20 mL of distilled water in a test tube.
2. Add 30 g of sugar.
3. Stir. Does this dissolve?
4. If it dissolves completely, add another 5 g of sugar to the test tube. Does it dissolve?
5. Continue adding 5-g amounts of sugar until no more sugar dissolves.
6. Now place the beaker of water on the hot plate and hang the thermometer from the ring stand so that the bulb is immersed about halfway into the beaker, making sure it does not touch the sides or bottom. Record the starting temperature.



(l)Matt Meadows, (r)Tim Courlas/Horizons Companies

7. Using a test-tube holder, place the test tube into the water.
8. Gradually increase the temperature of the hot plate, while stirring the solution in the tube, until all the sugar dissolves.
9. Note the temperature at which this happens.
10. Add another 5 g of sugar and continue. Note the temperature at which this additional sugar dissolves.
11. Continue in this manner until you have at least four data points. Note the total amount of sugar that has dissolved. Record your data on the data table.

Analyze Your Data

1. **Graph** your results using a line graph. Place grams of solute per 100 g of water (multiply the number of grams by five because you used only 20 mL of water) on the *y*-axis and place temperature on the *x*-axis.
2. **Interpret Data** Using your graph, estimate the solubility of sugar at 100°C and at 0°C, the boiling and freezing point of water, respectively.

Dissolving Sugar in Water

Temperature	Total Grams of Sugar Dissolved
Do not write in this book.	

Conclude and Apply

1. How did the saturation change as the temperature was increased?
2. **Compare** your results with those given in **Table 2.**

Communicating Your Data

Compare your results with those of other groups and discuss any differences noted. Why might these differences have occurred? **For more help, refer to the Science Skill Handbook.**

Matt Meadows

SCIENCE Stats

Weird Solutions

Did you know...

... The "brightest" solutions can glow like a streetlight. Glowing rods called light sticks are an example. Each rod contains two liquids in separate glass or plastic containers. When you flex the rod, the containers break, and the solutions mix and react to produce luminescence, or glowing light. A similar process called bioluminescence allows some living organisms, like fireflies, to glow.

... One of the hardest solutions is steel, a solid solution of iron, carbon, and other elements. When you add some chromium and nickel to the mix, you get stainless steel, which is a tough, rust-resistant solution. In 1998, the United States produced nearly 100 million metric tons of raw steel—enough to make more than 1,800 Empire State Buildings.

... The saltiest and largest body of solution in the western hemisphere is the Great Salt Lake in Utah. If all the salt in the lake dried out and hardened, the result would be a rock with a mass of about 4 1/2 trillion kg—as heavy as 300 million large trucks.

Applying Math

1. Great Salt Lake's salinity is 5 percent when the water is highest and 30 percent when the water is lowest. What is the lake's salinity when the water level is halfway between its highest and lowest levels?
2. Glow sticks shine for about 10 h. If you kept a glow stick glowing continuously in your window for seven days, how many sticks would you need?

chapter 22 Study Guide

Reviewing Main Ideas

Section 1 How Solutions Form

1. A solution is a mixture that has the same composition, color, density, and taste throughout.
2. The substance being dissolved is called a solute, and the substance that does the dissolving is called a solvent.
3. The rate of dissolving can be increased by stirring, increasing surface area, or increasing temperature.
4. Under similar conditions, small particles of solute dissolve faster than large particles.

Section 2 Solubility and Concentration

1. Some compounds are more soluble than others, and this can be measured.
2. *Concentrated* and *dilute* are not precise terms used to describe concentration of solutions.
3. Concentrations can be expressed as percent by volume.
4. An unsaturated solution can dissolve more solute, and a saturated solution, like this tea, cannot. A supersaturated solution is made by raising the temperature of a saturated solution and adding more solute. If it is cooled carefully, the supersaturated solution will retain the dissolved solute.

Section 3 Particles in Solution

1. Substances that dissolve in water to produce solutions that conduct electricity are called electrolytes.
2. When water pulls apart the molecules of a polar substance, forming ions, the process is called ionization.
3. When ionic solids dissolve in water, the process is called dissociation, because the ions are already present in the solid.

Section 4 Dissolving Without Water

1. Water cannot dissolve all solutes.
2. Nonpolar solvents are needed to dissolve nonpolar solutes.
3. Some vitamins are nonpolar and dissolve in the fat contained in some body cells.
4. Nonpolar solvents can be dangerous as well as helpful. Many products, including the substances shown here, are packaged with cautions of flammability and toxicity.

FOLDABLES™ Use the Foldable that you made at the beginning of this section to help you review the characteristics of solvents and solutes.

Icon Images

chapter 22 Review

Using Vocabulary

dissociation p. 677
electrolyte p. 676
ion p. 676
ionization p. 676
nonelectrolyte p. 676
nonpolar p. 681
polar p. 667
saturated solution p. 673
solubility p. 671
solution p. 664
solute p. 665
solvent p. 665
supersaturated solution p. 674
unsaturated solution p. 673

Fill in the blanks with correct vocabulary or words.

1. In lemonade, sugar is the _________ and water is the _________.

2. During _________, particles in an ionic solid are separated and drawn into solution.

3. If more of substance B dissolves in water than substance A, then substance B has a higher _________ than substance A.

4. Adding a seed crystal may cause solute to crystallize from a(n) _________.

5. More solute can be added to a(n) _________.

6. Nonpolar solutes in a solution are called _________.

Checking Concepts

Choose the word or phrase that best answers the question.

7. Which of the following is NOT a solution?
A) glass of flat soda
B) air in a scuba tank
C) bronze alloy
D) mud in water tank

8. What term is NOT appropriate to use when describing solutions?
A) heterogeneous **C)** liquid
B) gaseous **D)** solid

9. When iodine is dissolved in alcohol, what term is used to describe the alcohol?
A) alloy **C)** solution
B) solvent **D)** solute

10. What word is used to describe a mixture that is 85 percent copper and 15 percent tin?
A) alloy **C)** saturated
B) solvent **D)** solute

11. Solvents such as paint thinner and gasoline evaporate more readily than water because they are what type of compounds?
A) ionic
B) nonpolar
C) dilute
D) polar

12. What can a polar solvent dissolve?
A) any solute **C)** a nonpolar solute
B) a polar solute **D)** no solute

13. If a water solution conducts electricity, what must the solute be?
A) gas **C)** liquid
B) electrolyte **D)** nonelectrolyte

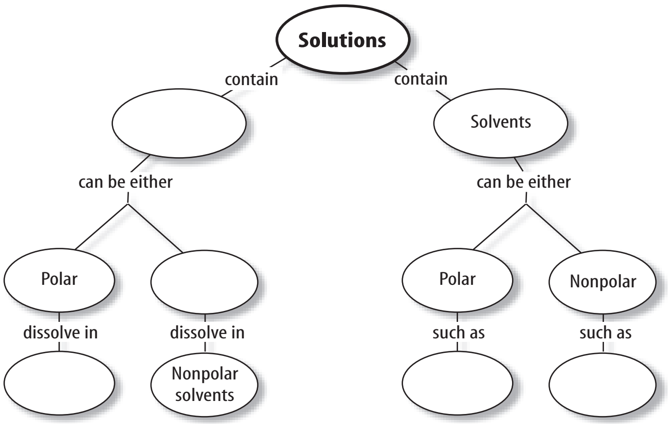
14. In forming a water solution, what process does an ionic compound undergo?
A) dissociation **C)** ionization
B) electrolysis **D)** no change

15. What can you increase to make a gas more soluble in a liquid?
A) particle size **C)** stirring
B) pressure **D)** temperature

16. If a solute crystallizes out of a solution when a seed crystal is added, what kind of solution is it?
A) unsaturated **C)** supersaturated
B) saturated **D)** dilute

Interpreting Graphics

17. Copy and complete the following concept map on solutions.



Use the table below to answer question 18.

Limits of Solubility

Compound	Type of Solution	Solubility in 100 g Water at 20°C
$CuSO_4$		32.0 g
KCl	Do not write	34.0 g
KNO_3	in this book.	31.6 g
$NaClO_3$		95.9 g

18. Identify Using the data in **Table 2,** fill in the following table. Use the terms *saturated*, *unsaturated*, and *supersaturated* to describe the type of solution.

Thinking Critically

19. Explain why potatoes might cook more quickly in salted water than in unsalted water.

20. Explain what happens when an ionic compound such as copper(II) sulfate, $CuSO_4$, dissolves in water.

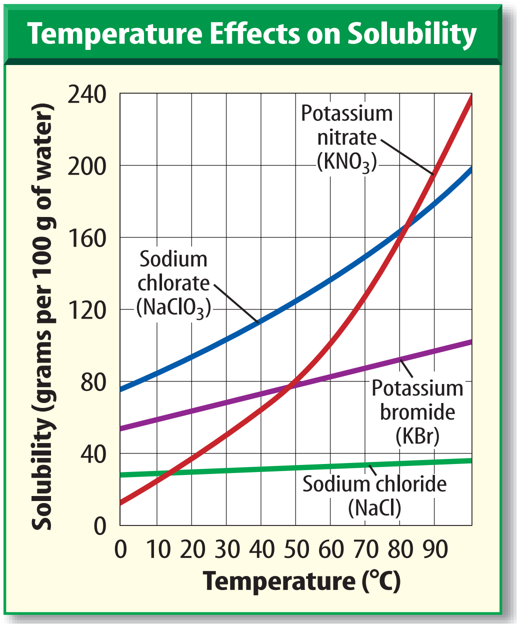
21. Explain why the term *dilute* is not precise.

22. Explain why the statement, "Water is the solvent in a solution," is not always true.

Applying Math

23. Measure in SI 153 g of potassium nitrate have been dissolved in enough water to make 1 L of this solution. You use a graduated cylinder to measure 80 mL of solution. What mass of potassium nitrate is in the 80-mL sample?

Use the graph below to answer question 24.



24. Interpret Data Determine the temperature at which a solution of 80 g potassium nitrate (KNO_3) in 100 mL of water is saturated.

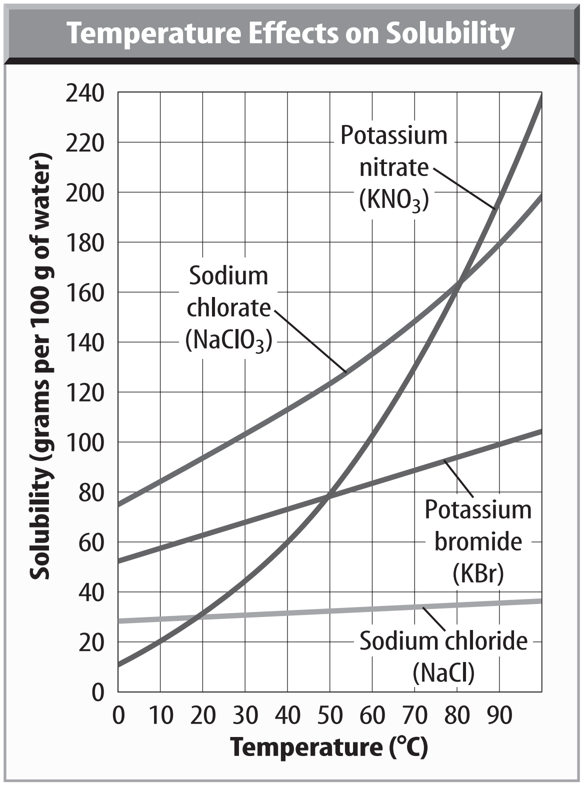
25. Use Numbers How would you make a 25 percent solution by volume of apple juice?

26. Make and Use Graphs Using **Table 2,** make a graph of solubility versus temperature for $CuSO_4$ (copper(II) sulfate) and KCl. How would you make a saturated solution of each substance at 80°C?

Part 1 Multiple Choice

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

Use the graph below to answer questions 1–3.



1. How much potassium nitrate will you have to add to 100 g of water at 40°C to make a saturated solution?
A. 60 g
B. 60 g
C. 100 g
D. 240 g

2. If 25 g of sodium chlorate are dissolved in 100 g of water at 70°C, how would you describe the solution?
A. concentrated
B. supersaturated
C. saturated
D. dilute

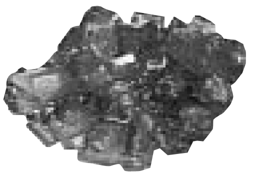
Test-Taking Tip

Answer Bubbles Double check that you are filling in the correct answer bubble for the question number you are working on.

3. Which of the following will make a saturated solution if added to 100 g of water?
A. 20 g of NaCl if the water is 50°C
B. 100 g of KBr if the water is 90°C
C. 80 g of $NaClO_3$ if the water is 30°C
D. 60 g of KNO_3 if the water is 100°C

4. Which of the following statements about solubility is true as the temperature increases?
A. The solubility of both gases and solids increases.
B. The solubility of both gases and solids decreases.
C. The solubility of gases increases, while the solubility of solids decreases.
D. The solubility of gases decreases, while the solubility of solids increases.

Use the illustration below to answer questions 5 and 6.



5. Which of the following will NOT make the crystal of rock candy dissolve faster in water?
A. stirring
B. heating
C. cooling
D. shaking

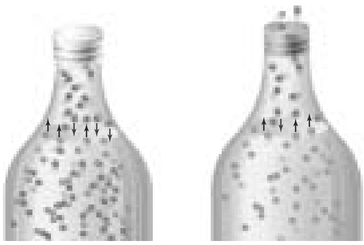
6. Which of the following statements is true about how grinding the crystal would affect its dissolving rate?
A. Grinding would increase the surface area and slow down dissolving.
B. Grinding would increase the surface area and speed up dissolving.
C. Grinding would decrease the surface are and slow down dissolving.
D. Grinding would decrease the surface area and speed up dissolving.

Part 2 Short Response/Grid In

Record your answers on the answer sheet provided by your teacher or on a sheet of paper.

7. A girl mixes a saturated solution of sugar in water in science lab on a Friday. On Monday, the open container has particles of sugar on the bottom. Explain possible reasons to explain why this happened.

Use the illustration below to answer questions 8 and 9.



8. The drawing above shows carbon dioxide gas dissolved in water. What are two ways you could make more gas dissolve in the water?

9. Why does shaking or pouring a carbonated drink cause gas to come out of solution?

10. The solubility of potassium chloride in water is 34 g per 100 g of water at 20°C. A warm solution containing 100 g of potassium chloride in 200 g of water is cooled to 20°C. How many grams of potassium chloride will come out of solution?

11. When water is heated slowly, small bubbles form in the liquid. These bubbles do not contain water vapor. What is in the bubbles and why do they form?

12. Why will turpentine remove oil-based paint from a paint brush while water will not?

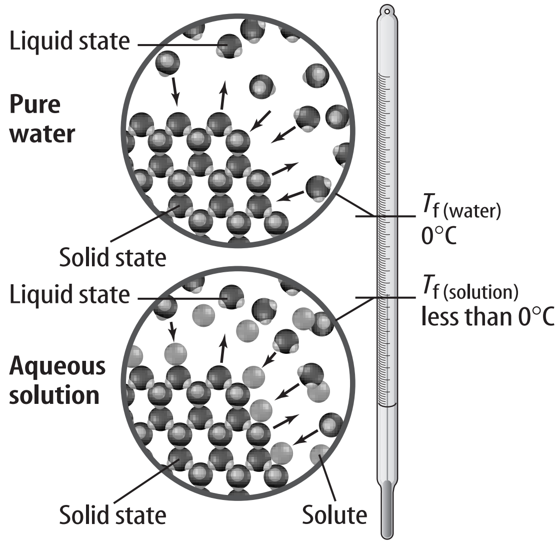
13. Why is salt mixed with the ice in a hand-crank ice cream maker?

Part 3 Open Ended

Record your answers on a sheet of paper.

14. Why can carp, catfish, and other fish with low oxygen needs live in warmer waters than can trout, which need large amounts of oxygen?

Use the illustration below to answer questions 15 and 16.



15. The drawing shows what happens to the freezing point of water when antifreeze is dissolved in the water to form a solution. Explain how this happens.

16. How can antifreeze also raise the boiling point of water?

17. When you take clothing to the dry cleaner, it is important to identify any stains that are on the clothing. Why does the dry cleaner need this information?

18. You are given a clear water solution containing potassium nitrate. How could you determine whether the solution is unsaturated, saturated, or supersaturated?

19. A solution conducts electricity. What do you know about the solution?