Chapter 7

Acids, Bases, and Solutions

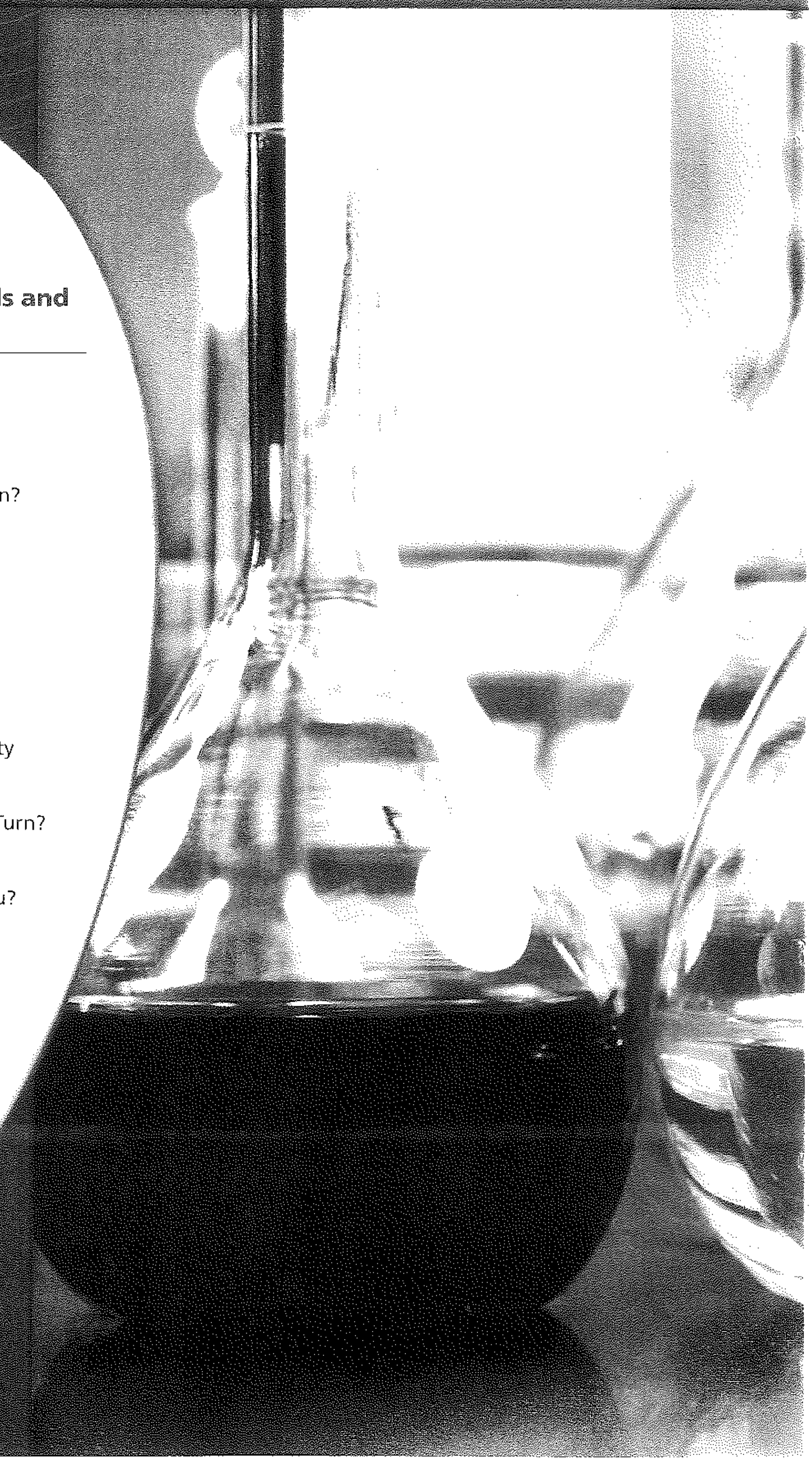
The BIG Idea

Properties of Matter

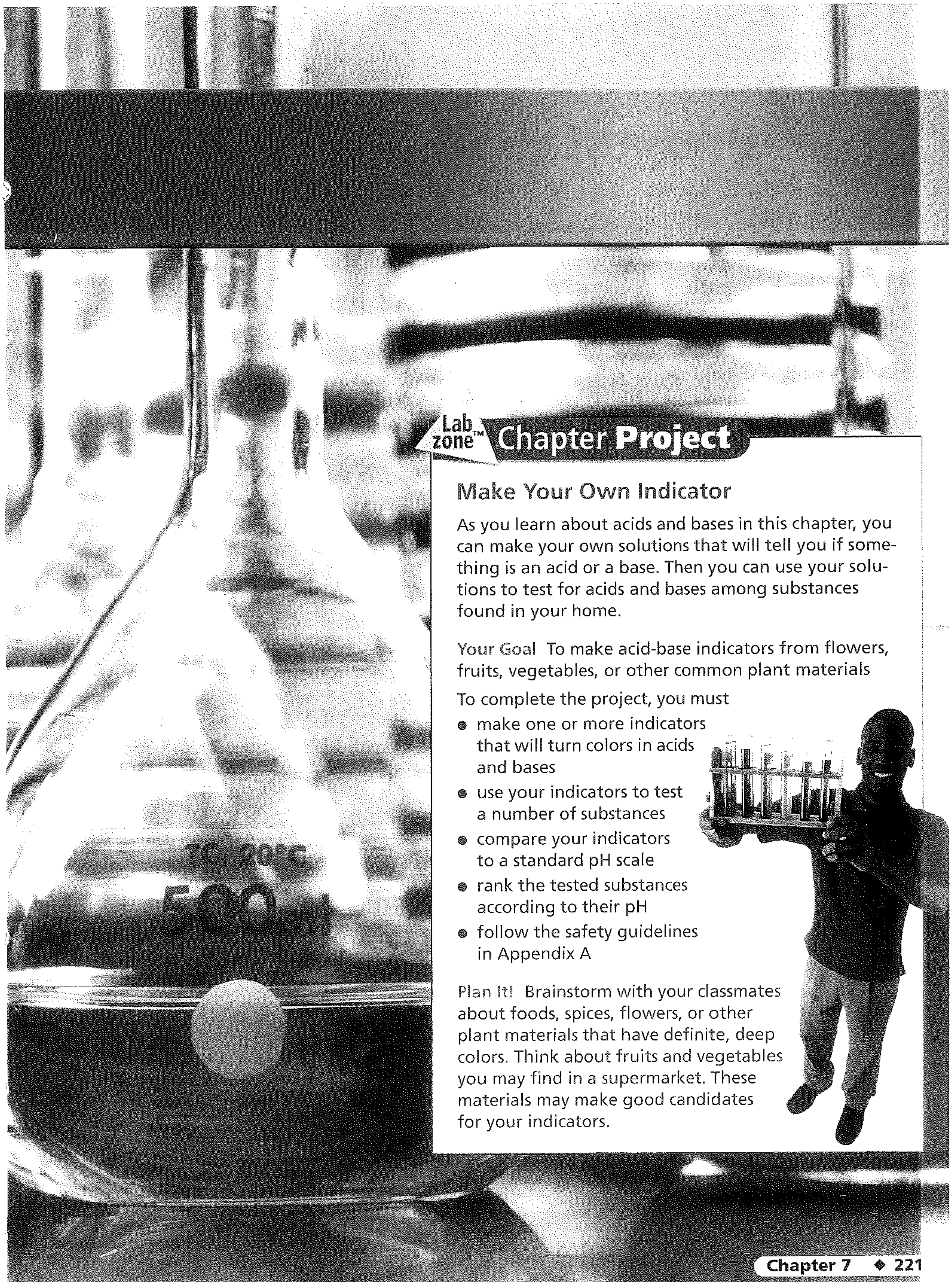
How may properties of acids and bases be determined?

Chapter Preview

1. **Understanding Solutions**
   Discover What Makes a Mixture a Solution?
   Try This Scattered Light
   Active Art Salt Dissolving in Water
   Design Your Own Lab Speedy Solutions
2. **Concentration and Solubility**
   Discover Does It Dissolve?
   Math Skills Calculating a Concentration
   Skills Activity Predicting
   Analyzing Data Temperature and Solubility
3. **Describing Acids and Bases**
   Discover What Colors Does Litmus Paper Turn?
4. **Acids and Bases in Solution**
   Discover What Can Cabbage Juice Tell You?
   Try This pHone Home
   Consumer Lab The Antacid Test
5. **Digestion and pH**
   Discover Where Does Digestion Begin?



Solutions containing transition metal compounds are often very colorful. ▶



Lab zone™ Chapter Project

Make Your Own Indicator

As you learn about acids and bases in this chapter, you can make your own solutions that will tell you if something is an acid or a base. Then you can use your solutions to test for acids and bases among substances found in your home.

Your Goal To make acid-base indicators from flowers, fruits, vegetables, or other common plant materials

To complete the project, you must

- make one or more indicators that will turn colors in acids and bases
- use your indicators to test a number of substances
- compare your indicators to a standard pH scale
- rank the tested substances according to their pH
- follow the safety guidelines in Appendix A

Plan It! Brainstorm with your classmates about foods, spices, flowers, or other plant materials that have definite, deep colors. Think about fruits and vegetables you may find in a supermarket. These materials may make good candidates for your indicators.

Section 1

Understanding Solutions

Reading Preview

Key Concepts

- What are the characteristics of solutions, colloids, and suspensions?
- What happens to the particles of a solute when a solution forms?
- How do solutes affect the freezing point and boiling point of a solvent?

Key Terms

- solution
- solvent
- solute
- colloid
- suspension

Target Reading Skill

Identifying Main Ideas As you read the *What Is a Solution?* section, write the main idea in a graphic organizer like the one below. Then write supporting details that further explain the main idea.

Main Idea		
A solution consists of at least one solute in a well-mixed . . .		
Detail	Detail	Detail

Lab zone Discover Activity

What Makes a Mixture a Solution?

1. Put about 50 or 60 milliliters of water into a plastic cup. Add a spoonful of pepper and stir well.
2. To a similar amount of water in a second cup, add a spoonful of table salt. Stir well.
3. Compare the appearance of the two mixtures.

Think It Over

Observing What is the difference between the two mixtures? What other mixtures have you seen that are similar to pepper and water? That are similar to table salt and water?

Imagine a hot summer day. You've been outdoors and now you're really thirsty. A tall, cool glass of plain tap water would taste great. But exactly what is tap water?

Tap water is more than just water. It's a mixture of pure water (H_2O) and a variety of other substances, such as chloride, fluoride, and metallic ions. Gases, such as oxygen and carbon dioxide, are also dissolved in tap water. The dissolved substances give tap water its taste.

What Is a Solution?

Tap water is one example of a mixture called a solution. A **solution** is a well-mixed mixture that contains a solvent and at least one solute. The **solvent** is the part of a solution present in the largest amount. It dissolves the other substances. The **solute** is the substance that is present in a solution in a smaller amount and is dissolved by the solvent. **A solution has the same properties throughout. It contains solute particles (molecules or ions) that are too small to see.**

Solutions With Water In many common solutions, the solvent is water. Sugar in water, for example, is the starting solution for flavored soft drinks. Adding food coloring gives the drink color. Dissolving carbon dioxide gas in the mixture produces a fizzy soda. Water dissolves so many substances that it is often called the "universal solvent."

Life depends on water solutions. Nutrients used by plants are dissolved in water in the soil. Sap is a solution that carries sugar dissolved in water to tree cells. Water is the solvent in blood, saliva, and tears. Reactions in cells take place in solution. To keep cells working, you must replace the water you lose in sweat and urine—two other water solutions.

Solutions Without Water Many solutions are made with solvents other than water, as you can see in Figure 1. For example, gasoline is a solution of several different liquid fuels. You don't even need a liquid solvent to make solutions. A solution may be made of any combination of gases, liquids, or solids.

Reading Checkpoint **What solvent is essential to living things?**

Examples of Common Solutions

Solute	Solvent	Solution
Gas	Gas	Air (oxygen and other gases in nitrogen)
Gas	Liquid	Soda water (carbon dioxide in water)
Liquid	Liquid	Antifreeze (ethylene glycol in water)
Solid	Liquid	Dental filling (silver in mercury)
Solid	Liquid	Ocean water (sodium chloride and other compounds in water)
Solid	Solid	Brass (zinc and copper)

FIGURE 1
Solutions can be made from any combination of solids, liquids, and gases.
Interpreting Photos *What are the solutes and solvent for stainless steel?*

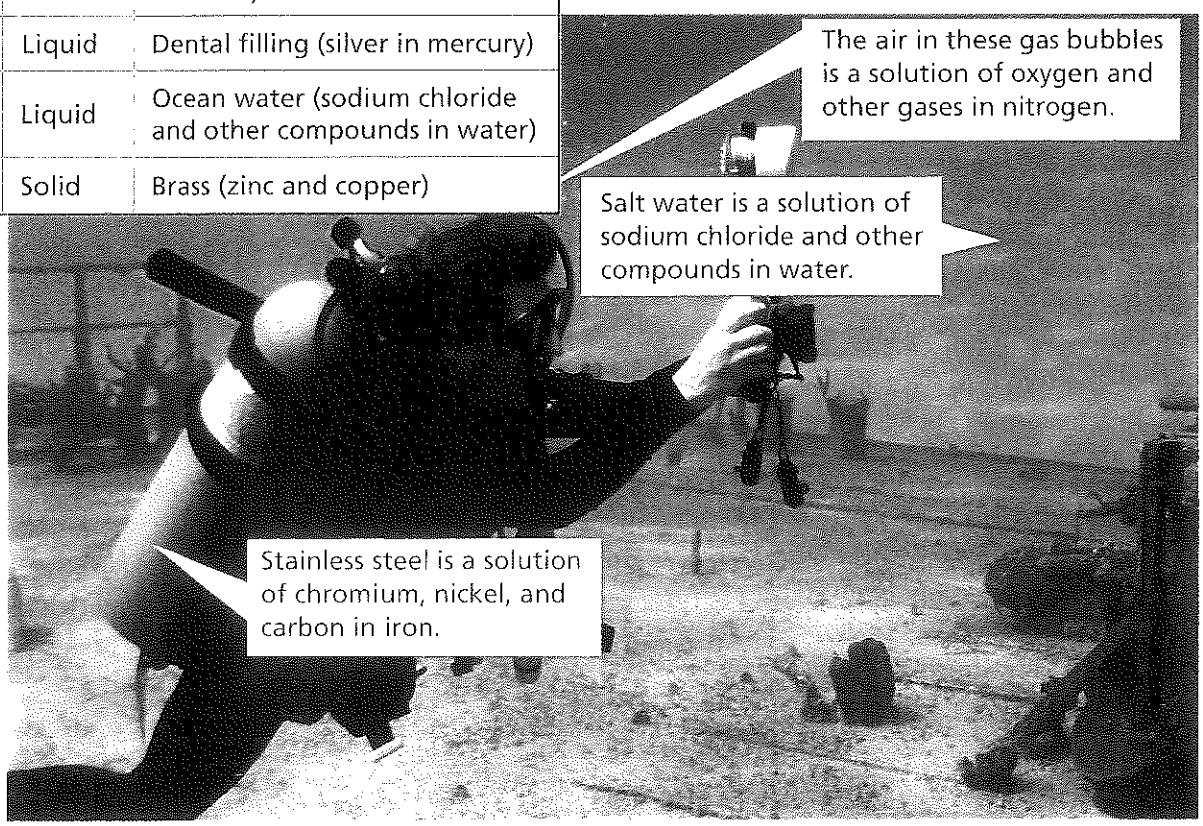
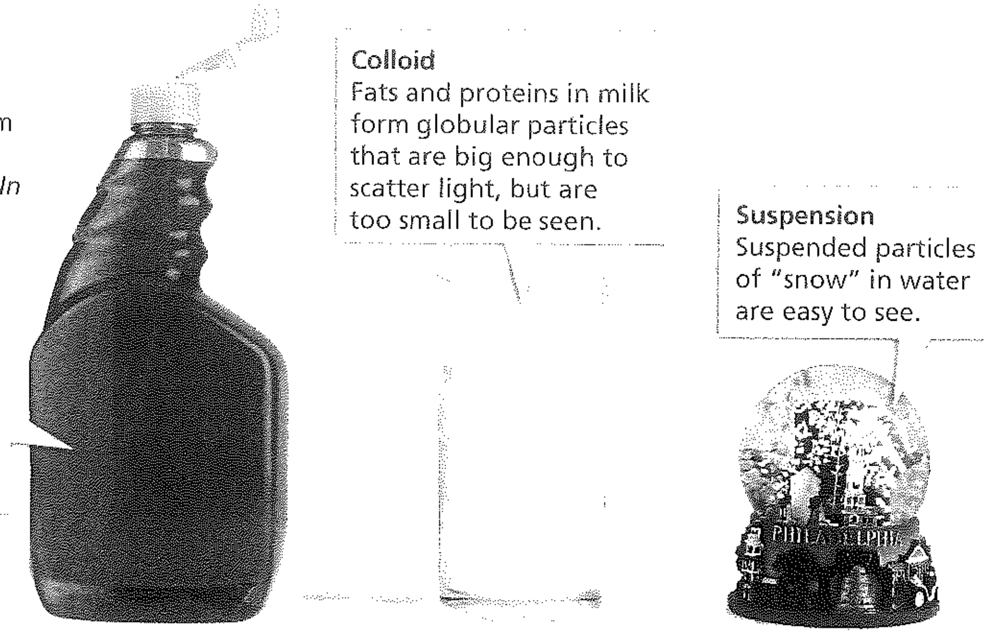


FIGURE 2
Comparing Three Mixtures
Solutions are different from colloids and suspensions.
Interpreting Photographs *In which mixture can you see the particles?*



Solution
In a solution of glass cleaner, particles are uniformly distributed and too small to scatter light.

Colloid
Fats and proteins in milk form globular particles that are big enough to scatter light, but are too small to be seen.

Suspension
Suspended particles of "snow" in water are easy to see.

Colloids and Suspensions

Not all mixtures are solutions. Colloids and suspensions are mixtures that have different properties than solutions.

Colloids Have you ever made a gelatin dessert? To do so, you stir powdered gelatin in hot water until the two substances are uniformly mixed. The liquid looks like a solution, but it's not. Gelatin is a colloid. A **colloid** (KAHL oyd) is a mixture containing small, undissolved particles that do not settle out.

Solutions and colloids differ in the size of their particles and how they affect the path of light. **A colloid contains larger particles than a solution. The particles are still too small to be seen easily, but are large enough to scatter a light beam.** For example, fog—a colloid that consists of water droplets in air—scatters the headlight beams of cars. In addition to gelatin and fog, milk, mayonnaise, shaving cream, and whipped cream are examples of colloids.

Suspensions If you did the Discover Activity, you noticed that no matter how much you stir pepper and water, the two never really seem to "mix" completely. When you stop stirring, you can still see pepper flakes floating on the water's surface and collecting at the bottom of the cup. Pepper and water make a suspension. A **suspension** (suh SPEN shun) is a mixture in which particles can be seen and easily separated by settling or filtration. **Unlike a solution, a suspension does not have the same properties throughout. It contains visible particles that are larger than the particles in solutions or colloids.**

Reading Checkpoint **Which kind of mixture has the largest particles?**

Lab zone Try This Activity

Scattered Light

1. Pour 50 mL of a gelatin-and-water mixture into a small, clean glass beaker.
2. Pour 50 mL of a saltwater solution into another clean beaker that is about the same size.
3. Compare the appearance of the two liquids.
4. In a darkened room, shine a small flashlight through the side of the beaker that contains gelatin. Repeat this procedure with the saltwater solution.
5. Compare the appearance of the light inside the two beakers.

Inferring What evidence tells you that gelatin is a colloid?

Particles in a Solution

Why do solutes seem to disappear when you mix them with a solvent? If you had a microscope powerful enough to look at the mixture's particles, what would you see? **When a solution forms, particles of the solute leave each other and become surrounded by particles of the solvent.**

Ionic and Molecular Solutes Figure 3 shows what happens when an ionic solid mixes with water. The positive and negative ions are attracted to the polar water molecules. Water molecules surround each ion as it leaves the surface of the crystal. As each layer of the solid is exposed, more ions can dissolve.

However, not every substance breaks into ions when it dissolves in water. A molecular solid, such as sugar, breaks up into individual neutral molecules. The polar water molecules attract the slightly polar sugar molecules. This causes the sugar molecules to move away from each other. But covalent bonds within the molecules are not broken.

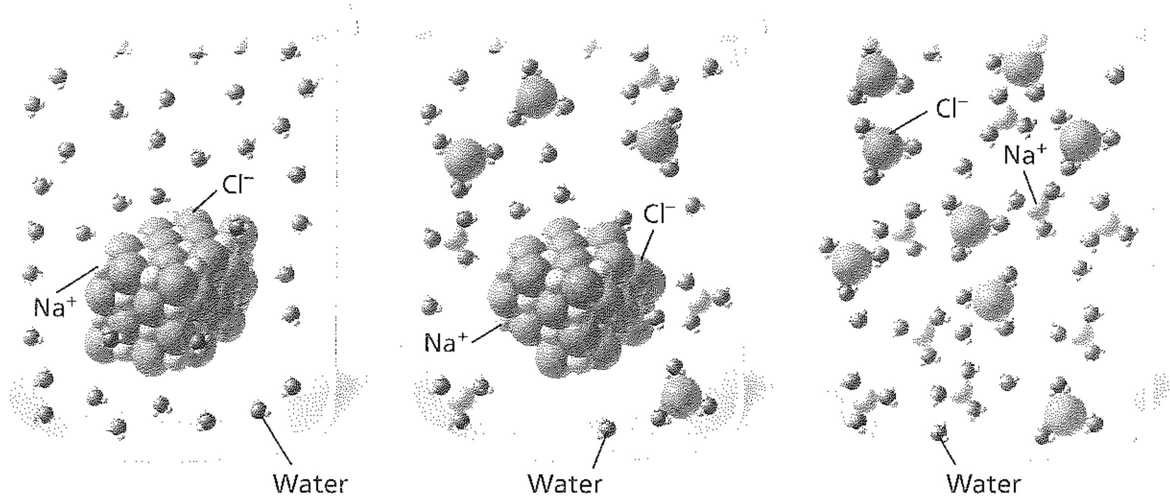
Solutes and Conductivity You have a water solution, but you don't know if the solute is salt or sugar. How could you find out? Think about what you learned about the electrical conductivity of compounds. A solution of ionic compounds in water conducts electricity, but a water solution of molecular compounds may not. You could test the conductivity of the solution. If no ions are present (as in a sugar solution), electricity will not flow.

Reading Checkpoint **Which kind of solution conducts electricity?**

Go Online
active art

For: Salt Dissolving in Water activity
Visit: PHSchool.com
Web Code: cgp-2031

FIGURE 3
Salt Dissolving in Water
When an ionic solid—like table salt—dissolves, water molecules surround and separate the positive and negative ions. Notice that the sodium ions attract the oxygen ends of the water molecules.



Lab zone Skills Activity

Designing Experiments

How does the mass of a solute affect the boiling temperature of a given volume of water? Design an experiment using a solute, water, a balance, a hot plate, and a thermometer.

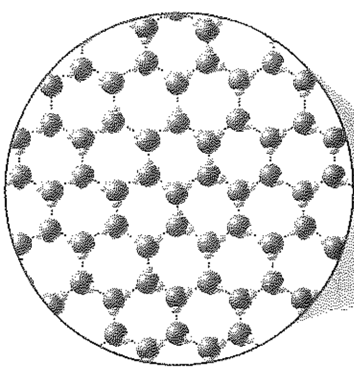
What variables should remain constant in your experiment? What is the manipulated variable? What will be the responding variable?

With approval from your teacher, do the experiment.

Effects of Solutes on Solvents

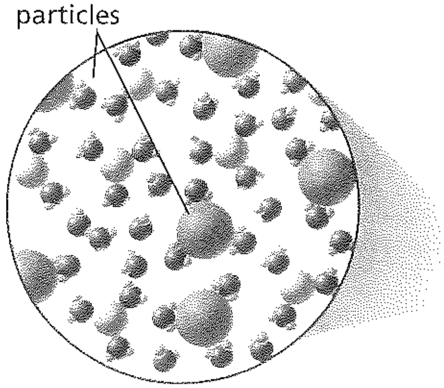
The freezing point of water is 0°C, and the boiling point is 100°C. These statements are true enough for pure water under everyday conditions, but the addition of solutes to water can change these properties. **Solutes lower the freezing point and raise the boiling point of a solvent.**

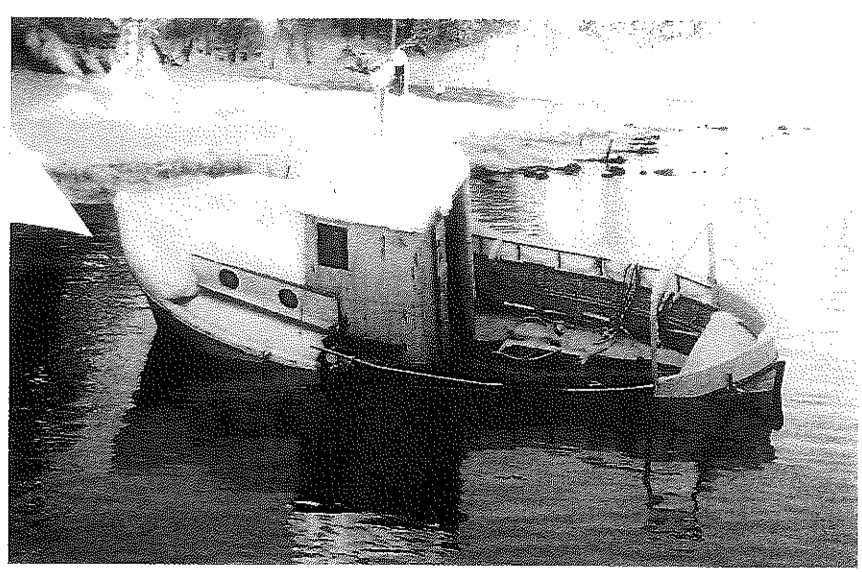
Lower Freezing Points Solutes lower the freezing point of a solvent. When liquid water freezes, water molecules join together to form crystals of solid ice. Pure water is made only of water molecules that freeze at 0°C. In a salt solution, solute particles are present in the water when it freezes. The solute particles make it harder for the water molecules to form crystals. The temperature must drop lower than 0°C for the solution to freeze. Figure 4 illustrates the particles in pure water and in a saltwater solution.



Freshwater lake ▶

Solute particles





Saltwater bay ▶

FIGURE 4
Salt's Effect on Freezing Point
Fresh water on the surface of a lake is frozen. Under similar conditions, salt water is not frozen.

Higher Boiling Points Solutes raise the boiling point of a solvent. To see why, think about the difference between the molecules of a liquid and those of a gas of the same substance. In a liquid, molecules are moving close to each other. In a gas, they are far apart and moving more rapidly. As the temperature of a liquid rises, the molecules gain energy and escape into the air. In pure water, all the molecules are water. But in a solution, some of the particles are water molecules and others are particles of solute. The presence of the solute makes it harder for the water molecules to escape, so more energy is needed. The temperature must go higher than 100°C for the water to boil.

Car manufacturers make use of the effects of solutes to protect engines from heat and cold. The coolant in a car radiator is a solution of water and another liquid called antifreeze. (Often the antifreeze is ethylene glycol.) The mixture of the two liquids has a higher boiling point and lower freezing point than water alone. Because this solution can absorb more of the heat given off by the running engine, risk of damage to the car from overheating is greatly reduced. The risk of damage from freezing in very cold weather is also reduced.

FIGURE 5
Calling Solutes to the Rescue?
This man might have prevented his car from overheating by using the proper coolant in the radiator.
Relating Cause and Effect *Explain how coolant works.*

Reading Checkpoint **Does salt water have a lower or higher freezing point than pure water?**

Section 1 Assessment

Target Reading Skill Identifying Main Ideas
Use your graphic organizer to help you answer Question 1 below.

Reviewing Key Concepts

1. a. Defining What is a solution?
   b. Comparing and Contrasting How are solutions different from colloids and suspensions?
   c. Inferring Suppose you mix food coloring in water to make it blue. Have you made a solution or a suspension? Explain.
2. a. Reviewing What happens to the solute particles when a solution forms?
   b. Sequencing Describe as a series of steps how table salt in water makes a solution that can conduct electricity.
3. a. Summarizing What effects do solutes have on a solvent's freezing and boiling points?
   b. Relating Cause and Effect Why is the temperature needed to freeze ocean water lower than the temperature needed to freeze the surface of a freshwater lake?
   c. Applying Concepts Why does salt sprinkled on icy roads cause the ice to melt?

Lab zone At-Home Activity

Passing Through With a family member, mix together a spoonful each of sugar and pepper in about 100 mL of warm water in a plastic container. Pour the mixture through a coffee filter into a second container. Ask your family member what happened to the sugar. Let the water evaporate overnight. Describe the difference between a solution and a suspension.

Lab zone **Design Your Own Lab**

Speedy Solutions

Problem
How can you control the rate at which certain salts dissolve in water?

Skills Focus
controlling variables, drawing conclusions, designing experiments

Materials
- spoon
- solid stoppers, #4
- thermometers
- hot plate
- balance
- stirring rods
- ice
- timer or watch
- test tube rack
- test tubes, 25 × 150 mm
- coarse, rock, and table salt
- graduated cylinders and beakers, various sizes

Design a Plan
1. Make a list of all the variables you can think of that could affect the speed at which sodium chloride dissolves in water.
2. Compare your list with your classmates' lists, and add other variables.
3. Choose one variable from your list to test.
4. Write a hypothesis predicting the effect of your chosen variable on the speed of dissolving.
5. Decide how to work with your choice.
   - If you choose temperature, you might perform tests at 10°C, 20°C, 30°C, 40°C, and 50°C.
   - If you choose stirring, you might stir for various amounts of time.
6. Plan at least three tests for whichever variable you choose. Remember to control all other variables.
7. Write down a series of steps for your procedure and safety guidelines for your experiment. Be quite detailed in your plan.
8. As part of your procedure, prepare a data table in which to record your results. Fill in the headings on your table that identify the manipulated variable and the responding variable. (*Hint:* Remember to include units.)

Data Table

Manipulated Variable	Dissolving Time		
	Test 1	Test 2	Test 3

9. Have your teacher approve your procedure, safety guidelines, and data table.
10. Perform the experiment.

Analyze and Conclude

1. Controlling Variables Which is the manipulated variable in your experiment? Which is the responding variable? How do you know which is which?
2. Controlling Variables List three variables you held constant in your procedure. Explain why controlling these variables makes your data more meaningful.
3. Graphing Make a line graph of your data. Label the horizontal axis with the manipulated variable. Label the vertical axis with the responding variable. Use an appropriate scale for each axis and label the units.
4. Drawing Conclusions Study the shape of your graph. Write a conclusion about the effect of the variable you tested on the speed at which salt dissolves in water.
5. Drawing Conclusions Does your conclusion support the hypothesis you wrote in Step 4 of your Plan? Explain.
6. Designing Experiments What advantage would there be in running your tests a second or third time?
7. Predicting If you switched procedures with another student who tested the same variable as you, do you think you would get the same results? Explain why or why not.
8. Communicating Write an e-mail to a friend explaining how your results relate to what you have learned about particles and solubility.

More to Explore

Choose another variable from the list you made in Steps 1 and 2 of your Plan. Repeat the process with that variable. Of the two variables you chose, which was easier to work with? Explain.

Section 2

Concentration and Solubility

Reading Preview

Key Concepts

- How is concentration measured?
- Why is solubility useful in identifying substances?
- What factors affect the solubility of a substance?

Key Terms

- dilute solution
- concentrated solution
- solubility
- saturated solution
- unsaturated solution
- supersaturated solution

Target Reading Skill

Building Vocabulary As you read, carefully note the definition of each Key Term. Also note other details in the paragraph that contains the definition. Use all this information to write a meaningful sentence using the Key Term.

Lab zone Discover Activity

Does It Dissolve?

1. Put half a spoonful of soap flakes into a small plastic cup. Add about 50 mL of water and stir. Observe whether the soap flakes dissolve.
2. Clean out the cup. Repeat the test for a few other solids and liquids provided by your teacher.
3. Classify the items you tested into two groups: those that dissolved easily and those that did not.

Think It Over

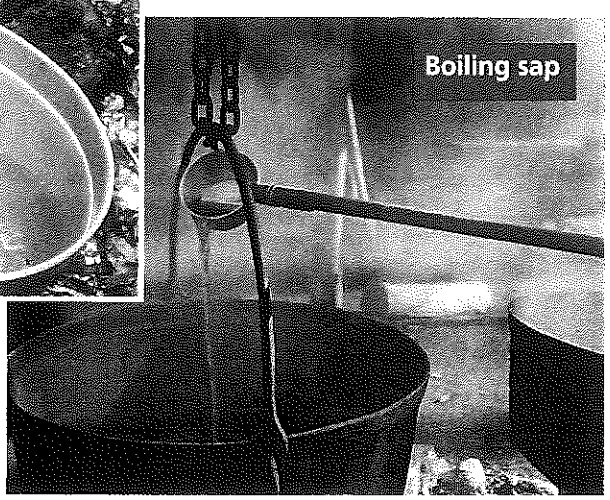
Drawing Conclusions Based on your observations, does the physical state (solid or liquid) of a substance affect whether or not it dissolves in water? Explain.

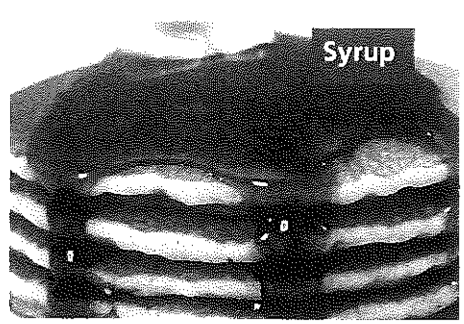
Have you ever had syrup on your pancakes? You probably know that it's made from the sap of maple trees. Is something that sweet really made in a tree? Well, not exactly.

Concentration

The sap of a maple tree and pancake syrup differ in their concentrations. That is, they differ in the amount of solute (sugar) dissolved in a certain amount of solvent (water). The sap is a **dilute solution,** a mixture that has only a little solute dissolved in a certain amount of solvent. The syrup, on the other hand, is a **concentrated solution**—one that has a lot of solute dissolved in the solvent.

Making Maple Syrup ▼





Changing Concentration You can change the concentration of a solution by adding more solute. You can also change it by adding or removing solvent. For example, fruit juices are sometimes packaged as concentrates, which are concentrated solutions. In making the concentrate, water was removed from the natural juice. When you make juice from the concentrate, you add water, making a dilute solution.

Measuring Concentration You know that maple syrup is more concentrated than maple sap. But you probably do not know the actual concentration of either solution. **To measure concentration, you compare the amount of solute to the amount of solvent or to the total amount of solution.**

Often, the method used to describe concentration depends on the type of solution. For example, you might measure the mass of a solute or solvent in grams. Or you might measure the volume of a solute or solvent in milliliters or liters. You can report concentration as the percent of solute in solution by volume or mass.

Reading Checkpoint **How can you change the concentration of a solution?**

Math Skills

Calculating a Concentration

To calculate the concentration of a solution, compare the amount of solute to the amount of solution and multiply by 100 percent.

For example, if a solution contains 10 grams of solute dissolved in 100 grams of solution, then its concentration can be reported as 10 percent.

$$\frac{10\text{ g}}{100\text{ g}} \times 100\% = 10\%$$

Practice Problem A solution contains 12 grams of solute dissolved in 36 grams of solution. What is the concentration of the solution?

Solubility

If a substance dissolves in water, a question you might ask is, "How much can dissolve?" Suppose you add sugar to a glass of iced tea. Is there a limit to how "sweet" you can make the tea? The answer is yes. At the temperature of iced tea, several spoonfuls of sugar are about all you can add. At some point, no matter how much you stir the tea, no more sugar will dissolve. **Solubility** is a measure of how much solute can dissolve in a solvent at a given temperature.

When you've added so much solute that no more dissolves, you have a **saturated solution.** If you add more sugar to a saturated solution of iced tea, the extra sugar just settles to the bottom of the glass. On the other hand, if you can continue to dissolve more solute, you still have an **unsaturated solution.**

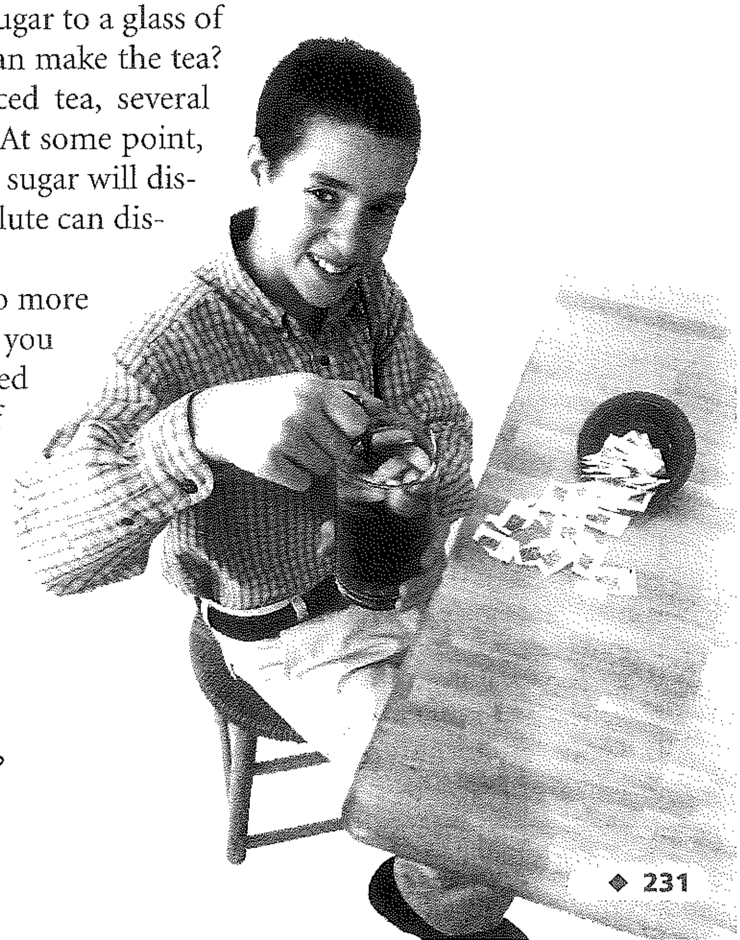


FIGURE 6
Dissolving Sugar in Tea
At some point, this boy will not be able to dissolve any more sugar in his tea.
Applying Concepts *What term describes how much sugar can dissolve in a solvent?*

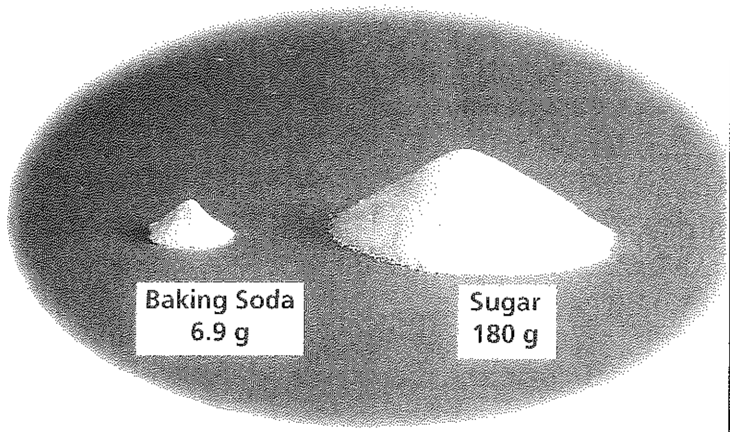


FIGURE 7
Each compound listed in the table dissolves in water, but in different amounts.
Interpreting Tables *Which compound is the most soluble? Which is the least soluble?*

Solubility in 100 g of Water at 0°C

Compound	Solubility (g)
Carbon dioxide (CO_2)	0.348
Baking soda ($NaHCO_3$)	6.9
Table salt ($NaCl$)	35.7
Table sugar ($C_{12}H_{22}O_{11}$)	180

Working With Solubility The solubility of a substance tells you how much solute you can dissolve before a solution becomes saturated. Solubility is given for a specific solvent (such as water) under certain conditions (such as temperature). Look at the table in Figure 7. It compares the solubility of some familiar compounds. In this case, the solvent is water and the temperature is 0°C. From the table, you can see that 6.9 grams of baking soda will dissolve in 100 grams of water at 0°C. But the same mass of water at the same temperature will dissolve 180 grams of table sugar!

Using Solubility **Solubility can be used to help identify a substance because it is a characteristic property of matter.** Suppose you had a white powder that looked like table salt or sugar. You wouldn't know for sure whether the powder is salt or sugar. And you wouldn't use taste to identify it. Instead, you could measure its solubility in water at 0°C and compare the results to the data in Figure 7.

Reading Checkpoint **What does the solubility of a substance tell you?**

Lab zone Skills Activity

Predicting

Make a saturated solution of baking soda in water. Add one small spoonful of baking soda to about 250 mL of cool water. Stir until the baking soda dissolves. Continue adding baking soda until no more dissolves. Keep track of how much baking soda you use. Then predict what would happen if you used warm water instead. Make a plan to test your prediction. With approval from your teacher, carry out your plan. Did your results confirm your prediction? Explain.

Factors Affecting Solubility

Which dissolves more sugar: iced tea or hot tea? You have already read that there is a limit to solubility. An iced tea and sugar solution quickly becomes saturated. Yet a hot, steaming cup of the same tea can dissolve much more sugar before the limit is reached. The solubilities of solutes change when conditions change. **Factors that affect the solubility of a substance include pressure, the type of solvent, and temperature.**

Pressure Pressure affects the solubility of gases. The higher the pressure of the gas over the solvent, the more gas can dissolve. To increase the carbon dioxide concentration in soft drinks, the gas is added under high pressure. Opening the bottle or can reduces the pressure. The escaping gas makes the sound you hear.

Scuba divers are aware of the effect of pressure on gases. Air is about 80 percent nitrogen. When divers breathe from tanks of compressed air, nitrogen from the air dissolves in their blood in greater amounts as they descend. This occurs because the pressure underwater increases with depth. If divers return to the surface too quickly, nitrogen bubbles come out of solution and block blood flow. Divers double over in pain, which is why this condition is sometimes called "the bends."

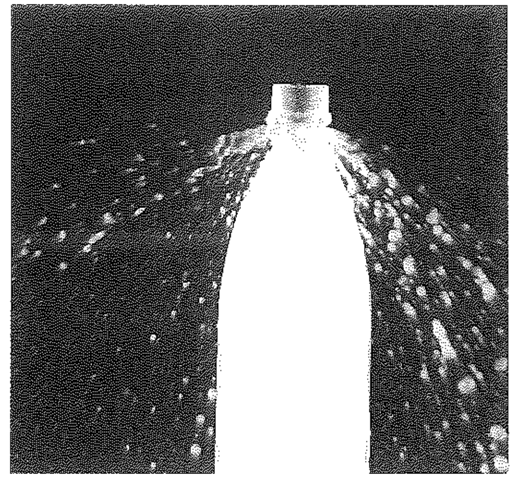


FIGURE 8
Pressure Changes Solubility
Opening a shaken bottle of soda water may produce quite a spray as dissolved gas comes out of solution.

Solvents Sometimes you just can't make a solution because the solute and solvent are not compatible. Have you ever tried to mix oil and vinegar, which is mostly water, to make salad dressing? If you have, you've seen how the dressing quickly separates into layers after you stop shaking it. Oil and water separate because water is a polar compound and oil is nonpolar. Polar compounds and nonpolar compounds do not mix very well.

For liquid solutions, the solvent affects how well a solute dissolves. The expression "like dissolves like" gives you a clue to which solutes are soluble in which solvents. Ionic and polar compounds usually dissolve in polar solvents. Nonpolar compounds do not usually dissolve in polar solvents. If you work with paints, you know that water-based (latex) paints can be cleaned up with just soap and water. But cleaning up oil-based paints may require a nonpolar solvent, such as turpentine.

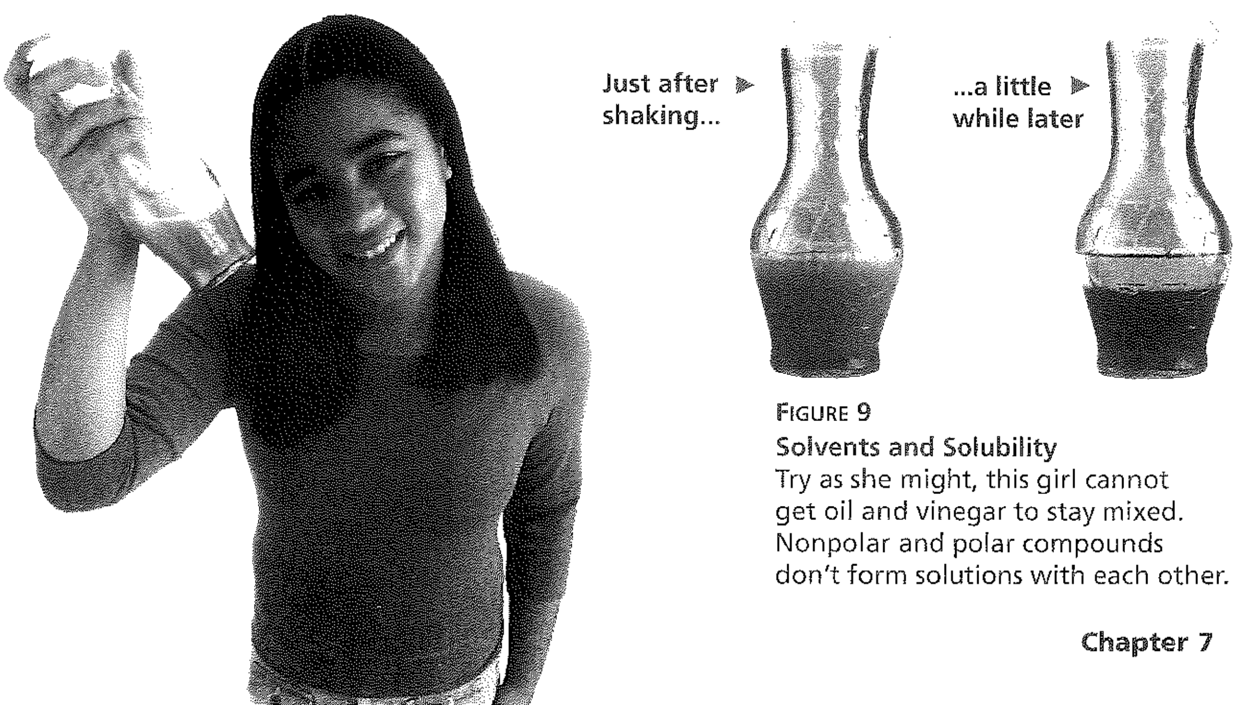


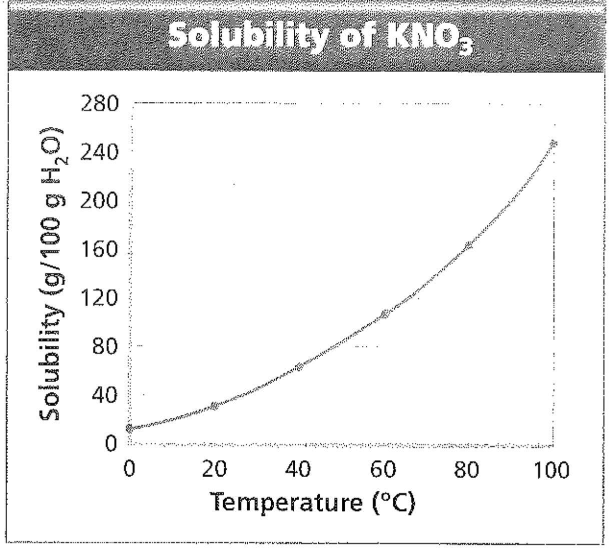
FIGURE 9
Solvents and Solubility
Try as she might, this girl cannot get oil and vinegar to stay mixed. Nonpolar and polar compounds don't form solutions with each other.

Math Analyzing Data

Temperature and Solubility

The solubility of the compound potassium nitrate (KNO_3) varies in water at different temperatures.

1. Reading Graphs At which temperature shown in the graph is KNO_3 least soluble in water?
2. Reading Graphs Approximately what mass of KNO_3 is needed to saturate a water solution at 40°C?
3. Calculating About how much more soluble is KNO_3 at 40°C than at 20°C?
4. Interpreting Data Does solubility increase at the same rate with every 20°C increase in temperature? Explain.



Temperature For most solids, solubility increases as the temperature increases. That is why the temperature is reported when solubilities are listed. For example, the solubility of table sugar in 100 grams of water changes from 180 grams at 0°C to 231 grams at 25°C to 487 grams at 100°C.

Cooks use this increased solubility of sugar when they make desserts such as rock candy, fudge, or peanut brittle. To make peanut brittle, you start with a mixture of sugar, corn syrup, and water. At room temperature, not enough of the required sugar can dissolve in the water. The mixture must be heated until it begins to boil. Nuts and other ingredients are added before the mixture cools. Some recipes call for temperatures above 100°C. Because the exact temperature can affect the result, cooks use a candy thermometer to check the temperature.

Unlike most solids, gases become less soluble when the temperature goes up. For example, more carbon dioxide will dissolve in cold water than in hot water. Carbon dioxide makes soda water fizzy when you pour it into a glass. If you open a warm bottle of soda water, carbon dioxide escapes the liquid in greater amounts than if the soda water had been chilled. Why does warm soda taste "flat"? It contains less gas. If you like soda water that's very fizzy, open it when it's cold!

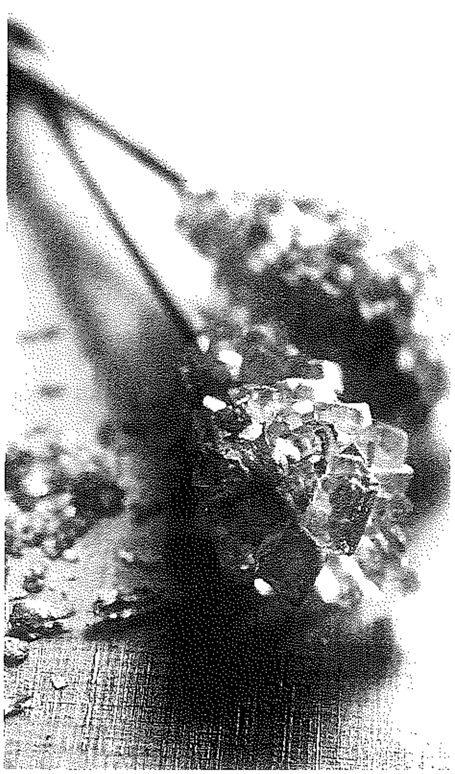


FIGURE 10
Temperature Changes Solubility
Some hard candy is made by cooling a sugar water solution. **Interpreting Photographs** *Why does sugar form crystals when the solution is cooled?*

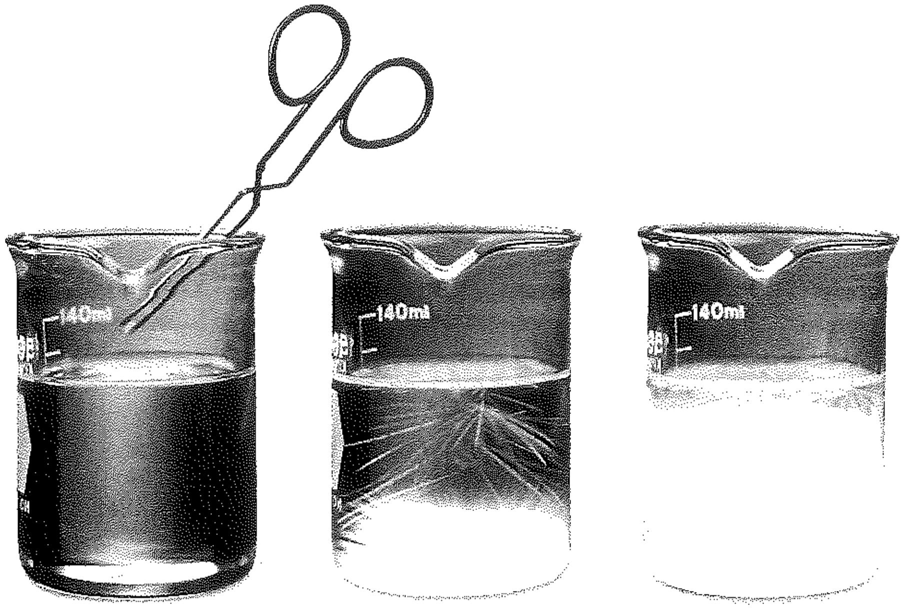


FIGURE 11
A Supersaturated Solution
Dropping a crystal of solute into a supersaturated solution (left) causes the excess solute to rapidly come out of solution (center). Soon, the formation of crystals is complete (right).

When heated, a solution can dissolve more solute than it can at cooler temperatures. If a heated, saturated solution cools slowly, sometimes the extra solute will remain dissolved. A **supersaturated solution** has more dissolved solute than is predicted by its solubility at the given temperature. When you disturb a supersaturated solution by dropping in a crystal of the solute, the extra solute will come out of solution.

Go Online SCI LINKS NSTA

For: Links on solubility
Visit: www.SciLinks.org
Web Code: scn-1232

Reading Checkpoint **As temperature increases, what happens to the solubility of a gas?**

Section 2 Assessment

Target Reading Skill Building Vocabulary Use your sentences about the Key Terms to help answer the questions.

Reviewing Key Concepts

1. a. Reviewing What is concentration?
   b. Describing What quantities are compared when the concentration of a solution is measured?
   c. Applying Concepts Solution A contains 50 g of sugar. Solution B contains 100 g of sugar. Can you tell which solution has a higher sugar concentration? Explain.
2. a. Defining What is solubility?
   b. Explaining How can solubility help you identify a substance?
   c. Calculating Look back at the table in Figure 7. At 0°C, about how many times more soluble in water is sugar than salt?
3. a. Listing What are three factors that affect solubility?
   b. Summarizing How does temperature affect the solubility of most solids?
   c. Relating Cause and Effect When you heat water and add sugar, all of the sugar dissolves. When you cool the solution, some sugar comes out of solution. Explain.

Math Practice

4. Calculating a Concentration What is the concentration of a solution that contains 45 grams of sugar in 500 grams of solution?
5. Calculating a Concentration How much sugar is dissolved in 500 grams of a solution if the solution is 70 percent sugar by mass?

Section 3 Describing Acids and Bases

Reading Preview

Key Concepts
- What are the properties of acids and bases?
- Where are acids and bases commonly used?

Key Terms
- acid
- corrosive
- indicator
- base

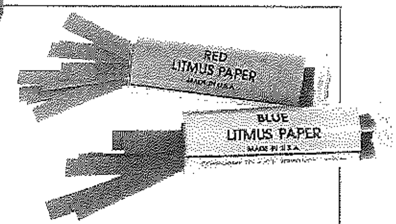
Target Reading Skill
Asking Questions Before you read, preview the red headings. In a graphic organizer like the one below, ask a *what* question for each heading. As you read, write the answers to your questions.

Describing Acids and Bases

Question	Answer
What is an acid?	An acid is . . .

Lab zone Discover Activity

What Colors Does Litmus Paper Turn?



1. Use a plastic dropper to put a drop of lemon juice on a clean piece of red litmus paper. Put another drop on a clean piece of blue litmus paper. Observe.
2. Rinse your dropper with water. Then test other substances the same way. You might test orange juice, ammonia cleaner, tap water, vinegar, and solutions of soap, baking soda, and table salt. Record all your observations.
3. Wash your hands when you are finished.

Think It Over

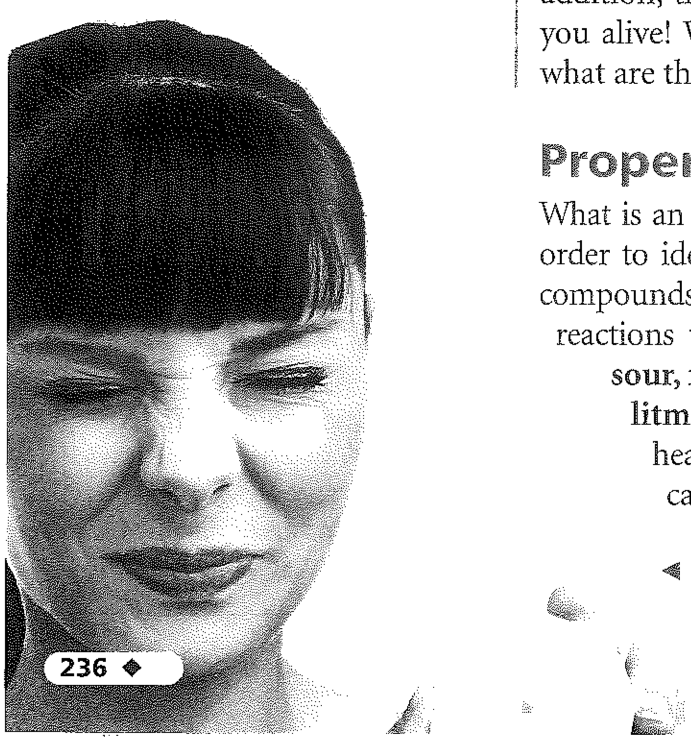
Classifying Group the substances based on how they make the litmus paper change color. What other properties do the items in each group have in common?

Did you have any fruit for breakfast today—perhaps an orange, an apple, or fruit juice? If so, an acid was part of your meal. The last time you washed your hair, did you use shampoo? If your answer is yes, then you may have used a base.

You use many products that contain acids and bases. In addition, the chemical reactions of acids and bases even keep you alive! What are acids and bases—how do they react, and what are their uses?

Properties of Acids

What is an acid, and how do you know when you have one? In order to identify an acid, you can test its properties. **Acids** are compounds whose characteristic properties include the kinds of reactions they undergo. **An acid is a substance that tastes sour, reacts with metals and carbonates, and turns blue litmus paper red.** Some common acids you may have heard of are hydrochloric acid, nitric acid, sulfuric acid, carbonic acid, and acetic acid.



◀ **Lemons are acidic.**

Sour Taste If you've ever tasted a lemon, you've had first-hand experience with the sour taste of acids. Can you think of other foods that sometimes taste sour, or tart? Citrus fruits—lemons, grapefruits, oranges, and limes—are acidic. They all contain citric acid. Other fruits (cherries, tomatoes, apples) and many other types of foods contain acids, too.

Although sour taste is a characteristic of many acids, it is not one you should use to identify a compound as an acid. Scientists never taste chemicals in order to identify them. Though acids in sour foods may be safe to eat, many other acids are not.

Reactions With Metals Do you notice the bubbles in Figure 12? Acids react with certain metals to produce hydrogen gas. Not all metals react this way, but magnesium, zinc, and iron do. When they react, the metals seem to disappear in the solution. This observation is one reason acids are described as **corrosive,** meaning they "eat away" at other materials.

The metal plate in Figure 12 is being etched with acid. Etching is one method of making printing plates that are then used to print works of art on paper. To make an etching, an artist first coats a metal plate with an acid-resistant material—often beeswax. Then the design is cut into the beeswax with a sharp tool, exposing some of the metal. When the plate is treated with acid, the acid eats away the design in the exposed metal. Later, ink applied to the plate collects in the grooves made by the acid. The ink is transferred to the paper when the etching is printed.

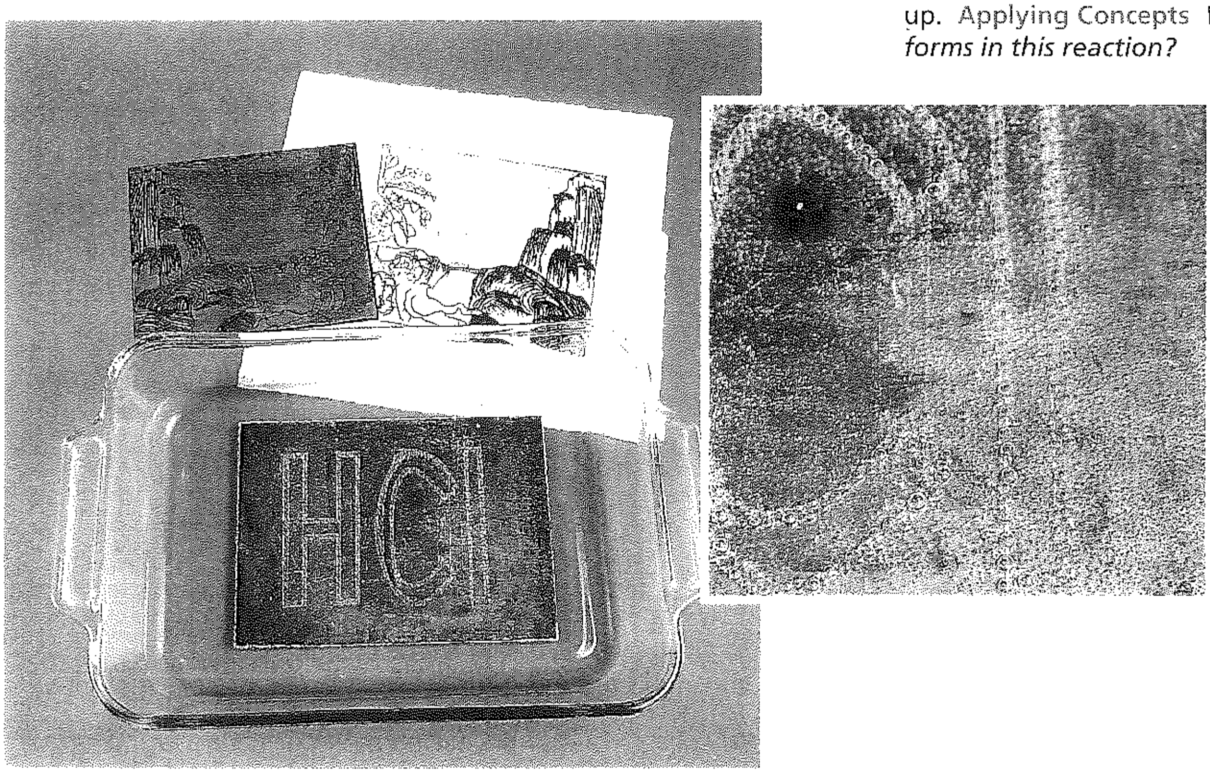


FIGURE 12
Etching With Acid
Metal etching takes advantage of the reaction of an acid with a metal. Lines are cut in a wax coating on a plate. Here, hydrochloric acid eats away at the exposed zinc metal, forming bubbles you can see in the close-up. Applying Concepts *What gas forms in this reaction?*

Reactions With Carbonates Acids also react with carbonate ions in a characteristic way. Recall that an ion is an atom or a group of atoms that has an electric charge. Carbonate ions contain carbon and oxygen atoms bonded together. They carry an overall negative charge (CO_3^{2-}). One product of an acid's reaction with carbonates is the gas carbon dioxide.

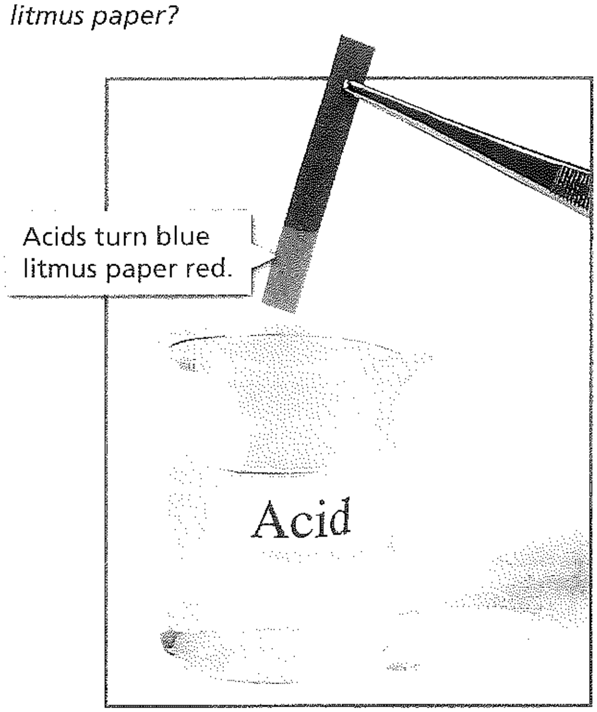
Geologists, scientists who study Earth, use this property of acids to identify rocks containing certain types of limestone. Limestone is a compound that contains the carbonate ion. If a geologist pours dilute hydrochloric acid on a limestone rock, bubbles of carbon dioxide appear on the rock's surface.

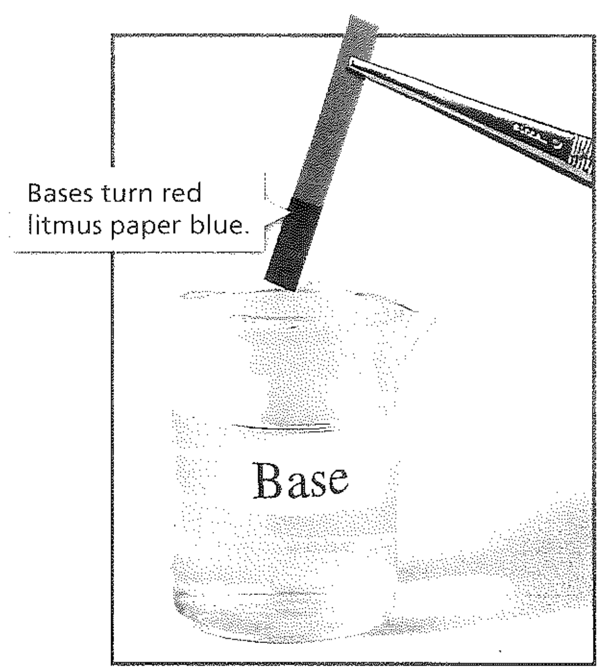
Reactions With Indicators If you did the Discover activity, you used litmus paper to test several substances. Litmus is an example of an **indicator,** a compound that changes color when in contact with an acid or a base. Look at Figure 13 to see what happens to litmus paper as it is dipped in a solution containing acid. Vinegar, lemon juice, and other acids turn blue litmus paper red. Sometimes chemists use other indicators to test for acids, but litmus is one of the easiest to use.

Properties of Bases

Bases are another group of compounds that can be identified by their common properties. **A base is a substance that tastes bitter, feels slippery, and turns red litmus paper blue.** Bases often are described as the "opposite" of acids. Common bases include sodium hydroxide, calcium hydroxide, and ammonia.

FIGURE 13
The Litmus Test
Litmus paper is an easy way to identify quickly whether an unknown compound is an acid or a base. Inferring *What can you infer about a liquid that does not change the color of blue litmus paper?*





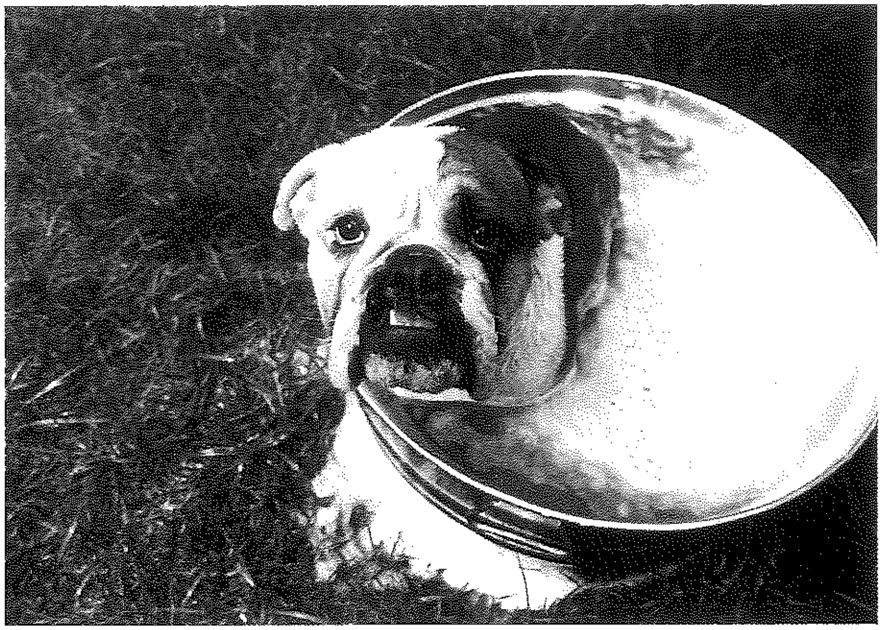


FIGURE 14
Bases in Soaps
If you give a dog a sudsy bath, bases in the soap could make your hands feel slippery.

Bitter Taste Have you ever tasted tonic water? The slightly bitter taste is caused by the base quinine. Bases taste bitter. Soaps, some shampoos, and detergents taste bitter too, but you wouldn't want to identify these as bases by a taste test!

Slippery Feel Picture yourself washing a dog. As you massage the soap into the dog's fur, you notice that your hands feel slippery. This slippery feeling is another characteristic of bases. But just as you avoid tasting a substance to identify it, you wouldn't want to touch it. Strong bases can irritate or burn your skin. A safer way to identify bases is by their other properties.

Reactions With Indicators As you might guess, if litmus paper can be used to test acids, it can be used to test bases, too. Look at Figure 13 to see what happens to a litmus paper as it is dipped in a basic solution. Bases turn red litmus paper blue. Like acids, bases react with other indicators. But litmus paper gives a reliable, safe test. An easy way to remember which color litmus turns for acids or bases is to remember the letter *b*. Bases turn litmus paper **b**lue.

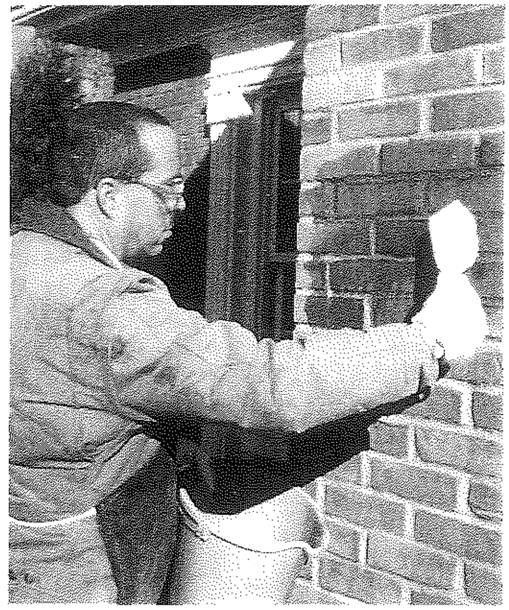
Other Reactions of Bases Unlike acids, bases don't react with carbonates to produce carbon dioxide. At first, you may think it is useless to know that a base doesn't react with certain chemicals. But if you know what a compound doesn't do, you know something about it. For example, you know it's not an acid. Another important property of bases is how they react with acids. You will learn more about these reactions in Section 4.

Reading Checkpoint **What is one safe way to identify a base?**

Go Online SCI LINKS NSTA
For: Links on acids and bases
Visit: www.SciLinks.org
Web Code: scn-1233

Figure 15
Uses of Acids
Acids play an important role in our nutrition and are also found in valuable products used in homes and industries.

Acids in the Home ▶
People often use dilute solutions of acids to clean brick and other surfaces. Hardware stores sell muriatic (hydrochloric) acid, which is used to clean bricks and metals.

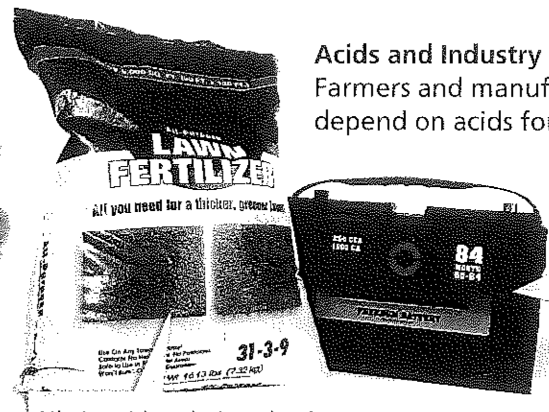


Acids and Food ▼
Many of the vitamins in the foods you eat are acids.

Tomatoes and oranges contain ascorbic acid, or vitamin C.

Folic acid, needed for healthy cell growth, is found in green leafy vegetables.

Acids and Industry ▼
Farmers and manufacturers depend on acids for many uses.



Sulfuric acid is used in car batteries, to refine petroleum, and to treat iron and steel.

Nitric acid and phosphoric acid are used to make fertilizers for crops, lawns, and gardens.

Uses of Acids and Bases

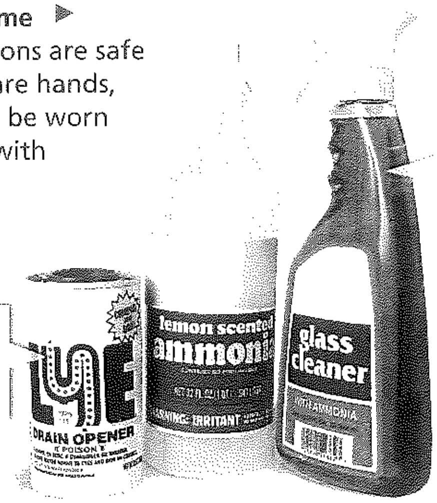
Where can you find acids and bases? Almost anywhere. You already learned that acids are found in many fruits and other foods. In fact, many of them play important roles in the body as vitamins, including ascorbic acid, or vitamin C, and folic acid. Many cell processes also produce acids as waste products. For example, lactic acid builds up in your muscles when you make them work hard.

Manufacturers, farmers, and builders are only some people who depend on acids and bases in their work. **Acids and bases have many uses around the home and in industry.** Look at Figure 15 and Figure 16 to learn about a few of them. Many of the uses of bases take advantage of their ability to react with acids.

Reading Checkpoint **What vitamin is an acid?**

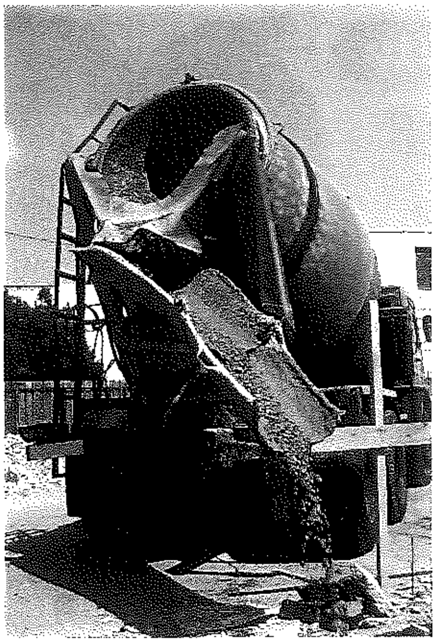
FIGURE 16
Uses of Bases
The reactions of bases make them valuable raw materials for a range of products.

Bases in the Home ▶
Ammonia solutions are safe to spray with bare hands, but gloves must be worn when working with drain cleaners.



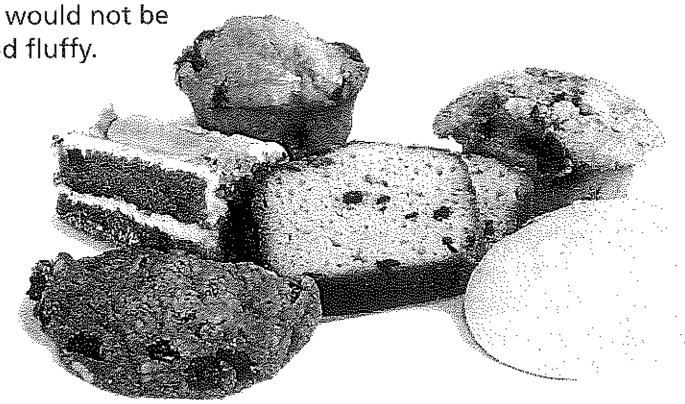
Drain cleaners contain sodium hydroxide (lye).

You can't mistake the odor of household cleaning products made with ammonia.



Bases and Industry ▲
Mortar and cement are manufactured using the bases calcium oxide and calcium hydroxide. Gardeners sometimes add calcium oxide to soil to make the soil less acidic for plants.

Bases and Food ▼
Baking soda reacts with acids to produce carbon dioxide gas in baked goods. Without these gas bubbles, this delicious variety of breads, biscuits, cakes, and cookies would not be light and fluffy.



Section 3 Assessment

Target Reading Skill Asking Questions Work with a partner to check the answers in your graphic organizer.

Reviewing Key Concepts

1. a. Listing What are four properties of acids? Of bases?
   b. Describing How can you use litmus paper to distinguish an acid from a base?
   c. Applying Concepts How might you tell if a food contains an acid as one of its ingredients?
2. a. Reviewing What are three practical uses of an acid? Of a base?
   b. Making Generalizations Where are you most likely to find acids and bases in your own home? Explain.
   c. Making Judgments Why is it wise to wear gloves when spreading fertilizer in a garden?

Writing in Science

Wanted Poster A bottle of acid is missing from the chemistry lab shelf! Design a wanted poster describing properties of the missing acid. Also include descriptions of tests a staff member from the chemistry lab could *safely* perform to determine if a bottle that is found actually contains acid. Add a caution on your poster that warns people *not* to touch any bottles they find. Instead, they should notify the chemistry lab.

Section 4

Acids and Bases in Solution

Reading Preview

Key Concepts

- What kinds of ions do acids and bases form in water?
- What does pH tell you about a solution?
- What happens in a neutralization reaction?

Key Terms

- hydrogen ion (H^+)
- hydroxide ion (OH^-)
- pH scale • neutralization • salt

Target Reading Skill

Previewing Visuals When you preview, you look ahead at the material to be read. Preview Figure 21. Then write two questions that you have about the diagram in a graphic organizer like the one below. As you read, answer your questions.

Neutralization

Q. What is a neutral solution?
A.
Q.

Lab zone **Discover Activity**

What Can Cabbage Juice Tell You?

1. Using a dropper, put 5 drops of red cabbage juice into each of three separate plastic cups.
2. Add 10 drops of lemon juice (an acid) to one cup. Add 10 drops of ammonia cleaner (a base) to another. Keep the third cup for comparison. Record the colors you see.
3. Now add ammonia, 1 drop at a time, to the cup containing lemon juice. Keep adding ammonia until the color no longer changes. Record all color changes you see.
4. Add lemon juice a drop at a time to the ammonia until the color no longer changes. Record the changes you see.

Think It Over

Forming Operational Definitions Based on your observations, what could you add to your definitions of acids and bases?

A chemist pours hydrochloric acid into a beaker. Then she adds sodium hydroxide to the acid. The mixture looks the same, but the beaker becomes warm. If she tested the solution with litmus paper, what color would the paper turn? Would you be surprised if it did not change color at all? If exactly the right amounts and concentrations of the acid and the base were mixed, the beaker would hold nothing but salt water!

Acids and Bases in Solution

How can two corrosive chemicals, an acid and a base, produce something harmless to the touch? To answer this question, you must know what happens to acids and bases in solution.

Acids What do acids have in common? Notice that each formula in the list of acids in Figure 17 begins with hydrogen. The acids you will learn about in this section produce one or more hydrogen ions and a negative ion in solution with water. A **hydrogen ion** (H^+) is an atom of hydrogen that has lost its electron. The negative ion may be a nonmetal or a polyatomic ion. Hydrogen ions are the key to the reactions of acids.

Go Online PHSchool.com

For: More on pH scale
Visit: PHSchool.com
Web Code: cgd-2034

Important Acids and Bases			
Acid	**Formula**	**Base**	**Formula**
Hydrochloric acid	HCl	Sodium hydroxide	$NaOH$
Nitric acid	HNO_3	Potassium hydroxide	KOH
Sulfuric acid	H_2SO_4	Calcium hydroxide	$Ca(OH)_2$
Carbonic acid	H_2CO_3	Aluminum hydroxide	$Al(OH)_3$
Acetic acid	$HC_2H_3O_2$	Ammonia	NH_3
Phosphoric acid	H_3PO_4	Calcium oxide	CaO

FIGURE 17
The table lists some commonly encountered acids and bases.
Making Generalizations *What do all of the acid formulas in the table have in common?*

Acids in water solution separate into hydrogen ions (H^+) and negative ions. In the case of hydrochloric acid, for example, hydrogen ions and chloride ions form:

$$HCl \xrightarrow{\text{water}} H^+ + Cl^-$$

Now you can add to the definition of acids you learned in Section 3. **An acid is any substance that produces hydrogen ions (H^+) in water.** These hydrogen ions cause the properties of acids. For instance, when you add certain metals to an acid, hydrogen ions interact with the metal atoms. One product of the reaction is hydrogen gas (H_2). Hydrogen ions also react with blue litmus paper, turning it red. That's why every acid gives the same litmus test result.

Bases The formulas of bases give you clues to what ions they have in common. You can see in the table in Figure 17 that many bases are made of positive ions combined with hydroxide ions. The **hydroxide ion (OH^-)** is a negative ion, made of oxygen and hydrogen. When bases dissolve in water, the positive ions and hydroxide ions separate. Look, for example, at what happens to sodium hydroxide:

$$NaOH \xrightarrow{\text{water}} Na^+ + OH^-$$

Not every base contains hydroxide ions. For example, the gas ammonia (NH_3) does not. But in solution, ammonia is a base that reacts with water to form hydroxide ions.

$$NH_3 + H_2O \longrightarrow NH_4^+ + OH^-$$

Notice that in both reactions, there are negative hydroxide ions. **A base is any substance that produces hydroxide ions (OH^-) in water.** Hydroxide ions are responsible for the bitter taste and slippery feel of bases, and turn red litmus paper blue.

FIGURE 18
Comparing Bases
Many bases are made of positive ions combined with hydroxide ions.

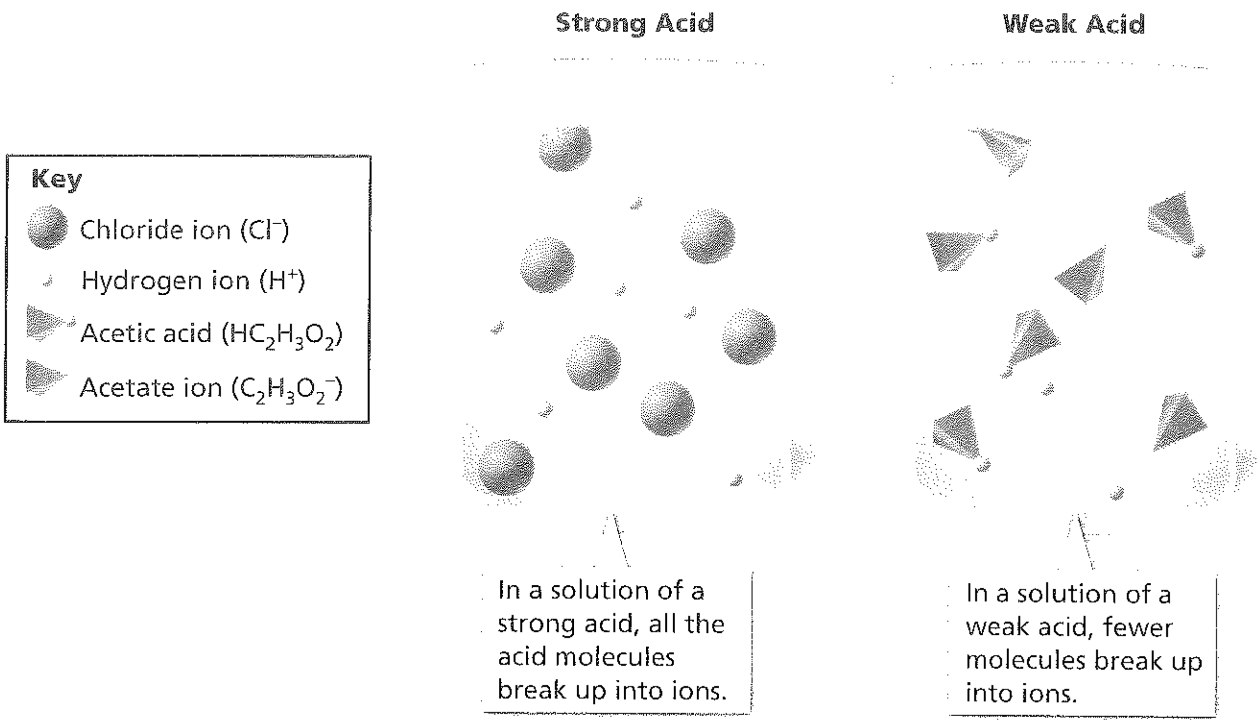


FIGURE 19
Acids in Solution
Strong acids and weak acids act differently in water. Hydrochloric acid (left) is a strong acid. Acetic acid (right) is a weak acid.

Lab zone Try This Activity

pHone Home

1. Select materials such as fruit juices, soda water, coffee, tea, and antacids. If the sample is solid, dissolve some in a cup of water. Use a liquid as is.
2. Predict which materials are most acidic or most basic.
3. Using a plastic dropper, transfer a drop of one sample onto a fresh strip of pH test paper.
4. Compare the color of the strip to the pH test scale on the package.
5. Repeat for all your samples, rinsing the dropper between tests.

Interpreting Data List the samples from lowest to highest pH. Did any results surprise you?

Strength of Acids and Bases

Acids and bases may be strong or weak. Strength refers to how well an acid or a base produces ions in water. As shown in Figure 19, the molecules of a strong acid react to form ions in solution. With a weak acid, very few molecules form ions. At the same concentration, a strong acid produces more hydrogen ions (H^+) than a weak acid does. Examples of strong acids include hydrochloric acid, sulfuric acid, and nitric acid. Most other acids, such as acetic acid, are weak acids.

Strong bases react in a water solution in a similar way to strong acids. A strong base produces more hydroxide (OH^-) ions than does an equal concentration of a weak base. Ammonia is a weak base. Lye, or sodium hydroxide, is a strong base.

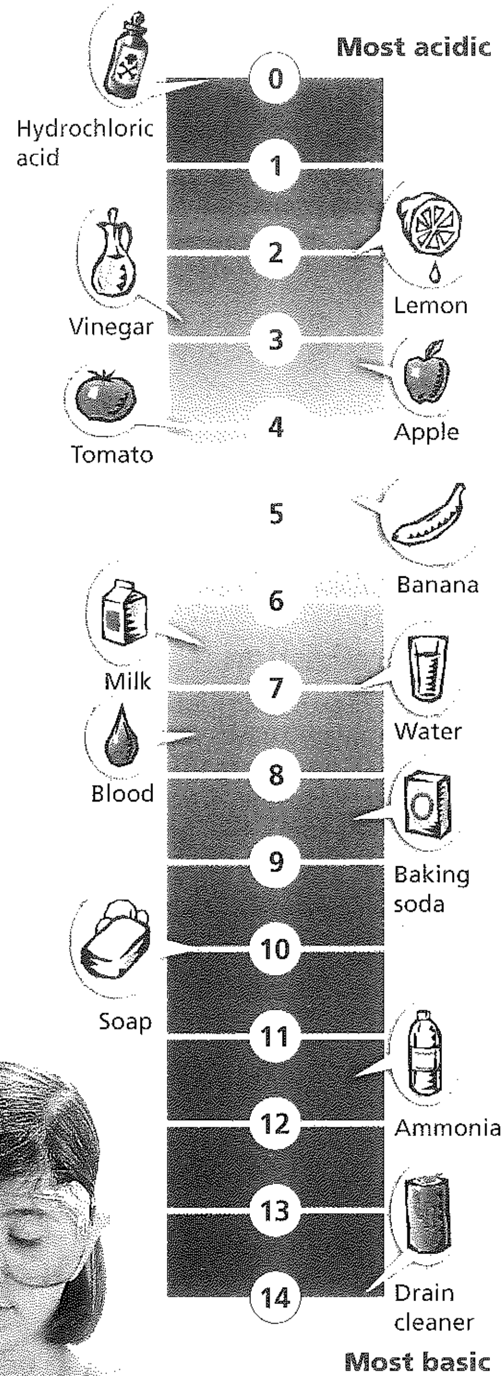
Measuring pH Knowing the concentration of hydrogen ions is the key to knowing how acidic or basic a solution is. To describe the concentration of ions, chemists use a numeric scale called pH. The **pH scale** is a range of values from 0 to 14. It expresses the concentration of hydrogen ions in a solution.

Figure 20 shows where some familiar substances fit on the pH scale. Notice that the most acidic substances are at the low end of the scale. The most basic substances are at the high end of the scale. You need to remember two important points about pH. **A low pH tells you that the concentration of hydrogen ions is high. In contrast, a high pH tells you that the concentration of hydrogen ions is low.** If you keep these ideas in mind, you can make sense of how the scale works.

You can find the pH of a solution by using indicators. The student in Figure 20 is using indicator paper that turns a different color for each pH value. Matching the color of the paper with the colors on the test scale tells how acidic or basic the solution is. A pH lower than 7 is acidic. A pH higher than 7 is basic. If the pH is 7, the solution is neutral. That means it's neither an acid nor a base. Pure water has a pH of 7.

Using Acids and Bases Safely Strength determines, in part, how safe acids and bases are to use. People often say that a solution is weak when they mean it is dilute. This could be a dangerous mistake! Even a dilute solution of hydrochloric acid can eat a hole in your clothing. An equal concentration of acetic acid, however, will not. In order to handle acids and bases safely, you need to know both their pH and their concentration.

Reading Checkpoint **How would a weak base differ from an equal concentration of a strong base?**



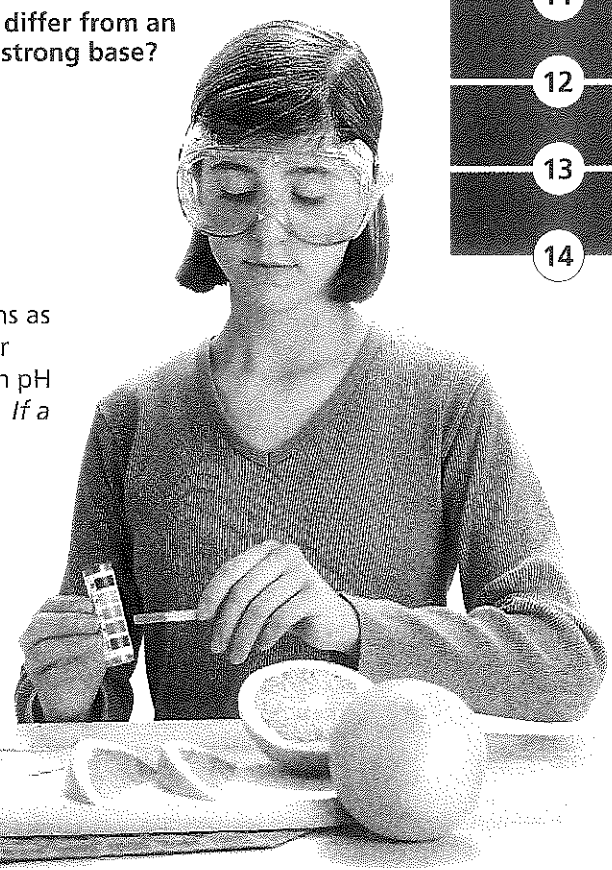


FIGURE 20
The pH Scale
The pH scale classifies solutions as acidic or basic. Indicator paper turns a different color for each pH value. Interpreting Diagrams *If a solution has a pH of 9, is it acidic or basic?*

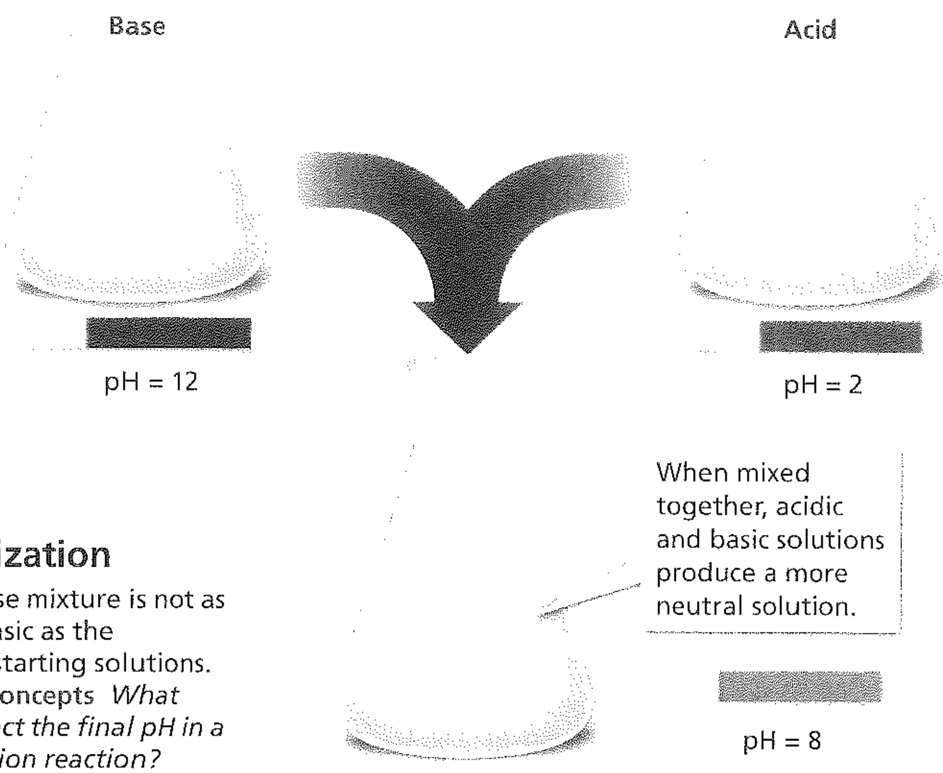


FIGURE 21
Neutralization
An acid-base mixture is not as acidic or basic as the individual starting solutions. **Applying Concepts** *What factors affect the final pH in a neutralization reaction?*

Acid-Base Reactions

The story at the start of this section describes a chemist who mixed hydrochloric acid with sodium hydroxide. She got a solution of table salt (sodium chloride) and water.

$$HCl + NaOH \longrightarrow H_2O + Na^+ + Cl^-$$

If you tested the pH of the mixture, it would be close to 7, or neutral. In fact, a reaction between an acid and a base is called **neutralization** (noo truh lih ZAY shun).

Reactants After neutralization, an acid-base mixture is not as acidic or basic as the individual starting solutions were. Sometimes an acid-base reaction even results in a neutral solution. The final pH depends on such factors as the volumes, concentrations, and identities of the reactants. For example, some acids and bases react to form products that are not neutral. Also, common sense tells you that if only a small amount of strong base is reacted with a much larger amount of strong acid, the solution will remain acidic.

Products "Salt" may be the familiar name of the stuff you sprinkle on food. But to a chemist, the word refers to a specific group of compounds. A **salt** is any ionic compound that can be made from the neutralization of an acid with a base. A salt is made from the positive ion of a base and the negative ion of an acid.

Look at the equation for the reaction of nitric acid with potassium hydroxide:

$$HNO_3 + KOH \rightarrow H_2O + K^+ + NO_3^-$$

One product of the reaction is water. The other product is potassium nitrate (KNO_3), a salt. **In a neutralization reaction, an acid reacts with a base to produce a salt and water.** Potassium nitrate is written in the equation as separate K^+ and NO_3^- ions because it is soluble in water. Some salts, such as potassium nitrate, are soluble. Others form precipitates because they are insoluble. Look at the table in Figure 22 to see a list of some common salts and their formulas.

Common Salts

Salt	Uses
Sodium chloride $NaCl$	Food flavoring; food preservative
Potassium iodide KI	Additive in "iodized" salt that prevents iodine deficiency
Calcium chloride $CaCl_2$	De-icer for roads and walkways
Potassium chloride KCl	Salt substitute in foods
Calcium carbonate $CaCO_3$	Found in limestone and seashells
Ammonium nitrate NH_4NO_3	Fertilizer; active ingredient in cold packs

FIGURE 22
Each salt listed in this table can be formed by the reaction between an acid and a base.

Reading Checkpoint **What is a salt?**

Section 4 Assessment

Target Reading Skill Previewing Visuals Refer to your questions and answers about Figure 21 to help you answer Question 3 below.

Reviewing Key Concepts

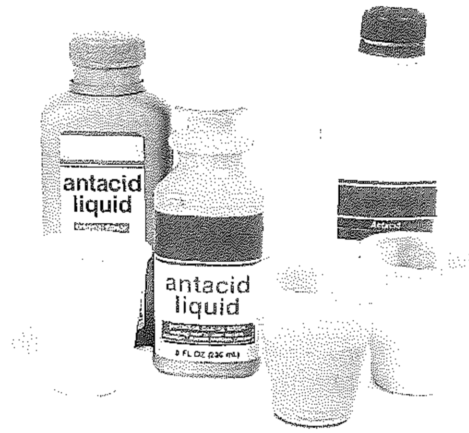
1. a. Identifying Which element is found in all the acids described in this section?
   b. Describing What kinds of ions do acids and bases form in water?
   c. Predicting What ions will the acid HNO_3 form when dissolved in water?
2. a. Reviewing What does a substance's pH tell you?
   b. Comparing and Contrasting If a solution has a pH of 6, would the solution contain more or fewer hydrogen ions (H^+) than an equal volume of solution with a pH of 3?
   c. Making Generalizations Would a dilute solution of HCl also be weak? Explain.
3. a. Reviewing What are the reactants of a neutralization reaction?
   b. Explaining What happens in a neutralization reaction?
   c. Problem Solving What acid reacts with KOH to produce the salt KCl?

Lab zone At-Home Activity

pH Lineup With a family member, search your house and refrigerator for the items found on the pH scale shown in Figure 20. Line up what you are able to find in order of increasing pH. Then ask your family member to guess why you ordered the substances in this way. Use the lineup to explain what pH means and how it is measured.

Lab zone **Consumer Lab**

The Antacid Test



Problem

Which antacid neutralizes stomach acid with the smallest number of drops?

Skills Focus

designing experiments, interpreting data, measuring

Materials

- 3 plastic droppers
- small plastic cups
- dilute hydrochloric acid (HCl), 50 mL
- methyl orange solution, 1 mL
- liquid antacid, 30 mL of each brand tested

Procedure

PART 1

1. Using a plastic dropper, put 10 drops of hydrochloric acid (HCl) into one cup. **CAUTION:** *HCl is corrosive. Rinse spills and splashes immediately with water.*
2. Use another plastic dropper to put 10 drops of liquid antacid into another cup.
3. In your notebook, make a data table like the one below. Record the colors of the HCl and the antacid.

Data Table		
Substance	Original Color	Color With Indicator
Hydrochloric Acid		
Antacid Brand A		
Antacid Brand B		

4. Add 2 drops of methyl orange solution to each cup. Record the colors you see.
5. Test each of the other antacids. Discard all the solutions and cups as directed by your teacher.

PART 2

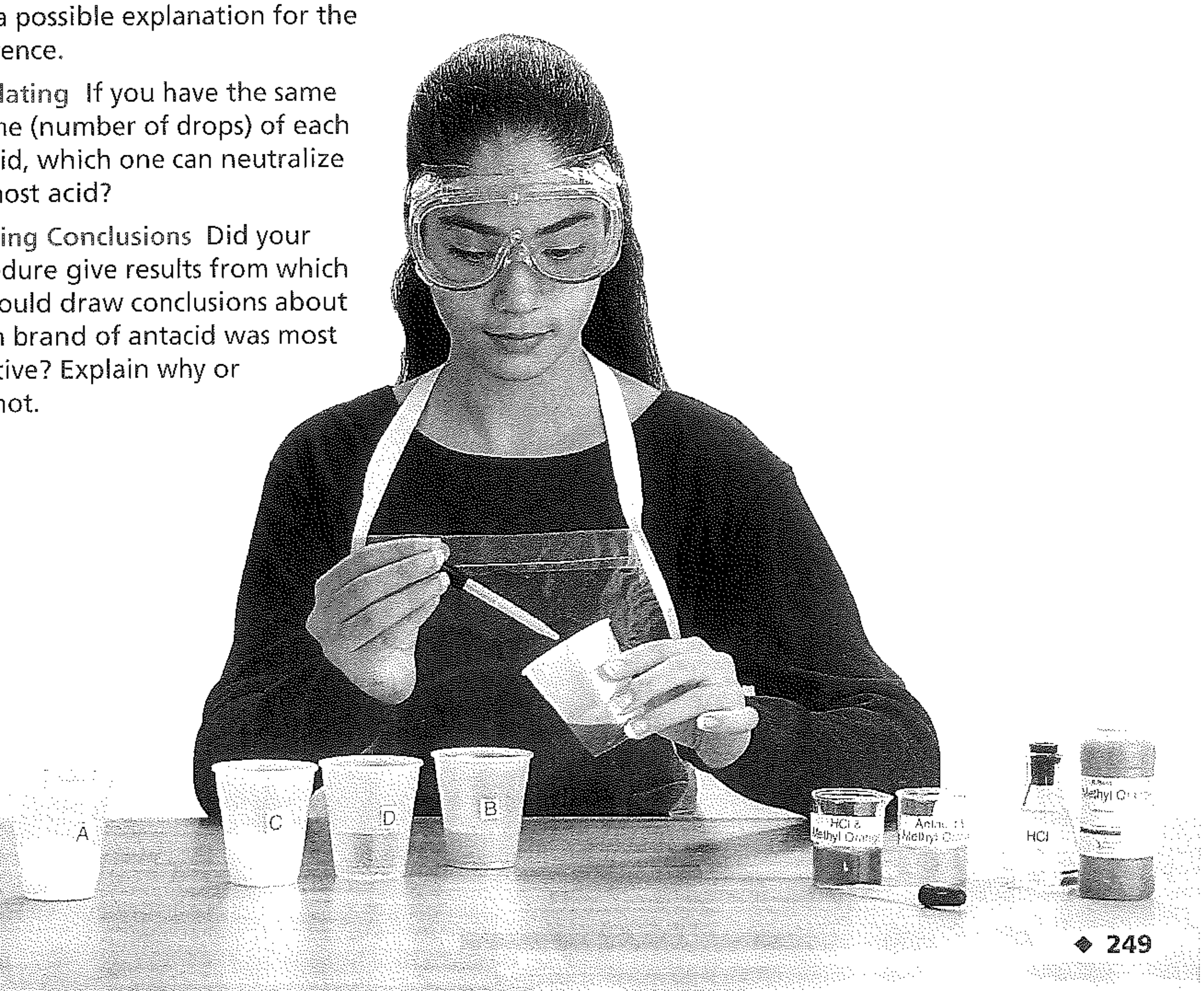
6. Methyl orange changes color at a pH of about 4. Predict the color of the solution you expect to see when an antacid is added to a mixture of methyl orange and HCl.
7. Design a procedure for testing the reaction of each antacid with HCl. Decide how many drops of acid and methyl orange you need to use each time.
8. Devise a plan for adding the antacid so that you can detect when a change occurs. Decide how much antacid to add each time and how to mix the solutions to be sure the indicator is giving accurate results.
9. Make a second data table to record your observations.
10. Carry out your procedure and record your results.
11. Discard the solutions and cups as directed by your teacher. Rinse the plastic droppers thoroughly.
12. Wash your hands thoroughly when done.

Analyze and Conclude

1. Designing Experiments What is the function of the methyl orange solution?
2. Interpreting Data Do your observations support your predictions from Step 6? Explain why or why not.
3. Inferring Why do you think antacids reduce stomach acid? Explain your answer, using the observations you made.
4. Controlling Variables Explain why it is important to use the same number of drops of HCl in each trial.
5. Measuring Which antacid neutralized the HCl with the smallest number of drops? Give a possible explanation for the difference.
6. Calculating If you have the same volume (number of drops) of each antacid, which one can neutralize the most acid?
7. Drawing Conclusions Did your procedure give results from which you could draw conclusions about which brand of antacid was most effective? Explain why or why not.
8. Communicating Write a brochure that explains to consumers what information they need to know in order to decide which brand of antacid is the best buy.

Design an Experiment

A company that sells a liquid antacid claims that its product works faster than tablets to neutralize stomach acid. Design an experiment to compare how quickly liquid antacids and chewable antacid tablets neutralize hydrochloric acid. *Obtain your teacher's permission before carrying out your investigation.*



Section 5

Integrating Life Science

Digestion and pH

Reading Preview

Key Concepts

- Why must your body digest food?
- How does pH affect digestion?

Key Terms

- digestion
- mechanical digestion
- chemical digestion

Target Reading Skill

Sequencing A sequence is the order in which a series of events occurs. As you read, make a flowchart that shows the sequence of changes in pH as food moves through the digestive system.

pH During Digestion

At a pH near 7, enzymes in the mouth start to break down carbohydrates.

↓

At a pH near 2, stomach enzymes break down proteins.

↓

Lab zone **Discover Activity**

Where Does Digestion Begin?

1. Obtain a bite-sized piece of crusty bread.
2. Chew the bread for about one minute. Do not swallow until after you notice a change in taste.

Think It Over

Inferring How did the bread taste before and after you chewed it? How can you explain the change in taste?

You may have seen commercials like the following: A man has a stomachache after eating spicy food. A voice announces that the problem is excess stomach acid. The remedy is an antacid tablet.

Ads like this one highlight the role of chemistry in digestion. You need to have acid in your stomach. But too much acid is a problem. Other parts of your digestive system need to be basic. What roles do acids and bases play in the digestion of food?

What Is Digestion?

Foods are made mostly of water and three groups of compounds: carbohydrates, proteins, and fats. Except for water, your body can't use foods in the form they are in when you eat them. **Foods must be broken down into simpler substances that your body can use for raw materials and energy.**

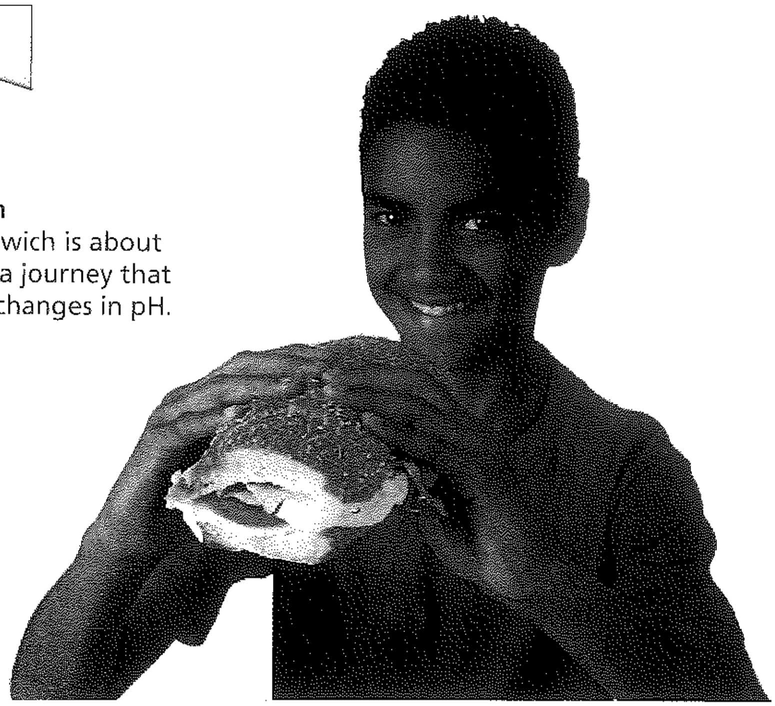


FIGURE 23
Digestion
This sandwich is about to begin a journey that includes changes in pH.

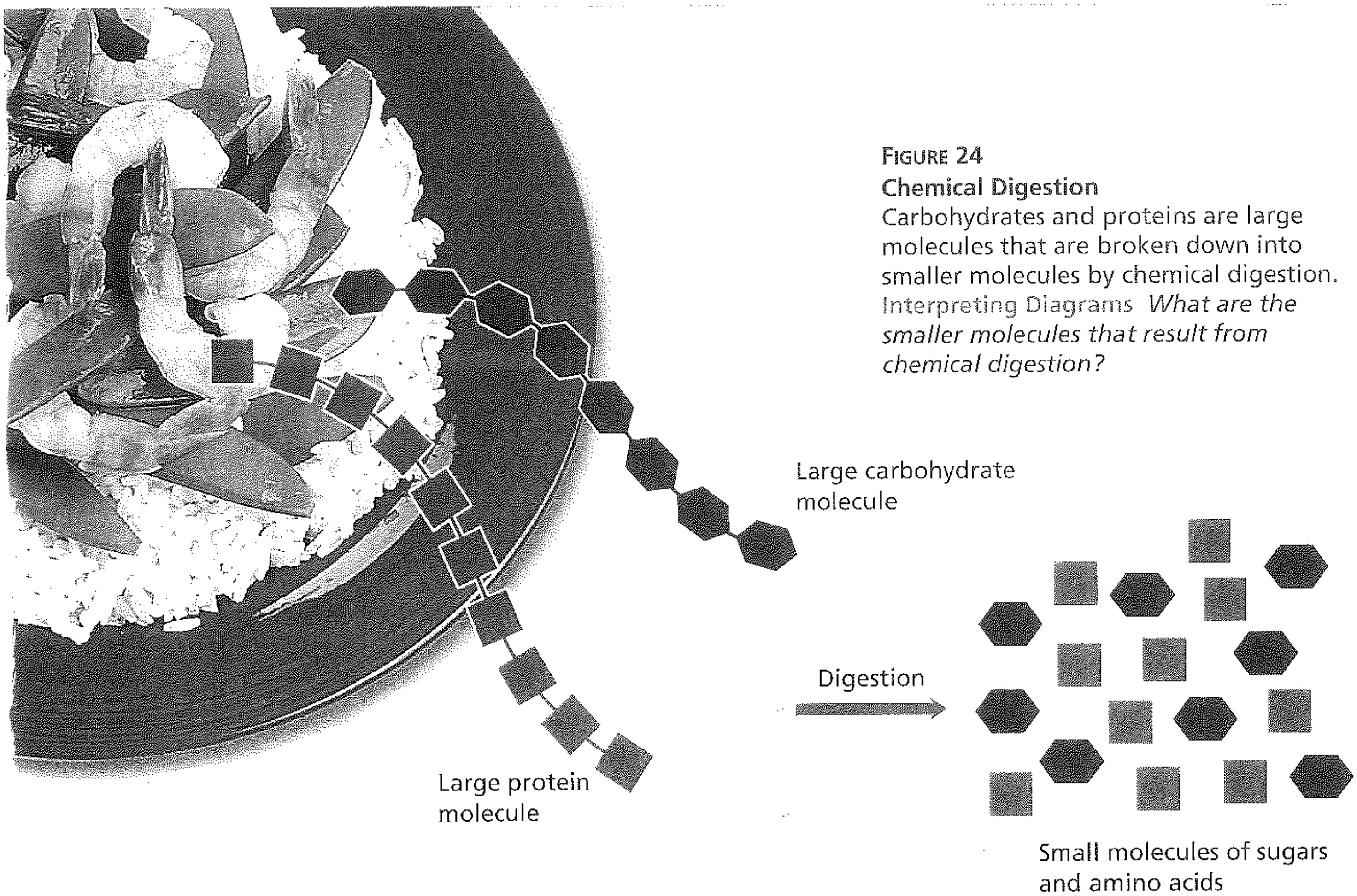


FIGURE 24
Chemical Digestion
Carbohydrates and proteins are large molecules that are broken down into smaller molecules by chemical digestion.
Interpreting Diagrams *What are the smaller molecules that result from chemical digestion?*

The process of **digestion** breaks down the complex molecules of foods into smaller molecules. Digestion has two parts—mechanical and chemical.

Mechanical Digestion **Mechanical digestion** is a physical process in which large pieces of food are torn and ground into smaller pieces. The result is similar to what happens when a sugar cube is hit with a hammer. The size of the food is reduced, but the food isn't changed into other compounds.

Chemical Digestion **Chemical digestion** breaks large molecules into smaller ones. Look at Figure 24 to see what happens to large carbohydrate and protein molecules during chemical digestion. They are broken down into much smaller molecules. Some molecules are used by the body to get energy. Others become building blocks for muscle, bone, skin, and other organs.

Chemical digestion takes place with the help of enzymes. You may recall that enzymes are catalysts that speed up reactions in living things. Enzymes require just the right conditions to work, including temperature and pH. **Some digestive enzymes work at a low pH. For others, the pH must be high or neutral.**

Reading Checkpoint **What happens to foods during chemical digestion?**

pH in the Digestive System

A bite of sandwich is about to take a journey through your digestive system. Figure 25 shows the main parts of the human digestive system. As you read, trace the food's pathway through the body. Keep track of the pH changes that affect the food molecules along the way.

Your Mouth The first stop in the journey is your mouth. Your teeth chew and mash the food. The food also is mixed with a watery fluid called saliva. Have you ever felt your mouth water at the smell of something delicious? The odor of food can trigger production of saliva.

What would you expect the usual pH of saliva to be? Remember that saliva tastes neither sour nor bitter. So you're correct if you think your mouth has a pH near 7, the neutral point.

Saliva contains amylase (AM uh lays), an enzyme that helps break down the carbohydrate starch into smaller sugar molecules. Amylase works best when the pH is near 7. You can sense the action of this enzyme if you chew a piece of bread. After about two minutes in your mouth, the starch is broken down into sugars. The sugars make the bread taste sweet.

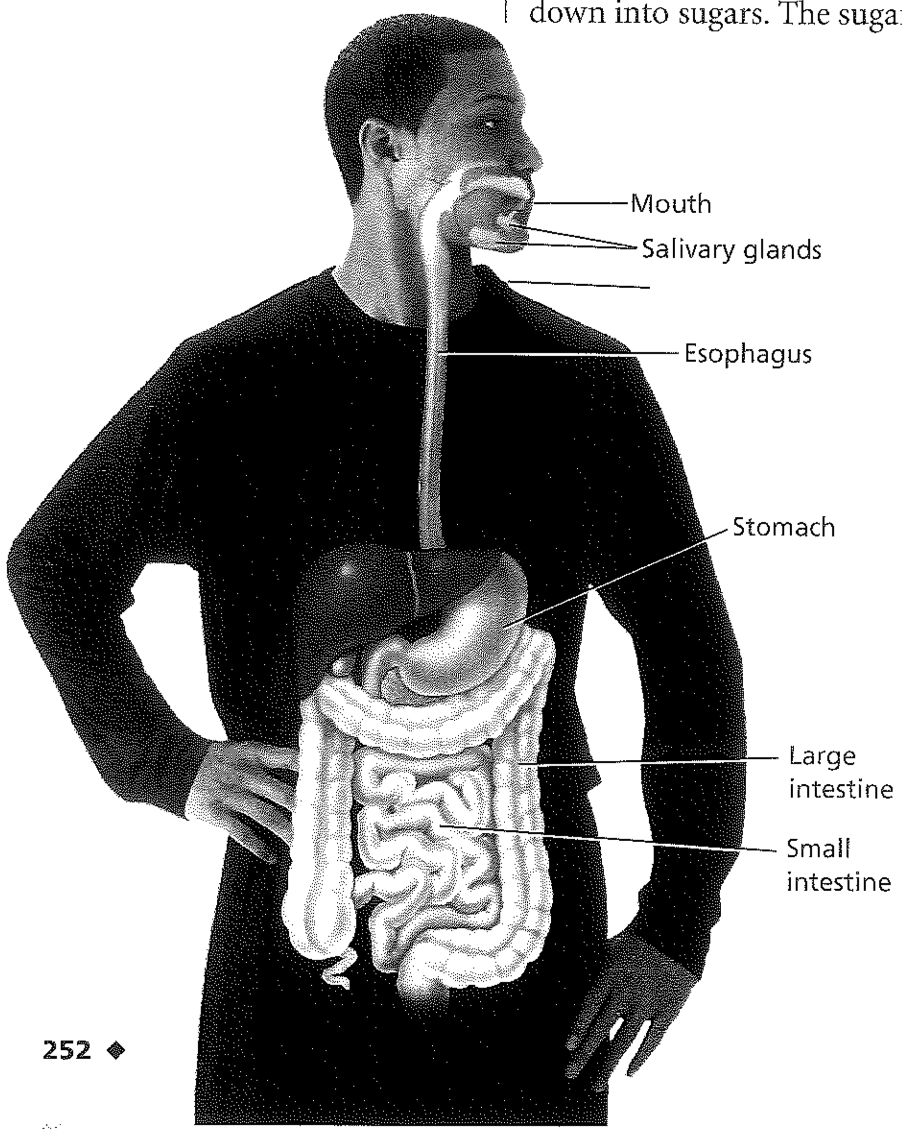


FIGURE 25
Foods are exposed to several changes in pH as they move through the digestive system.
Relating Cause and Effect *Why do certain digestive enzymes work only in certain parts of the digestive system?*

pH Changes During Digestion

Organ	pH
Mouth	7
Stomach	2
Small intestine	8

Your Stomach Next, the food is swallowed and arrives in your stomach, where mechanical digestion continues. Also, chemical digestion begins for foods that contain protein, such as meat, fish, and beans. Cells in the lining of your stomach release enzymes and hydrochloric acid. In contrast to the near-neutral pH of your mouth, the pH here drops to a very acidic level of about 2.

The low pH in your stomach helps digestion take place. Pepsin is one enzyme that works in your stomach. Pepsin helps break down proteins into small molecules called amino acids. Most enzymes work best in a solution that is nearly neutral. But pepsin is different. It works most effectively in acids.

Your Small Intestine Your stomach empties its contents into the small intestine. Here, digestive fluid containing bicarbonate ions (HCO_3^-) surrounds the food. This ion creates a slightly basic solution, with a pH of about 8. At this slightly basic pH, enzymes of the small intestine work best. These enzymes complete the breakdown of carbohydrates, fats, and proteins.

By now, the large food molecules from the sandwich have been split up into smaller ones. These smaller molecules pass through the walls of the small intestine into your bloodstream and are carried to the cells that will use them.

Reading Checkpoint **What acid do the cells in the lining of your stomach release?**

Go Online
SCI LINKS NSTA
For: Links on digestion and pH
Visit: www.SciLinks.org
Web Code: scn-1235

Section 5 Assessment

Target Reading Skill Sequencing Refer to your flowchart about the digestive system as you answer Question 2.

Reviewing Key Concepts

1. a. Reviewing What are the two parts of digestion?
   b. Comparing and Contrasting How do these two processes differ?
   c. Inferring People who have lost most of their teeth may have trouble chewing their food. How does this affect their digestive process?
2. a. Listing What is the pH in your mouth? Stomach? Small intestine?
   b. Sequencing Arrange the three body locations in part (a) from least acidic to most acidic.
   c. Applying Concepts Why are pH variations in different parts of the digestive system important to the process of digestion?

Writing in Science

News Report Suppose you are a news reporter who can shrink down in size and be protected from changes in the environment with a special suit. You are assigned to accompany a bite of food as it travels through the digestive system. Report your findings in a dramatic but accurate way. Include a catchy headline.

Chapter 7 Study Guide

The BIG Idea **Properties of Matter** When acids and bases form solutions in water, their properties may be tested with indicators and observed in chemical reactions.

1 Understanding Solutions

Key Concepts

- A solution has the same properties throughout. It contains solute particles that are too small to see.
- A colloid contains larger particles than a solution. The particles are still too small to be seen easily, but are large enough to scatter a light beam.
- Unlike a solution, a suspension does not have the same properties throughout. It contains visible particles that are larger than the particles in solutions or colloids.
- When a solution forms, particles of the solute leave each other and become surrounded by particles of the solvent.
- Solutes lower the freezing point and raise the boiling point of a solvent.

Key Terms

solution, solvent, solute, colloid, suspension

2 Concentration and Solubility

Key Concepts

- To measure concentration, you compare the amount of solute to the amount of solvent or to the total amount of solution.
- Solubility can be used to help identify a substance because it is a characteristic property of matter.
- Factors that affect the solubility of a substance include pressure, the type of solvent, and temperature.

Key Terms

dilute solution
concentrated solution
solubility
saturated solution
unsaturated solution
supersaturated solution

3 Describing Acids and Bases

Key Concepts

- An acid is a substance that tastes sour, reacts with metals and carbonates, and turns blue litmus paper red.
- A base is a substance that tastes bitter, feels slippery, and turns red litmus paper blue.
- Acids and bases have many uses around the home and in industry.

Key Terms

• acid • corrosive • indicator • base

4 Acids and Bases in Solution

Key Concepts

- An acid is any substance that produces hydrogen ions (H^+) in water.
- A base is any substance that produces hydroxide ions (OH^-) in water.
- A low pH tells you that the concentration of hydrogen ions is high. In contrast, a high pH tells you that the concentration of hydrogen ions is low.
- In a neutralization reaction, an acid reacts with a base to produce a salt and water.

Key Terms

• hydrogen ion (H^+) • hydroxide ion (OH^-)
• pH scale • neutralization • salt

5 Digestion and pH

Key Concepts

- Foods must be broken down into simpler substances that your body can use for raw materials and energy.
- Some digestive enzymes work at a low pH. For others, the pH must be high or neutral.

Key Terms

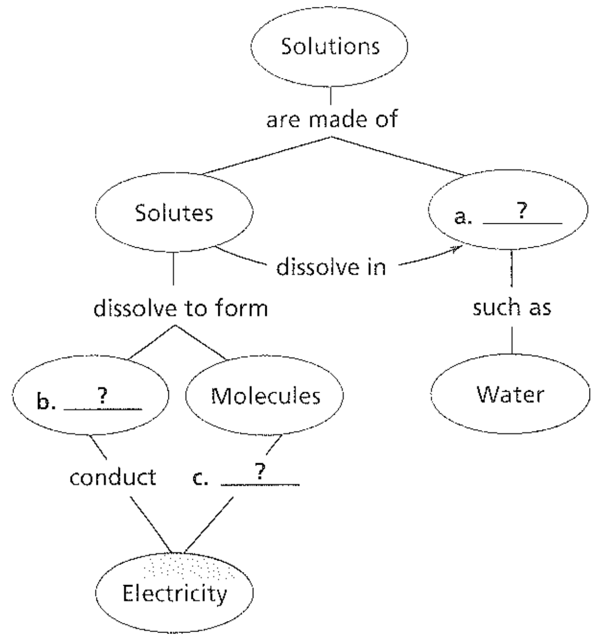
digestion, mechanical digestion, chemical digestion

Review and Assessment

Go Online
PHSchool.com
For: Self-Assessment
Visit: PHSchool.com
Web Code: cga-2030

Organizing Information

Concept Mapping Copy the concept map about solutions onto a sheet of paper. Then complete it and add a title. (For more on Concept Mapping, see the Skills Handbook.)



Reviewing Key Terms

Choose the letter of the best answer.

1. Sugar water is an example of a
   a. suspension.
   b. solution.
   c. solute.
   d. colloid.
2. A solution in which more solute may be dissolved at a given temperature is a(n)
   a. neutral solution.
   b. unsaturated solution.
   c. supersaturated solution.
   d. saturated solution.
3. A compound that changes color when it contacts an acid or a base is called a(n)
   a. solute.
   b. solvent.
   c. indicator.
   d. salt.
4. A polyatomic ion made of hydrogen and oxygen is called a
   a. hydroxide ion.
   b. hydrogen ion.
   c. salt.
   d. base.
5. Ammonia is an example of a(n)
   a. acid.
   b. salt.
   c. base.
   d. antacid.
6. The physical part of digestion is called
   a. digestion.
   b. mechanical digestion.
   c. chemical digestion.
   d. solubility.

Writing in Science

Product Label Suppose you are a marketing executive for a maple syrup company. Write a description of the main ingredients of maple syrup that can be pasted on the syrup's container. Use what you've learned about concentration to explain how dilute tree sap becomes sweet, thick syrup.

Review and Assessment

Checking Concepts

7. Explain how you can tell the difference between a solution and a clear colloid.
8. Describe at least two differences between a dilute solution and a concentrated solution of sugar water.
9. Tomatoes are acidic. Predict two properties of tomato juice that you would be able to observe.
10. Explain how an indicator helps you distinguish between an acid and a base.
11. Give an example of a very acidic pH value.
12. What combination of acid and base can be used to make the salt sodium chloride?

Thinking Critically

13. Applying Concepts A scuba diver can be endangered by "the bends." Explain how the effects of pressure on the solubility of gases is related to this condition.
14. Relating Cause and Effect If you leave a glass of cold tap water on a table, sometime later you may see tiny bubbles of gas form in the water. Explain what causes these bubbles to appear.
15. Drawing Conclusions You have two clear liquids. One turns blue litmus paper red and one turns red litmus paper blue. If you mix them and retest with both litmus papers, no color changes occur. Describe the reaction that took place when the liquids were mixed.
16. Comparing and Contrasting Compare the types of particles formed in a water solution of an acid with those formed in a water solution of a base.
17. Problem Solving Fill in the missing salt product in the reaction below.

$$HCl + KOH \longrightarrow H_2O + \underline{?}$$

18. Predicting Suppose a person took a dose of antacid greater than what is recommended. Predict how this action might affect the digestion of certain foods.

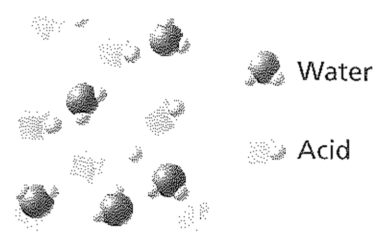
Math Practice

19. Calculating a Concentration If you have 1,000 grams of a 10-percent solution of sugar water, how much sugar is dissolved in the solution?
20. Calculating a Concentration The concentration of an alcohol and water solution is 25 percent alcohol by volume. What is the volume of alcohol in 200 mL of the solution?

Applying Skills

Use the diagram to answer Questions 21–24.

The diagram below shows the particles of an unknown acid in a water solution.



21. Interpreting Diagrams How can you tell that the solution contains a weak acid?
22. Inferring Which shapes in the diagram represent ions?
23. Making Models Suppose another unknown acid is a strong acid. Make a diagram to show the particles of this acid dissolved in water.
24. Drawing Conclusions Explain how the pH of a strong acid compares with the pH of a weak acid of the same concentration.

Lab zone Chapter Project

Performance Assessment Demonstrate the indicators you prepared. For each indicator, list the substances you tested in order from most acidic to least acidic. Would you use the same materials if you did this project again? Explain.

Standardized Test Prep

Test-Taking Tip

Eliminating Incorrect Answers

When answering a multiple choice question, you can often eliminate some answer choices because they are clearly incorrect. By doing so, you increase your odds of choosing the correct answer.

Sample Question

A scientist observes that an unknown solution turns blue litmus paper red and reacts with zinc to produce hydrogen gas. The unknown solution is most likely

A a colloid.
B an acid.
C a base.
D a suspension.

Answer

The correct answer is **B**. You can eliminate **A** and **D** because indicators, such as litmus paper, are used to determine whether a substance is an acid or a base. You have now narrowed your choices to **B** and **C**. **C** is incorrect because bases turn red litmus paper blue and do not react with metals to produce hydrogen gas.

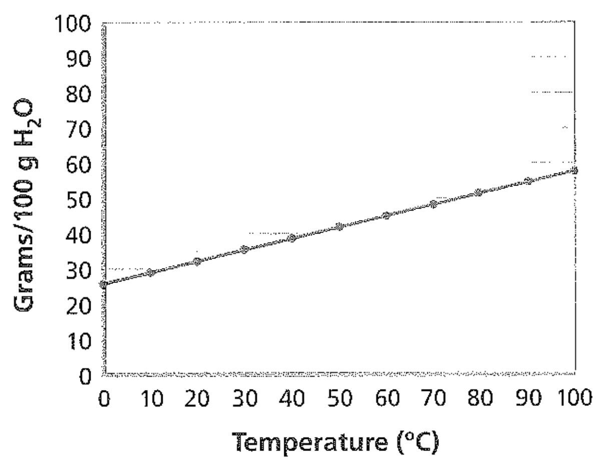
Choose the letter of the best answer.

1. Which of the following pH values indicates a solution with the highest concentration of hydrogen ions?
   A pH = 1
   B pH = 2
   C pH = 7
   D pH = 14

2. A small beaker contains 50 milliliters of water at 20°C. If three sugar cubes are placed in the beaker, they will eventually dissolve. Which action would speed up the rate at which the sugar cubes dissolve?
   F Use less water initially.
   G Transfer the contents to a larger beaker.
   H Cool the water and sugar cubes to 5°C.
   J Heat and stir the contents of the beaker.

Use the graph below and your knowledge of science to answer Question 3.

Solubility of Potassium Chloride (KCl)



3. If 30 grams of KCl are dissolved in 100 grams of water at 50°C, the solution can be best described as
   A saturated.
   B supersaturated.
   C unsaturated.
   D soluble.

4. Which safety procedures should be followed when using acids and bases in the laboratory?
   F Wear an apron and safety goggles.
   G Dispose of chemical wastes properly.
   H Wash your hands before leaving the lab.
   J all of the above

Constructed Response

5. Salt water is a solution of table salt (the solute) and water (the solvent). Describe a laboratory procedure that could be used to determine the concentration of salt in a sample of salt water. Indicate all measurements that must be made. (*Hint:* Remember that the concentration of a solution can be expressed as a ratio of the mass of the solute to the mass of the solution.)