CHAPTER 6

Acids, Bases, and Solutions

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Fruits and fruit juices often contain weak acids.

CHAPTER 6 PROJECT

Make Your Own Indicator

These delicious-looking fruits are more than just nutritious, juicy treats. Many fruits are acidic. And some fruits contain chemicals that change color in an acid or a base. Such chemicals are called acid-base indicators. These natural indicators can be found in different parts of many plants. You can find them in flowers, leaves, or the skins of some fruits.

As you learn about acids and bases in this chapter, you can make your own solutions that will tell you if a substance 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 remove acid-base indicators from plants and use them to test for acids and bases.

To complete the project you must

- make one or more acid-base indicators
- use your indicators to test a number of substances
- compare your indicators to a standard pH scale
- rank the tested substances based on their pH values
- follow the safety guidelines in Appendix A

Get Started 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 are good candidates for your indicators.

Check Your Progress You'll be working on this project as you study this chapter. To keep your project on track, look for Check Your Progress boxes at the following points.

Section 3 Review, page 197: Prepare the indicators.
Section 4 Review, page 203: Perform the tests.
Section 5 Review, page 208: Compare with pH paper.

Present Your Project At the end of the chapter (page 211), you will demonstrate your indicators and rank the tested substances by acidity.

Chapter 6 – Physical Science

SECTION 1

Understanding Solutions

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?

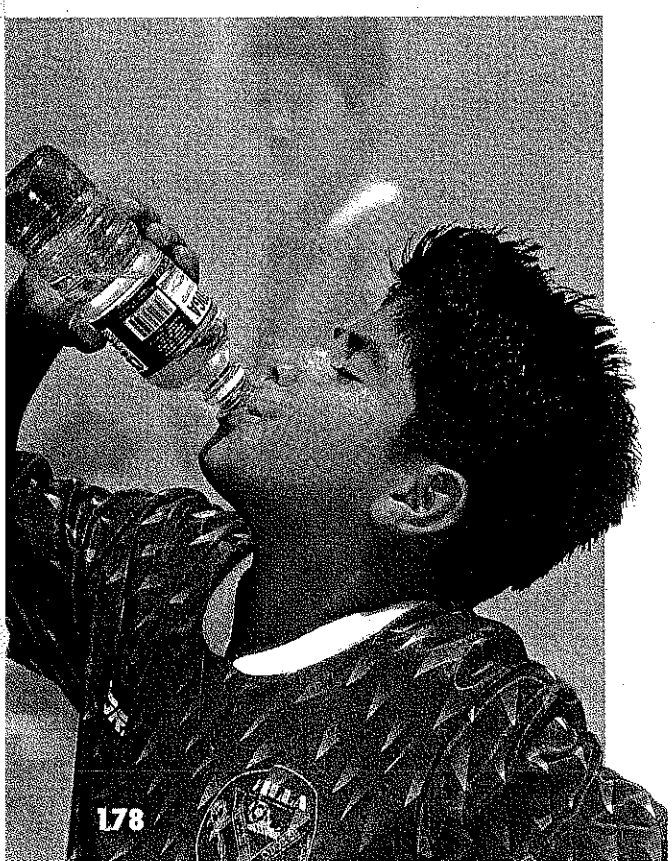
GUIDE FOR READING

- **How does a solution differ from other mixtures?**
- **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?**

Reading Tip **As you read, list the properties of solutions, suspensions and colloids.**

Imagine a hot summer day. You've been outdoors and now you're really thirsty. A tall, cool glass of just plain water would taste great. Or would it? Have you ever tasted distilled water? It tastes flat. Distilled water is "plain water." To make it, you boil tap water until it becomes water vapor. Then you cool the vapor and recollect it as a liquid. This process separates the water from dissolved materials that give it flavor.

Tap water is 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 water. As with all mixtures, the composition of tap water can vary. The water coming out of the tap can differ from one home to the next, across a town, or from state to state. Tap water is an example of a kind of mixture called a solution.



Solutions and Suspensions

What happens if you make a mixture of water and pepper? Not much. No matter how much you stir pepper and water, the two never really seem to "mix." When you stop stirring, you can still see pepper flakes floating on the water's surface and collecting at the bottom of the cup. You could scoop them out if you wanted to. 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. If you tasted the pepper suspension, you might find that one mouthful of it tastes more peppery than another mouthful. Such a mixture is not evenly mixed.

On the other hand, if you stir table salt into water, the salt disappears. Water and salt form a **solution**—a well-mixed mixture. If you taste a salt solution, any sip tastes just as salty as the next. **Unlike a suspension, a solution has the same properties throughout. Solutions and suspensions also differ in the size of their particles and the way the parts of the mixtures can be separated.** Dissolved particles are much smaller than suspended particles. They do not settle out of solution, and they pass through a filter. However, salt can be separated from water by boiling. Letting the water evaporate also works.

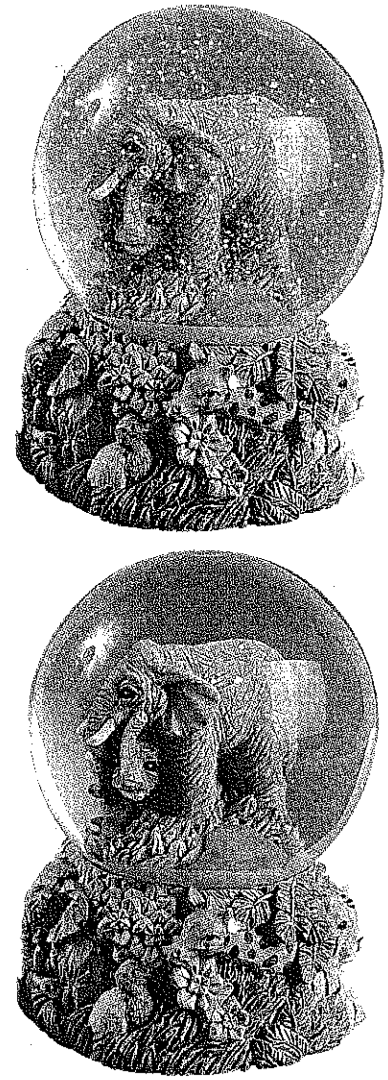


Figure 1 Glitter mixes with the water when you shake the paperweight, but settles out later. ***Classifying*** *Are the glitter particles in solution or in suspension?*

Solvents and Solutes

All solutions have at least two parts: the solvent and one or more solutes. The **solvent** is the part of a solution present in the largest amount. It dissolves the other substances. A substance that is present in a solution in a smaller amount and dissolved by the solvent is a **solute.** In a solution of table salt and water, the solvent is water and the solute is salt.

Water as a Solvent 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 soda. Water dissolves so many substances that it is often called the "universal solvent."

INTEGRATING LIFE SCIENCE Life depends on water solutions. Nutrients used by plants are dissolved in water in the soil. Sap is a solution that carries sugar 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.

Figure 2 When air bubbles are blown through a fish tank, oxygen gas dissolves in the water. Fish take in this oxygen through their gills. Without oxygen, the fish would die.

Figure 3 Solutions can be made from any combination of the three states of matter.
Interpreting Tables In which of these solutions is the solvent a substance other than water?

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 in copper)

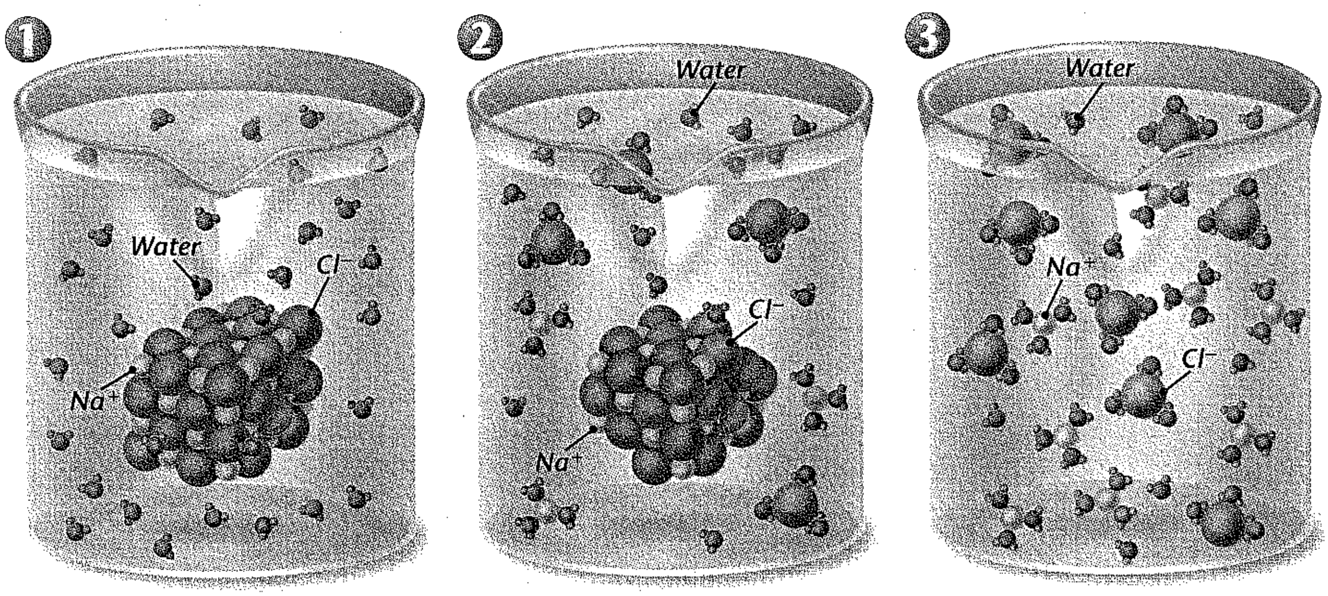
Solutions Without Water Many solutions are made with solvents other than water. For example, gasoline is a solution of several different liquid fuels. You don't even need a liquid solvent to make solutions. A solution may be made of any combination of gases, liquids, or solids.

Particles in a Solution

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

Ionic Solids in Water Figure 4 shows what happens when an ionic solid mixes with water. The positive and negative ions are attracted to 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.

Figure 4 Water molecules surround and separate positive and negative ions as an ionic solid dissolves. Notice that sodium ions attract the oxygen ends of the water molecules.



Molecular Solids in Water 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. Like ions, the sugar molecules become surrounded by water.

Solutions and Conductivity You have a water solution, but you don't know if the solute is salt or sugar. How could you use what you know about particles to find out? (Remember, a smart scientist never tastes chemicals!) 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 were present (as in a sugar solution), electricity would not flow.

☑ *Checkpoint* *How do ionic and molecular solids differ from each other in solution?*

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. It isn't a suspension either. Gelatin is a colloid. A **colloid** (KAHL oyd) is a mixture with small undissolved particles that do not settle out. A colloid has properties that differ from both solutions and suspensions.

Solutions and colloids differ in the size of their particles and how they affect the path of light. Unlike a solution, a colloid contains particles large enough to scatter a light beam. These particles, however, are not as large as those in a suspension. Other colloids include mayonnaise, shaving cream, and whipped cream.

TRY THIS

Scattered Light

Find out how a beam of light is affected by a colloid. **ACTIVITY**

1. Pour about 50 mL of a gelatin and water mixture into a small, clean glass beaker or jar.
2. Similarly, pour the same amount of a saltwater solution into another clean beaker or jar 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 container of gelatin. Repeat with the saltwater solution.
5. Compare the appearance of the light in each case.

Inferring What evidence tells you gelatin is a colloid?

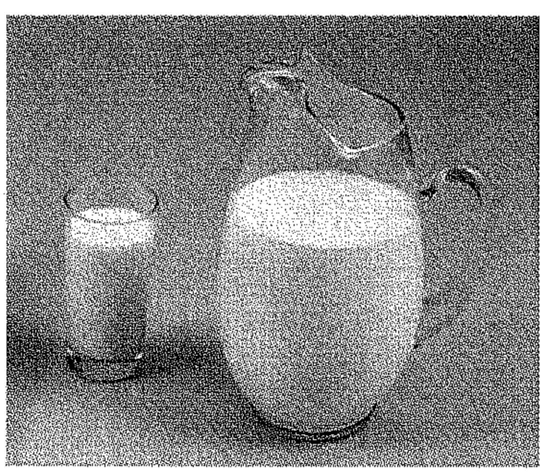


Figure 5 Milk bought in most grocery stores is a colloid. It has been processed to make the particles of water, proteins, and fats small enough to remain uniformly mixed.

Sharpen your Skills

Designing Experiments

ACTIVITY

How does the mass of a solute affect the boiling temperature 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. Report on your results.

Effects of Solutes on Solutions

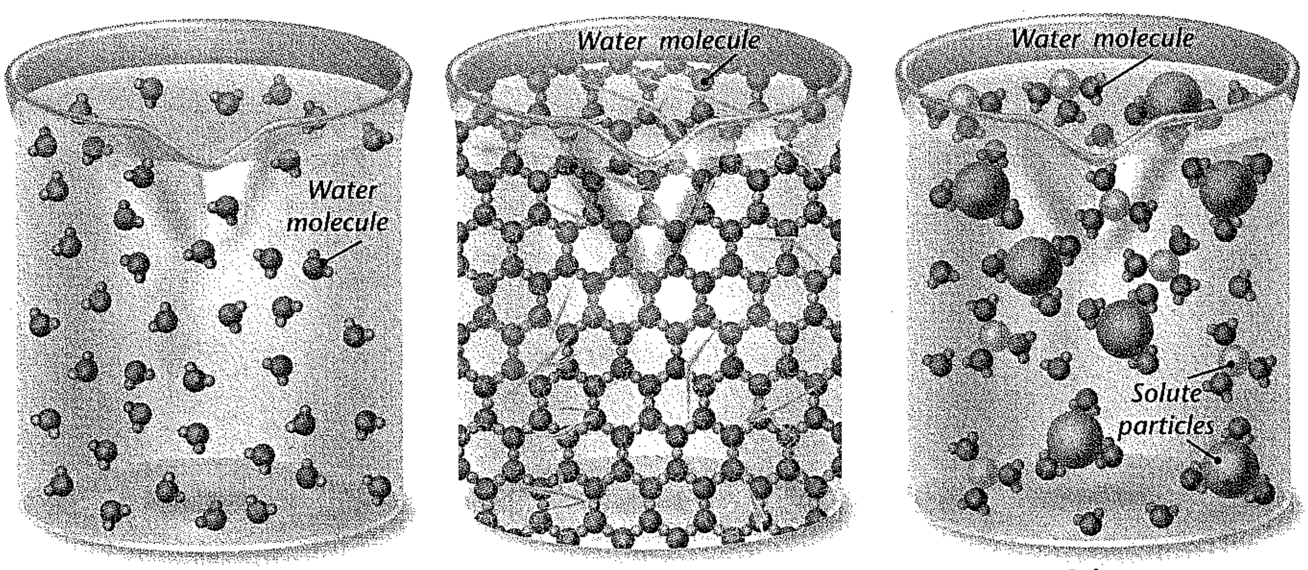
Have you ever made ice cream? First you mix cream, sugar, and other ingredients. Then you freeze the mixture by packing it in ice and water. But ice water by itself is not cold enough to do the job. Cream freezes at a temperature lower than the freezing point of water (0°C). Adding rock salt to the ice water creates a mixture that is several degrees cooler. This salt-ice-water mixture is cold enough to freeze the cream. Mmm!

Salt can affect boiling, too. When cooking spaghetti, people often add table salt to the water. As a result, the water boils at a temperature higher than 100°C, the boiling point of pure water. One small spoonful of salt in a liter of water will raise the boiling point about 0.25°C. A few large spoonfuls of salt in a liter of water could increase the boiling temperature by about 0.5 degrees. This change will cause the spaghetti to cook slightly faster.

Why does salt make cold water colder when it freezes and hot water hotter when it boils? The answer to both parts of this question depends on solute particles.

Lower Freezing Points **Solutes lower the freezing point of a solvent.** When liquid water freezes, the movement of molecules slows considerably. Instead, they form crystals of solid ice. Look at Figure 6 to compare the particles in pure water with those in a saltwater solution. Notice that pure water is made only of water molecules. In the salt solution, solute particles are present, too. In fact, they're in the way. The solute particles make it harder for the water molecules to form crystals. The temperature must drop lower than 0°C for a solid to form.

Figure 6 The freezing point and boiling point of water are affected by solute particles, which interfere with changes in state.



Higher Boiling Points Solutes **raise the boiling point of a solvent.** To see why this happens, think about what you learned in Chapter 2 about vaporization. As a liquid evaporates, molecules from its surface leave the liquid and enter the air above. If the temperature goes up, more evaporation takes place. When the temperature is high enough, bubbles of gas actually form within the liquid. That is, you see the liquid boil. Now, suppose you add solute particles to the liquid. The more solute particles added, the fewer solvent molecules there are exposed to the surface. So fewer escape to the air. As a result, the temperature must go higher for the solution to boil. In the case of water, that would be higher than 100°C.

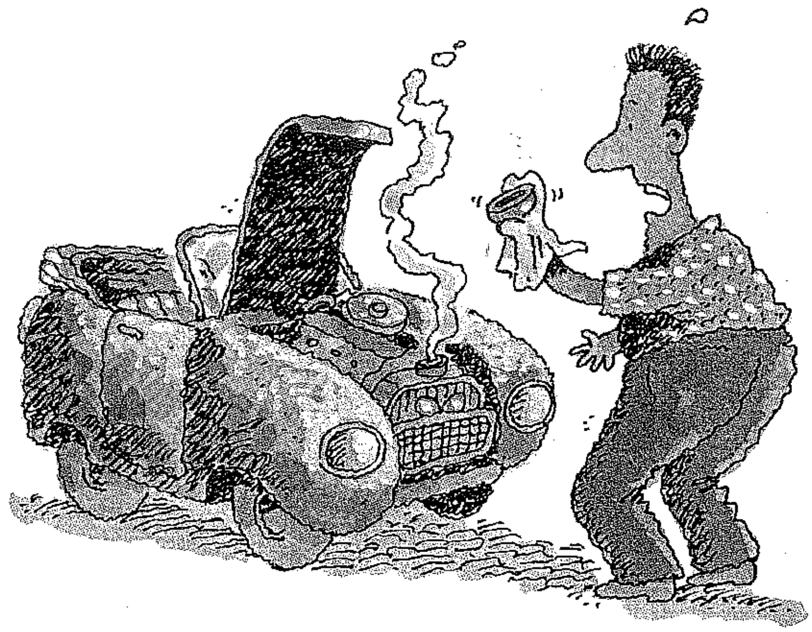


Figure 7 The coolant in a car radiator is a solution.
Predicting *On a very cold day, what might happen to a car that had only water in the radiator?*

INTEGRATING TECHNOLOGY 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, which freezes at –13°C and boils at 197°C. The mixture of the two liquids has a lower freezing point and higher boiling point than water alone. 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. So is the risk of damage from freezing in very cold weather.

Section 1 Review

1. List three ways to tell the difference between a solution and a suspension.
2. Describe what happens to the molecules of a solid, such as a sugar cube, when it dissolves in water. How does the process differ for an ionic compound, such as table salt?
3. Why does salt sprinkled on icy roads cause the ice to melt?
4. **Thinking Critically 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?

Science at Home

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

SECTION 2

Concentration and Solubility

DISCOVER — ACTIVITY

Does It Dissolve?

1. Put on your safety goggles.
2. Put half a spoonful of soapflakes into a small plastic cup. Add about 50 mL of water and stir. Observe whether or not the soap flakes dissolve in the water.
3. Clean out the cup. Repeat the test for a few other solids and liquids, such as chalk dust, baking soda, powdered sugar, hand cream, vegetable oil, vinegar, and apple juice.
4. Classify the items you tested into two groups: those that dissolved in water easily and those that did not dissolve easily.

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.

GUIDE FOR READING

- **How is concentration measured?**
- **What factors affect the solubility of a substance?**

Reading Tip **As you read, make a list of questions you would ask in order to review the ideas of this section.**

Suppose you make two cups of hot herbal tea for yourself and a friend. Your friend likes the tea "weak" and asks you to leave the tea bag in the cup for only fifteen seconds. You put another tea bag in your cup for a few minutes. When you're done, the tea in your cup is darker than the tea in your friend's cup. The cups may hold the same amount of liquid, but logic tells you that your cup holds more "tea."

Concentration

The two cups of tea differ in their concentrations. That is, they differ in the amount of solute (tea) dissolved in a certain amount of solvent (water). Chemists describe the first mixture as a **dilute solution** because only a little solute is dissolved in the water. By comparison, the darker tea is a **concentrated solution** because it has more solute dissolved in the water.

Figure 8 "Weak" tea is a dilute solution—one that actually contains several solutes that make up tea. "Strong" tea is a more concentrated solution of the same substances.

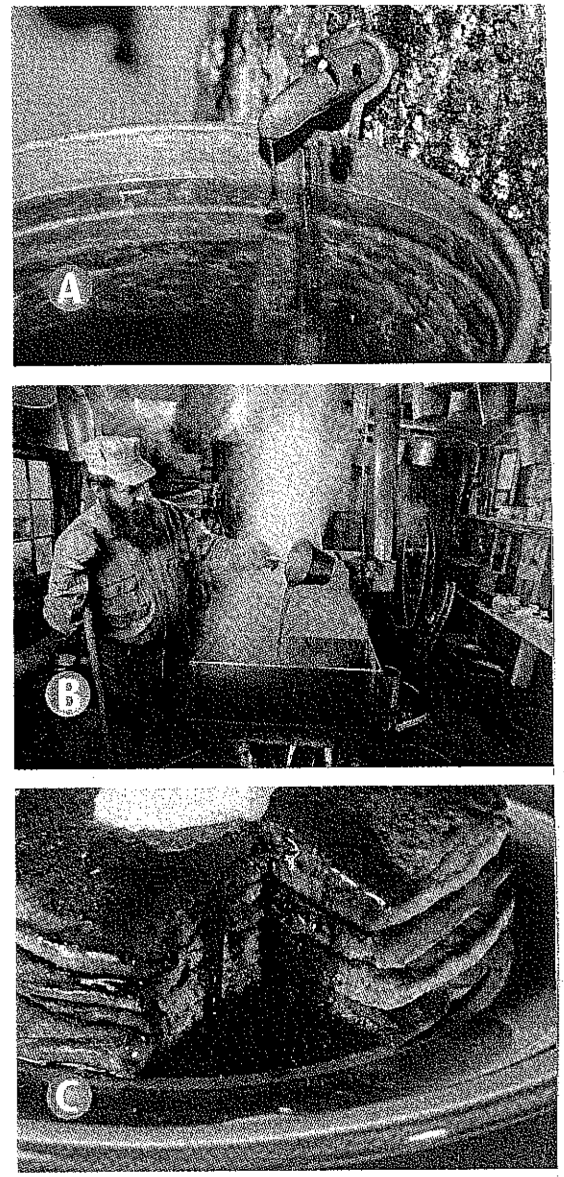


Figure 9 The sap **(a)** from sugar maple trees has almost no flavor. Much of the water must be boiled away **(b)** to produce the thick, sweet syrup people pour on pancakes **(c)**.

You can change the concentration of a solution by adding more solute. You can also change the concentration by adding or removing solvent. For example, fruit juices are sometimes packaged and sold as concentrates. When you add water, you make a more dilute solution. You replace the water that was removed to make the concentrate.

Measuring Concentration

You know that one solution in Figure 8 contains more concentrated tea than the other. But you 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. You can measure the mass of a solute or solvent in grams. You can 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.

Checkpoint *How do a dilute solution and a concentrated solution made from the same solute and solvent differ?*

Sample Problem

Rubbing alcohol sold in grocery stores is a mixture of isopropyl alcohol and water. The concentration of a 473.0-mL sample is 70% alcohol by volume. Find the volume of alcohol in the solution.

Analyze. If the solution is 70% alcohol, then 70% of 473.0 mL is alcohol. Written as a decimal, 70% is equal to 0.70, or 0.7.

Write the equation. *volume of alcohol = 0.7 x volume of solution*

Substitute and solve. *? mL = 0.7 x 473 mL = 331.1 mL*

Think about it. Check your answer by calculating the volume of water in the sample (30% of 473.0 mL). Your two answers should add up to 473.0 mL.

Practice Problems

1. The concentration of hydrogen peroxide in stores is 3% by volume in a water solution. How many milliliters of hydrogen peroxide are there in a 237-mL sample?
2. You dilute a 60-mL can of frozen grape juice concentrate with enough water to make a total of 240 mL. What is the concentration of juice in percent by volume in the final mixture?

Figure 10 Each compound listed in the table dissolves in water, but they have different solubilities.
Comparing and Contrasting
Which compound is the most soluble? Which is the least soluble?

Solubility in 100 g Water at 0°C	
Compound	**Solubility (g)**
Table salt (NaCl)	35.7
Baking soda ($NaHCO_3$)	6.9
Carbon dioxide (CO_2)	0.348
Sugar ($C_{12}H_{22}O_{11}$)	180

Solubility

If a substance dissolves in water, a question you might ask is, "How well does it dissolve?" Suppose you add sugar to a glass of iced tea. You could add half a spoonful to make the tea taste slightly sweet. Or, you could add two spoonfuls to make it sweeter. 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 well a solute can dissolve in a solvent at a given temperature.

Saturated and Unsaturated Solutions When no more sugar dissolves in the tea, you have a saturated solution. A **saturated solution** contains as much dissolved solute as possible at a given temperature. Adding more sugar to a saturated solution of iced tea does not change the concentration of sugar in the solution. The extra sugar just settles to the bottom of the glass. If, however, the sugar you add continues to dissolve, you have an unsaturated solution. An **unsaturated solution** does not hold as much of a solute as is possible at the given temperature.

Working with Solubility The solubility of a substance tells you how much solute you can add before a solution becomes saturated. Solubility is given for a specific solvent (such as water) under certain conditions (such as temperature). Look at Figure 10. 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!

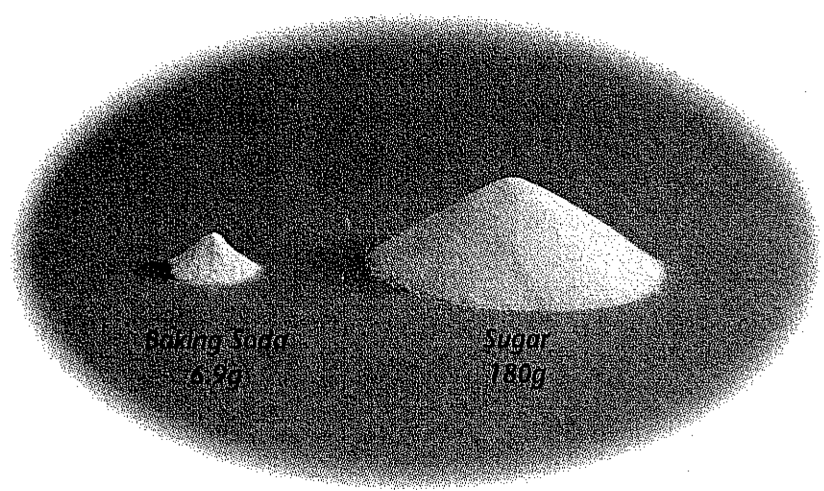


Figure 11 You would need far less baking soda than sugar to get a saturated solution in 100 grams of water at 0°C.

Solubility is a characteristic property of a compound. As with properties such as density and boiling point, you can use solubility to help identify a compound. Suppose you had a white powder that looked like table salt or sugar. You don't know for sure that 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 10.

☑ *Checkpoint* *Why doesn't solute added to a saturated solution dissolve?*

Changing Solubility

Which holds more sugar: iced tea or hot tea? You have already read that there is a limit on solubility. An iced tea and sugar solution quickly becomes saturated. Yet a hot, steaming cup of the same tea can hold much more sugar before the limit is reached. Later, if the solution is cooled, the solubility of sugar decreases. Sugar crystals may form. The solubilities of sugar and other solutes change when conditions change. **Among the factors that affect the solubility of a substance are temperature, pressure, and type of solvent.**

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 hard 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.

Sharpen your Skills

Graphing ACTIVITY

The table below shows how many grams of potassium nitrate (KNO_3) can dissolve in 100 g of water at different temperatures. Use the data to make a graph. Label the horizontal axis *Temperature* and the vertical axis *Solubility*.

Temperature (°C)	Solubility (g/100g H_2O)
0	13
20	31
40	65
60	108
80	164
100	247

What does the graph show?

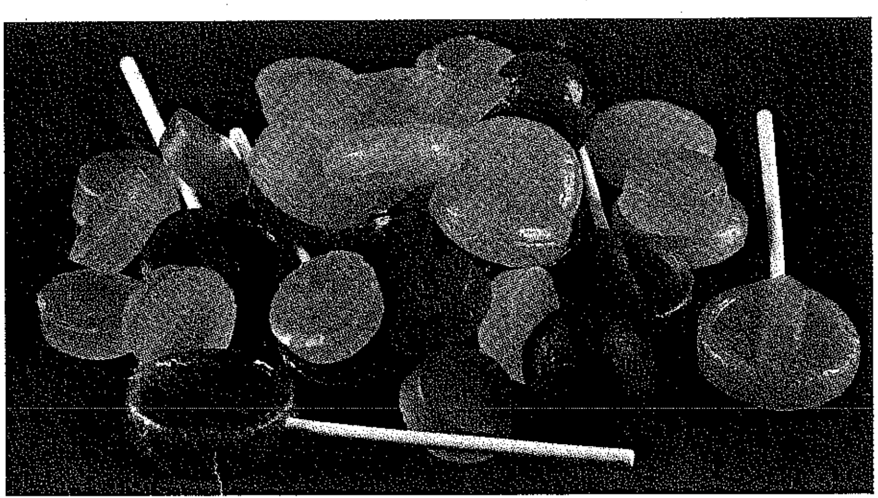


Figure 12 Hard candies are made by cooling a sugar-water solution to which different flavors and colorings are added.

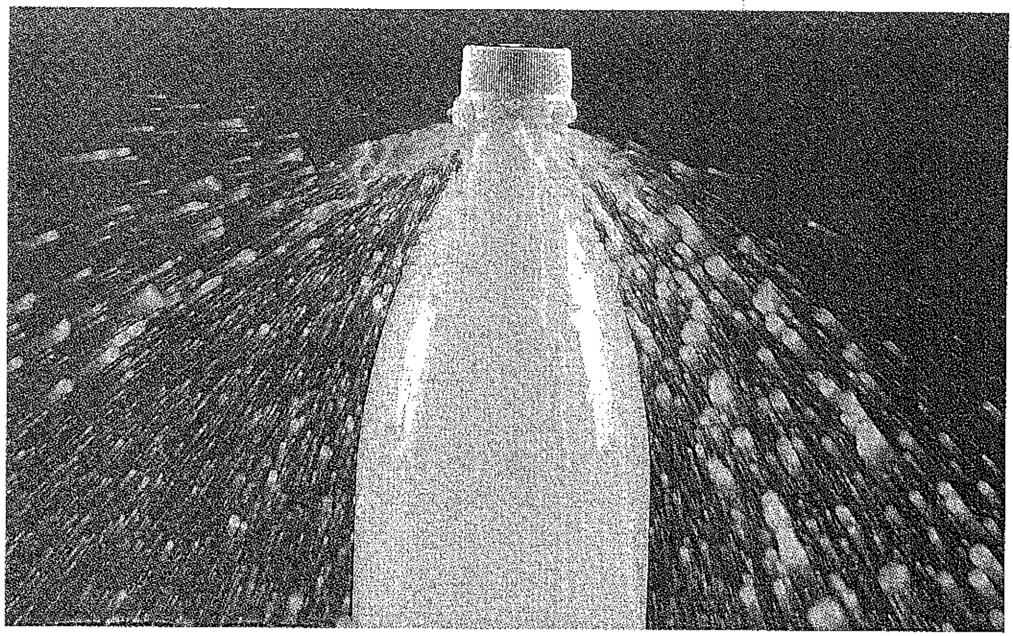


Figure 13 Has this ever happened to you? Opening a bottle of soda water can sometimes produce quite a spray as dissolved gas comes out of solution. *Relating Cause and Effect Why does more gas escape from a warm bottle of soda water than from a cold bottle?*

When heated, a solution can hold more solute than it can at cooler temperatures. If you allow a heated, saturated solution to cool 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. If you disturb a supersaturated solution by dropping in a crystal of the solute, the extra solute will come out of solution.

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!

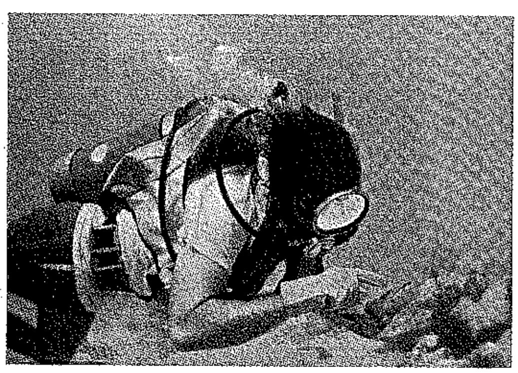


Figure 14 Divers must keep track of their depth and the effects of pressure. When ascending, they must rise no faster than 18 meters per minute to avoid "the bends."

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

Scuba divers are aware of the effect of pressure on gases. Air is 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 the 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."

Solvents If you've ever shaken a bottle of salad dressing, you've seen how quickly water and oil separate. (The vinegar in salad dressing is mostly water.) Oil and water separate because water is polar 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.

INTEGRATING TECHNOLOGY Vitamins are compounds that you need to keep your body working. There are two types of vitamins. Vitamins A, D, E, and K are soluble in fat and can be stored in your body. All the other vitamins, including vitamin C, are soluble in water. Water-soluble vitamins are not stored by your body. They are removed with waste products and must be replaced each day.

Sometimes vitamins are added to foods. For example, milk often contains extra vitamin D. If you eat lots of vegetables and fruits, you probably get enough vitamins to stay healthy. People who take vitamin pills need to consider the total amount of vitamins they get from all sources. Believe it or not, too much of a vitamin, especially vitamins A or D, can be almost as harmful as too little.

Figure 15 This house painter must clean her used brushes with a solvent that will dissolve the paint. ***Applying Concepts*** *What is one factor that helps her determine the kind of brush cleaner to use?*

Section 2 Review

1. What quantities are compared when the concentration of a solution is calculated?
2. Why would an ionic compound be more likely to dissolve in water than in oil?
3. How does a saturated solution differ from an unsaturated solution?
4. **Thinking Critically Relating Cause and Effect** When you heat tap water on the stove, you can see tiny bubbles of oxygen form. They rise to the surface long before the water begins to boil. Explain what causes these bubbles to appear.

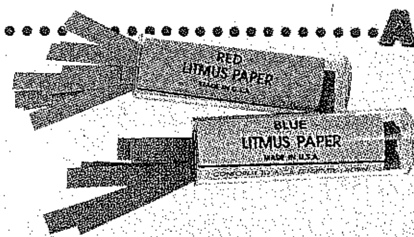
Science at Home

A Warming Trend With your family, 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 in this manner until no more dissolves. Keep track of how much baking soda you use. Then ask your family to predict what would happen if you used warm water instead. Test their predictions and compare the results with those of the first test.

SECTION 3

Describing Acids and Bases

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. Do you notice any other properties that the items in each group have in common?

GUIDE FOR READING

- What properties can you use to identify acids?
- What properties can you use to identify bases?

Reading Tip Before you read, preview *Exploring Uses of Acids* and *Exploring Uses of Bases*. List examples of acids and bases you are already familiar with.

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. Manufacturers, farmers, and builders depend on acids and bases in their work. 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? In this section you will start to find out.

Properties of Acids

What is an acid and how do you know when you have one? Test its properties. **Acids** are compounds that share characteristic properties in 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.**

Sour Taste If you've ever tasted a lemon, you've had firsthand 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) contain acids also. The vinegar used in salad dressing is made from a solution of water and acetic acid. Tea is acidic, too. So is spoiled milk, but you might not want to drink it!

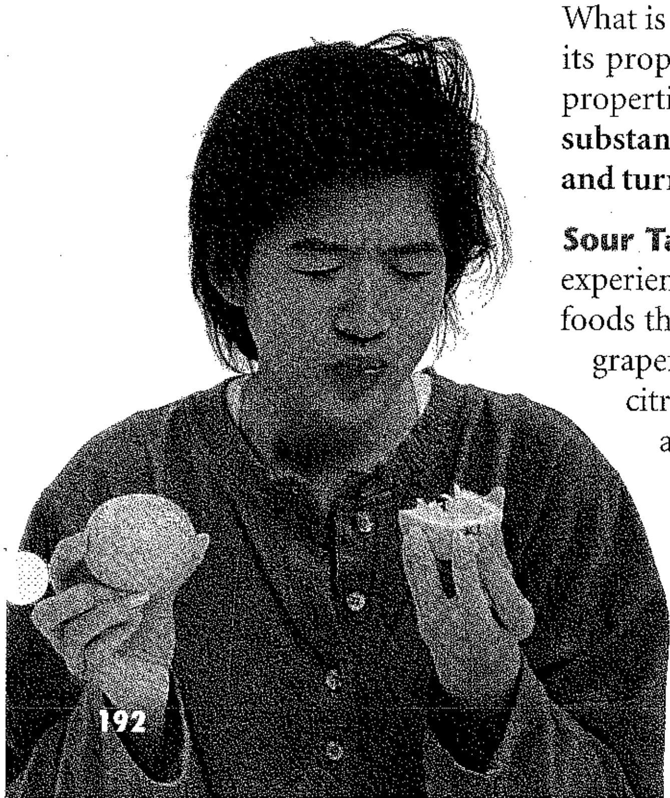


Figure 16 A sour taste often means that food is acidic.

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 bubbles in Figure 18? 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.

INTEGRATING TECHNOLOGY The metal plate in Figure 18 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.

Some Important Acids

Acid	Formula
Hydrochloric acid	HCl
Nitric acid	HNO_3
Sulfuric acid	H_2SO_4
Carbonic acid	H_2CO_3
Acetic acid	$HC_2H_3O_2$
Phosphoric acid	H_3PO_4

Figure 17 The table lists the names and formulas of some common acids.

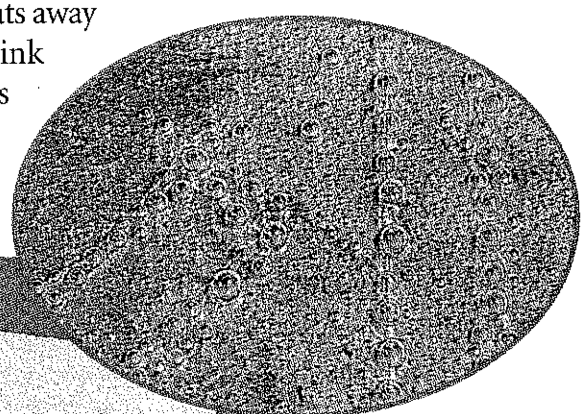


Figure 18 Metal etching takes advantage of the reaction of an acid with a metal. Lines are cut in the wax coating on the plate. Here, hydrochloric acid eats away at the exposed zinc metal, forming bubbles you can see in the close-up. *Applying Concepts What gas forms in this reaction?*

Language Arts CONNECTION

Putting someone to the "acid test" has nothing to do with litmus. The phrase is a figure of speech. It refers to a situation that tries someone's character, ability, courage, or other personal qualities. It comes from an old use of nitric acid to test the purity of gold. Many metals react with acid, but gold does not. Fake gold corrodes, while the value and quality of real gold are revealed.

In Your Journal

Write about a time you or someone you know went through an "acid test." What was hard about the situation? What did you learn from it about yourself or the other person?

Reactions With Carbonates Acids also react with carbonate ions in a characteristic way. Carbonate ions contain carbon and oxygen atoms bonded together. They carry an overall negative charge (CO_3^{2-}). When acids react with carbonate compounds, a gas forms. In this case, the gas is carbon dioxide.

INTEGRATING EARTH SCIENCE Geologists, scientists who study Earth, use the reaction of acids with carbonates to identify limestone. Limestone is made of calcium carbonate ($CaCO_3$). If a dilute solution of hydrochloric acid (HCl) is poured on a limestone rock, bubbles of carbon dioxide appear. Look at the equation for this reaction.

$$2\,HCl + CaCO_3 \rightarrow CaCl_2 + CO_2 + H_2O$$

Many forms of limestone come from organisms that live in the ocean. Coral rock, for example, comes from coral reefs. These are large structures made of the skeletons of millions of tiny sea animals that produce an outer layer of calcium carbonate. Another kind of limestone is chalk. It forms from the hard parts of microscopic sea animals deposited in layers on the sea floor. In time, the layers are pressed together and harden into chalk.

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. Vinegar and lemon juice turn blue litmus paper red. In fact, acids always turn litmus paper red. Sometimes chemists use other indicators to test for acids, but litmus is one of the easiest to use.

☑ *Checkpoint* *What is the purpose of using an indicator?*

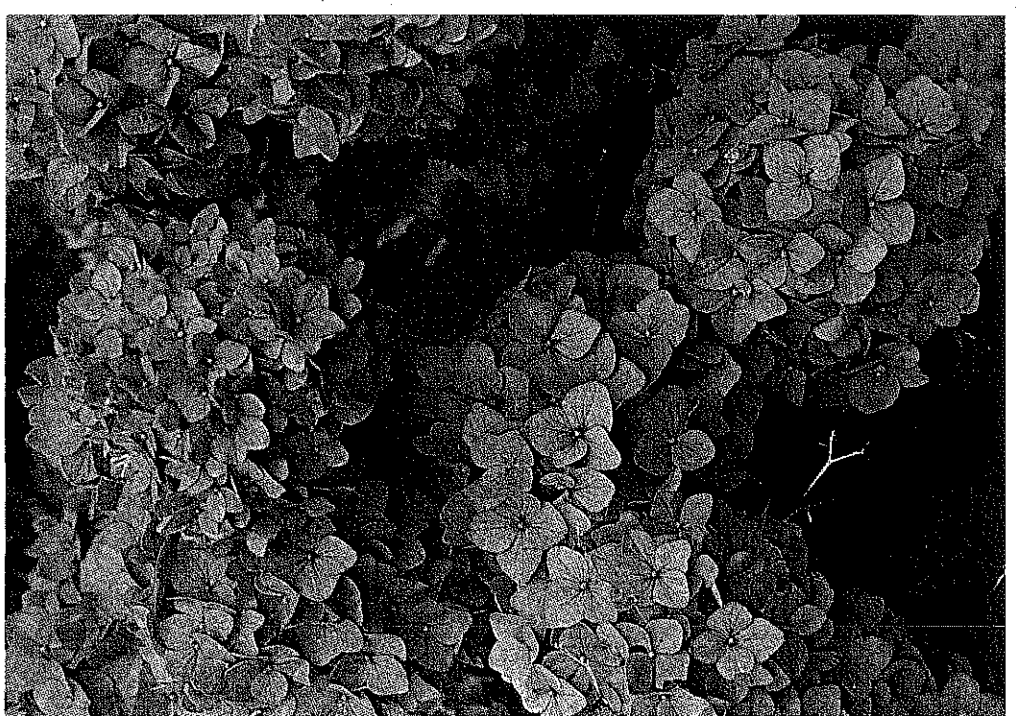
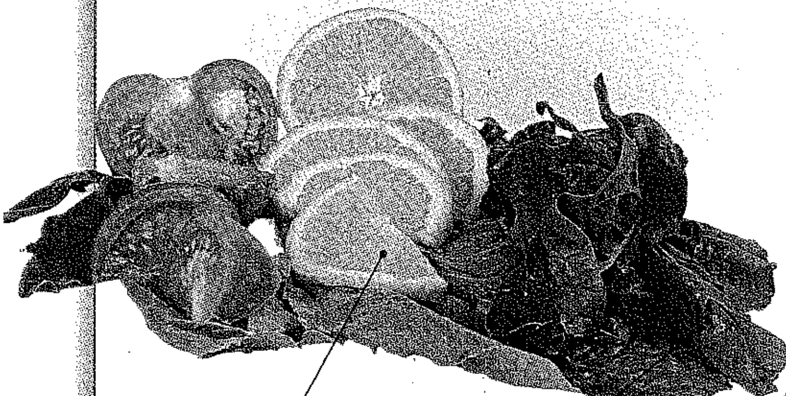


Figure 19 Hydrangea flowers are natural indicators. They may range in color from bright pink to blue, depending on the acidity of the soil in which the bush grows.

EXPLORING Uses of Acids

Acids play important roles in the chemistry of living things. Acids also are used to make valuable products for homes, farms, and industries.

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



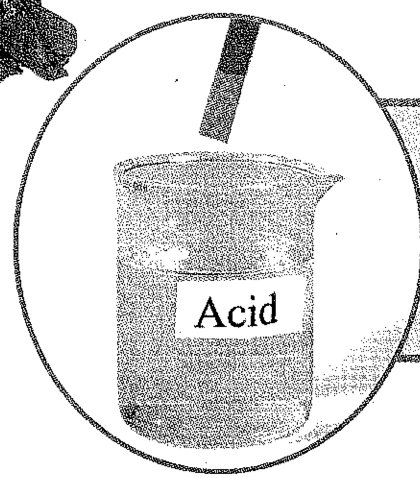
Oranges and tomatoes contain ascorbic acid, or vitamin C.

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

Acids in the body
Acids are useful in the body and are also waste products of cell processes.

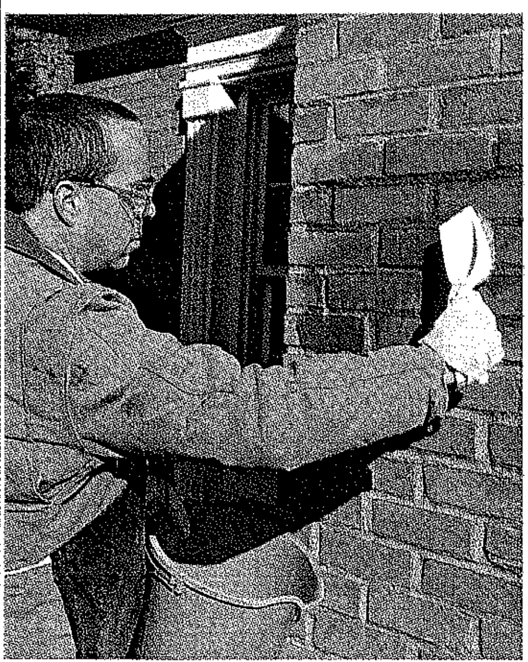
Acid in the stomach helps to digest protein.

During exercise, lactic acid builds up in hard-working muscles.

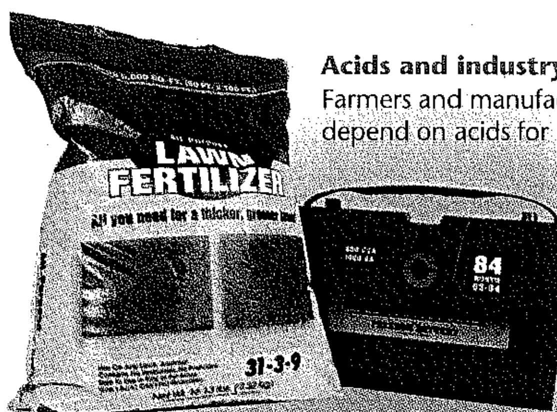


In solution, acids often look just like water, but they react very differently. A concentrated acid can burn a hole in metal, cloth, skin, wood, and other materials.

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 industry
Farmers and manufacturers depend on acids for many uses.



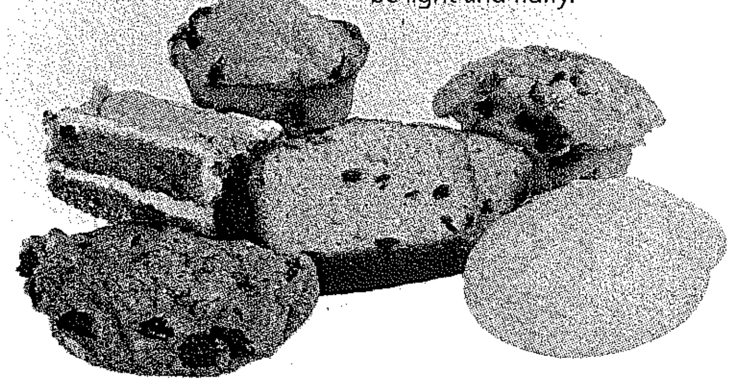
Sulfuric acid is used in car batteries, to refine petroleum, and to treat iron and steel.

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

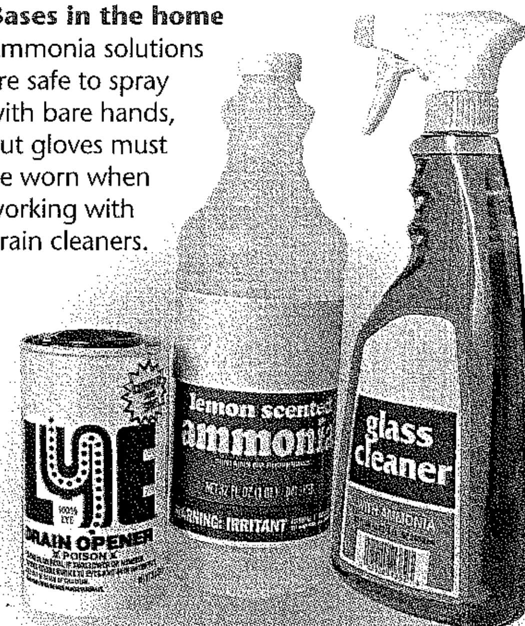
EXPLORING *Uses of Bases*

The reactions of bases make them valuable raw materials for a range of products.

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.

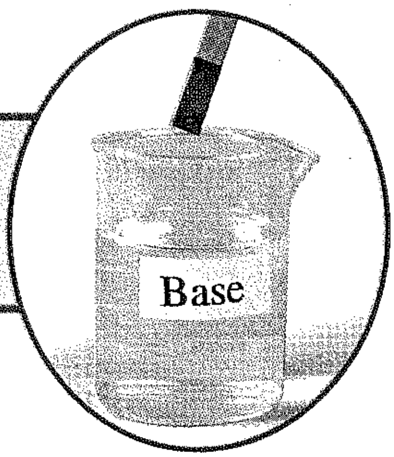


Bases in the home
Ammonia solutions are safe to spray with bare hands, but gloves must be worn when working with drain cleaners.



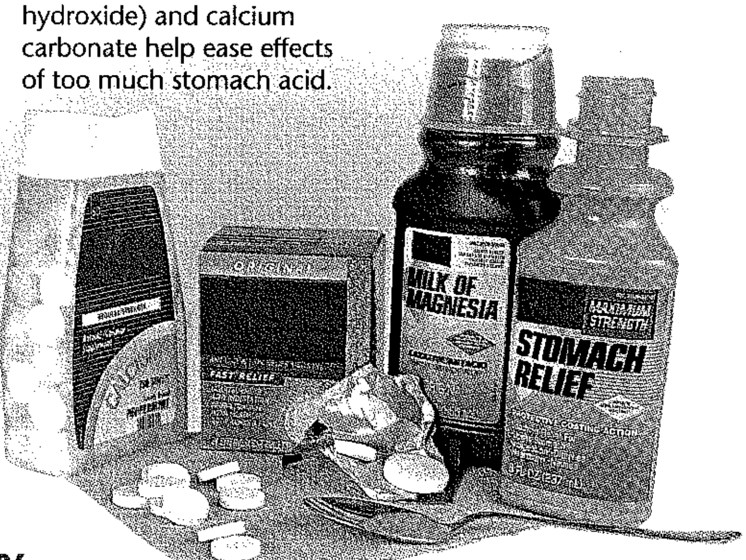
Drain cleaners contain sodium hydroxide (lye).

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

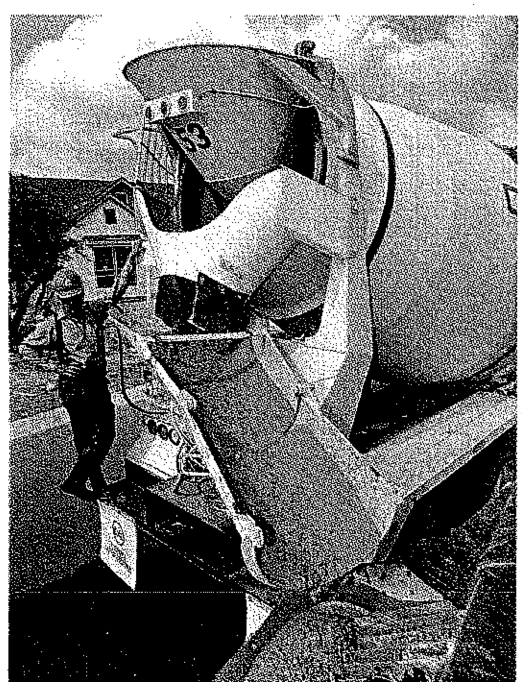


In solution, bases sometimes look like water, or they may be cloudy white. Some bases can burn your skin.

Bases and health
Bases such as milk of magnesia (magnesium hydroxide) and calcium carbonate help ease effects of too much stomach acid.



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.



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 blue.** Bases often are described as the "opposites" of acids.

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 bases by taste!

Slippery Feel Picture yourself washing your hands. You reach for a bar of soap and rub it between your hands underwater. Think about how slippery your hands feel. 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. Bases turn red litmus 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 **blue**.

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.

Some Important Bases

Base	Formula
Sodium hydroxide	$NaOH$
Potassium hydroxide	KOH
Calcium hydroxide	$Ca(OH)_2$
Magnesium hydroxide	$Mg(OH)_2$
Aluminum hydroxide	$Al(OH)_3$
Ammonia	NH_3
Calcium oxide	CaO

Figure 20 The table lists the names and formulas of some common bases.
Predicting *What color would any of these compounds turn litmus paper?*

Section 3 Review

1. How can you use litmus paper to distinguish an acid from a base?
2. How can you tell if a food may contain an acid or a base as one of its ingredients?
3. Name at least two ways that acids and bases are useful around your home.
4. **Thinking Critically Comparing and Contrasting** Make a table that compares at least three properties of acids and bases.

CHAPTER PROJECT

Check Your Progress

Select sources for your indicators. Explore ways to crush each material and squeeze out its juice. You may have to add some water and remove any solid. (*Hint:* Refrigerate any samples you are not going to use immediately.) Write down your procedure and get your teacher's approval before preparing your indicators.

Section 4 Acids and Bases in Solution

DISCOVER ACTIVITY

What Can Cabbage Juice Tell You?

1. Using a dropper, put five 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, one 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, how could you expand your definitions of acids and bases?

GUIDE FOR READING

- **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?**

Reading Tip **As you read, write one sentence to summarize the main idea discussed under each heading.**

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 turn 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! How could those two corrosive chemicals produce something harmless to the touch? In this section, you will find the answer.

Acids in Solution

What do acids have in common? Notice that each formula in Figure 21 begins with hydrogen. The acids you will learn about in this section contain hydrogen. They react with water to produce hydrogen ions. A **hydrogen ion** (H^+) is an atom of hydrogen that has lost its electron. When hydrochloric acid, for example, reacts with water, hydrogen ions and chloride ions form.

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

If another acid were used, the negative ion would be different. It could be another simple nonmetal ion. Or, it could be a polyatomic ion such as nitrate (NO_3^-), which forms from nitric acid. However, hydrogen ions would be produced in each case. These hydrogen ions are the key to the reactions of acids.

Figure 21 You can find at least one hydrogen atom in the formula of each of these acids.

Acid Formulas

Name	Formula
Hydrochloric acid	HCl
Nitric acid	HNO_3
Sulfuric acid	H_2SO_4
Acetic acid	$HC_2H_3O_2$

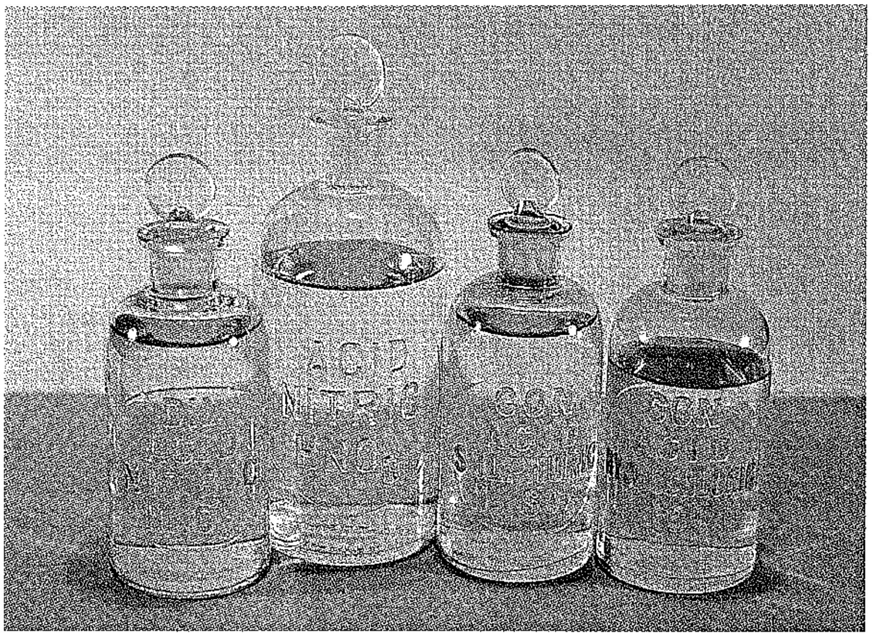


Figure 22 Acids share certain chemical and physical properties when dissolved in water. Most acids are very soluble.

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.** It is the hydrogen ions that cause the properties of acids you can see. 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 in Solution

The formulas of bases give you clues to what ions they have in common. Look at Figure 23. Many bases are made of positive ions combined with hydroxide ions. The **hydroxide ion (OH^-)** is polyatomic, made of oxygen and hydrogen. It has a negative charge.

When bases like those in Figure 23 dissolve in water, the positive ions and hydroxide ions separate. Look, for example, at what happens to sodium hydroxide:

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

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.

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

Notice that in both reactions, there are negative hydroxide ions. These examples give you another way to define bases. **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. Hydroxides also turn red litmus blue.

☑ *Checkpoint* *What is a hydroxide ion made of?*

Figure 23 Many, but not all, bases dissolve well in water. *Making Generalizations What do all of the base formulas in the table have in common?*

Base Formulas

Name	Formula
Sodium hydroxide	NaOH
Potassium hydroxide	KOH
Calcium hydroxide	$Ca(OH)_2$
Magnesium hydroxide	$Mg(OH)_2$

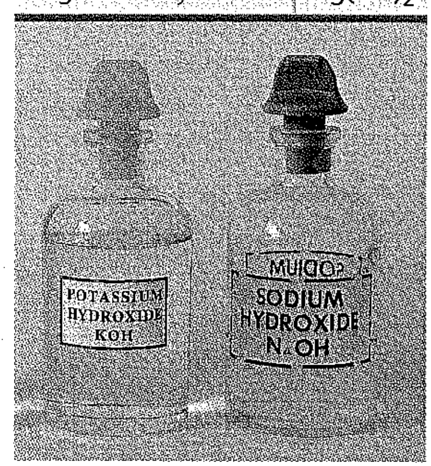
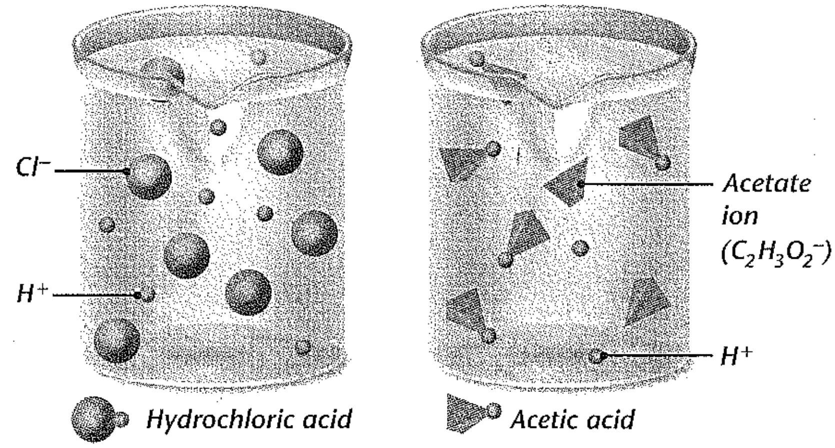
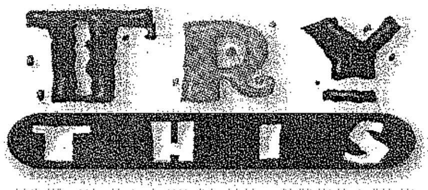


Figure 24 In a solution of a strong acid, all the acid molecules break up into ions. In a solution of a weak acid, however, fewer molecules do so.





pHone Home

ACTIVITY

Find out the pH of familiar substances in your home.

1. Put on your safety goggles and apron.
2. Select substances such as fruit juices, soda water, coffee, tea, or antacids.
3. Predict which substances are most acidic or most basic.
4. If the sample is solid, dissolve some in a cup of water. Use a liquid as is.
5. Using a plastic dropper, transfer a drop of each sample onto a fresh strip of paper for testing pH.
6. Compare the color of the strip to the pH values on the package.
7. Repeat for all your samples. Remember to rinse the dropper between tests.

Interpreting Data List the samples from lowest to highest pH. Which results, if any, surprised you?

Strengths 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. With a strong acid, most of the molecules react to form ions in solution. With a weak acid, fewer molecules do. 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, which is sodium hydroxide, is a strong base.

Strength determines, in part, how safe acids and bases are to use. For example, all the acids that are safe to eat, such as acetic acid and citric acid, are weak. Ammonia cleaner may irritate your hands slightly if you use it. But the same concentration of drain cleaner, which contains sodium hydroxide, would burn your skin.

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 or sting your skin. An equal concentration of acetic acid would not.

☑ *Checkpoint* *How would a weak base differ from an equal concentration of a strong base in solution?*

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 in a convenient way, 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 25 shows where some familiar substances fit on the pH scale. Notice that the most acidic substances are at the low end of the scale. At the same time, 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. By comparison, 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 25 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.

A concentrated solution of acetic acid can have a lower pH than a dilute solution of hydrochloric acid. In order to handle acids and bases safely, you need to know both their pH and their concentration. Hydrochloric acid is more acidic (has a lower pH) than acetic acid. But a concentrated (strong) solution of acetic acid can have a lower pH than a dilute (weak) solution of hydrochloric acid. To safely handle acids and bases, you need to know the pH of the *solutions* you are using.

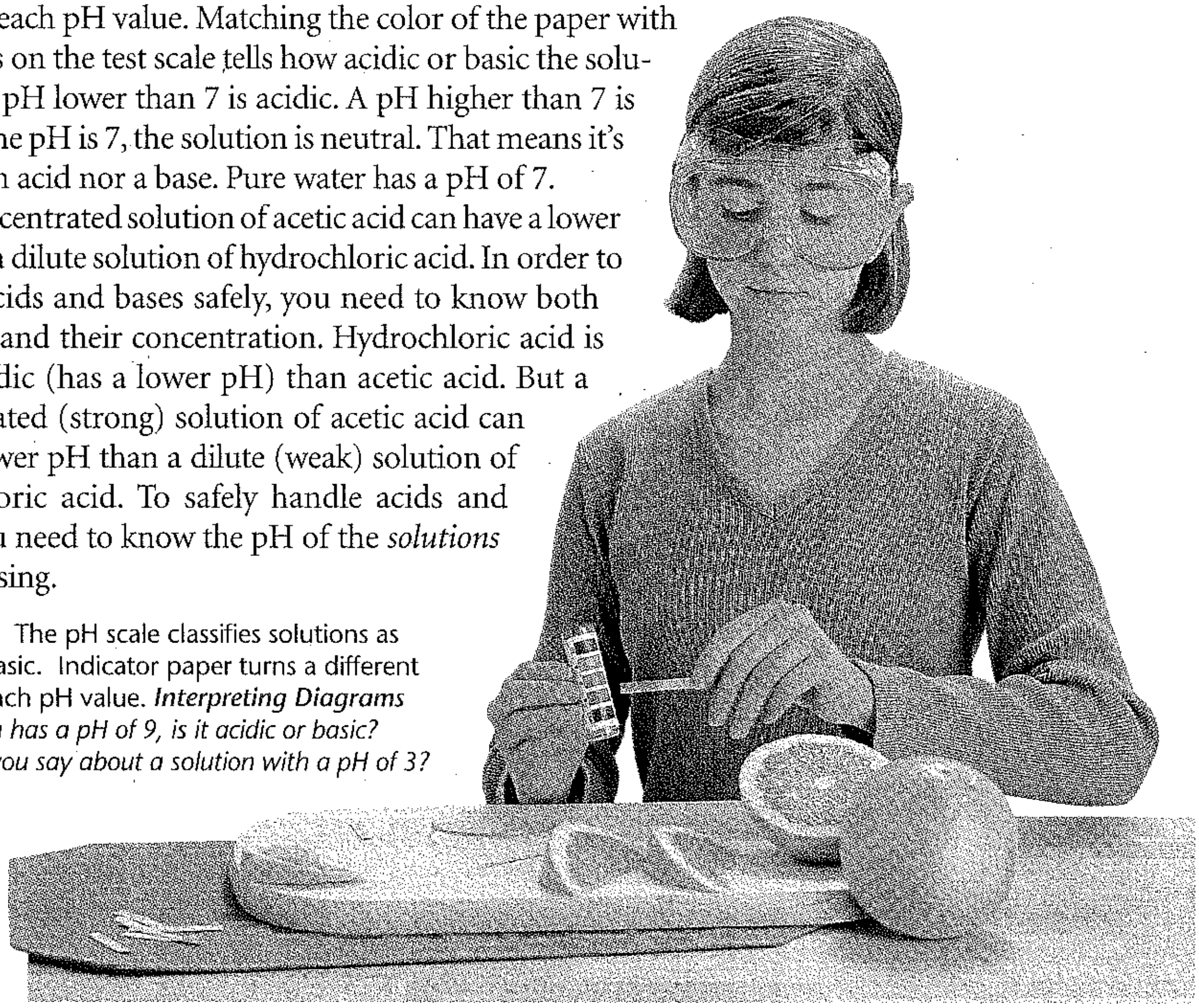
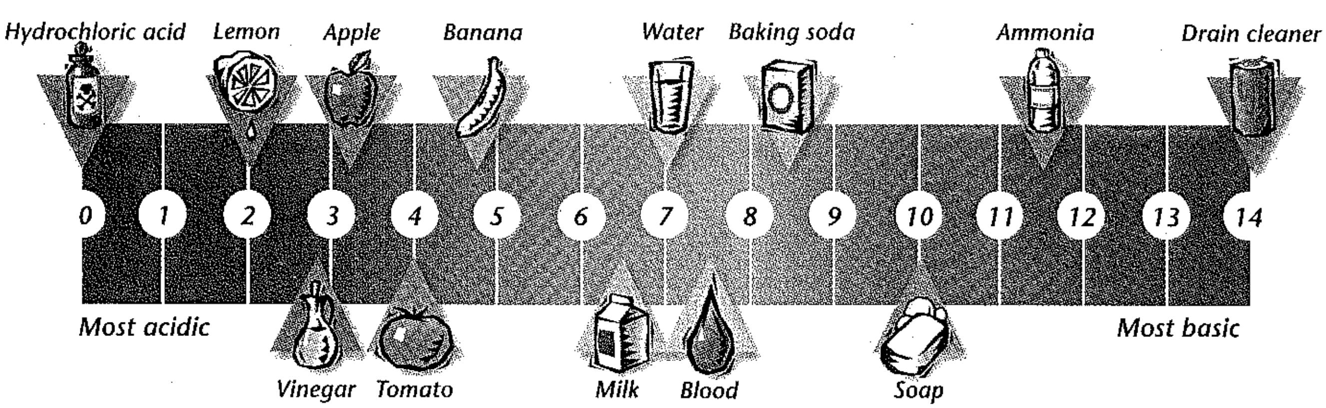


Figure 25 The pH scale classifies solutions as acidic or basic. Indicator paper turns a different color for each pH value. ***Interpreting Diagrams*** *If a solution has a pH of 9, is it acidic or basic? What can you say about a solution with a pH of 3?*



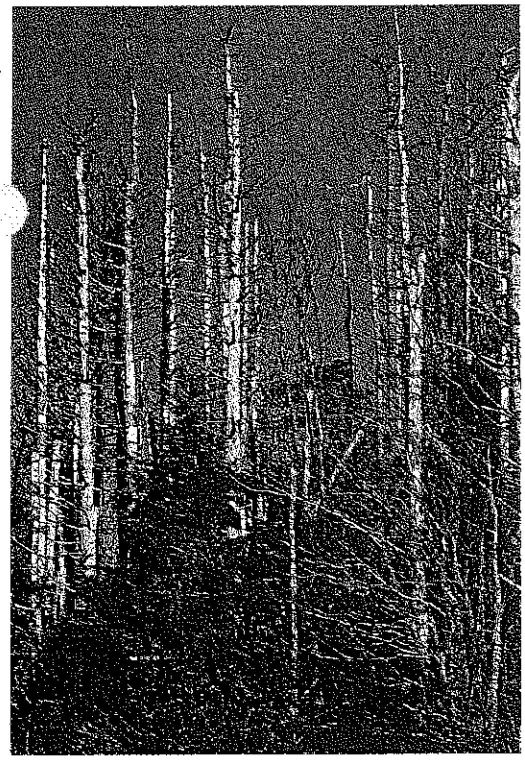


Figure 26 Acid rain weakens trees by damaging their leaves and removing nutrients from the soil. Portions of forests can die off when weakened trees become diseased or are further damaged by severe cold or drought.

Acid Rain

INTEGRATING ENVIRONMENTAL SCIENCE Normal rainfall is slightly acidic, with a pH of approximately 5.5. This acidity comes from carbon dioxide in the air. Carbon dioxide dissolves in rainwater, producing carbonic acid, a weak acid.

$$H_2O + CO_2 \rightarrow H_2CO_3$$

Acid rain is more acidic than normal rainwater. The pH of acid rain in the United States today can be as low as about 4.3. The extra acidity comes from nitrogen oxides and sulfur oxides. These gases are released into the air as pollutants from industry and motor vehicles. These oxides react with water in the air to produce acids, including nitric acid and sulfuric acid. Rainwater containing these acids has more hydrogen ions. It has a lower pH and is more corrosive. Acid rain can damage statues and buildings, destroy forests, and kill fish in lakes.

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.

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

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 a **neutralization** (noo truh lih ZAY shun). As a result of neutralization, an acid-base mixture is not as acidic or basic as the individual starting solutions were.

Sometimes an acid-base reaction results in a neutral solution. But not always. 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.

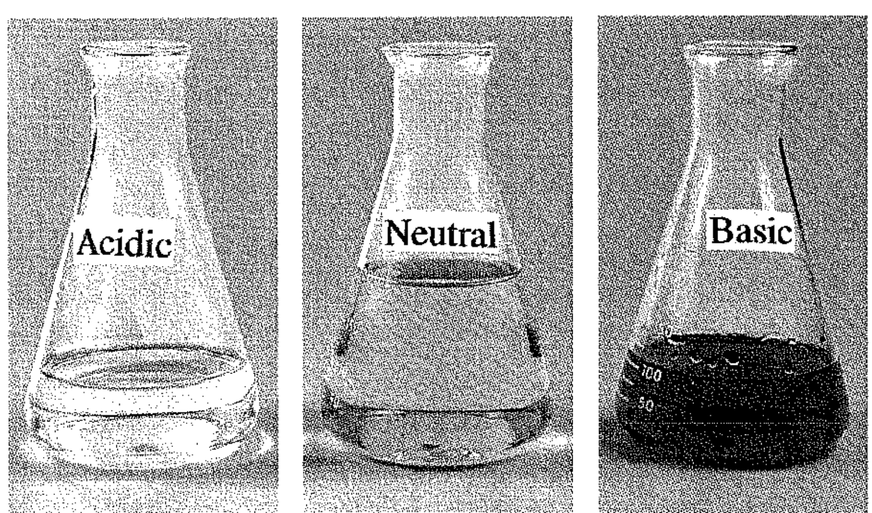


Figure 27 The solution on the left is acidic. The solution on the right is basic. When mixed, these solutions produced the neutral solution in the center.
Interpreting Photos What tells you if the solution is an acid, a base, or neutral?

Some Salts and Their Uses		
Salt	**Formula**	**Uses**
Sodium chloride	$NaCl$	Food flavoring; preservative
Potassium iodide	KI	Additive in "iodized" salt that prevents iodine deficiency (goiter)
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 sea shells
Ammonium nitrate	NH_4NO_3	Fertilizer; active ingredient in some cold packs

Figure 28 Each salt listed in this table can be formed by the reaction between an acid and a base.

Products of Acid-Base Reactions

"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. Potassium nitrate is written in the equation as separate K^+ and NO_3^- ions because it is soluble in water. **A neutralization reaction produces water and a salt.** Some salts, such as potassium nitrate, are soluble. Others form precipitates because they are insoluble.

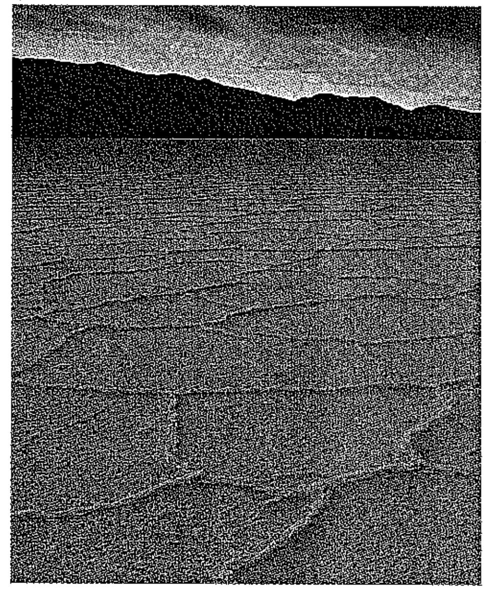


Figure 29 These salt flats were left behind in Death Valley, California, when the water in which the salts were dissolved evaporated.

Section 4 Review

1. What ions would you expect to find when an acid dissolves in water? What ions would you expect to find when a base dissolves in water?
2. If the pH of a solution is 6, would you expect to find more or fewer hydrogen ions (H^+) than in a solution with a pH of 3? Explain why.
3. What does the term *salt* mean to a chemist, and how may a salt form?
4. **Thinking Critically Predicting** What salt would form from a reaction between hydrochloric acid, HCl, and calcium hydroxide, $Ca(OH)_2$? Explain your answer.

CHAPTER PROJECT

Check Your Progress

Use each indicator to test for acids and bases in familiar substances. For example, try vinegar, household ammonia, lemon juice, milk, and soapy water. (*Hint:* Use small amounts of indicator and test samples. Watch for a color change, especially where the sample comes in contact with the indicator. If you do not see a color change, add a few more drops of the sample.) Summarize your results in a table.

SECTION 5 Digestion and pH

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?

GUIDE FOR READING

- Why is it necessary for your body to digest food?
- How does pH affect digestion?

Reading Tip Before you read, preview Figure 32. List the organs of the digestive system in the order in which food passes through them.

You may have seen the following commercial: 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 forms you eat. **Foods must be broken down into simpler substances that your body can use for raw materials and energy.** The process of **digestion** breaks down the complex molecules of foods into smaller molecules.

Digestion has two parts—mechanical and chemical. **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** breaks large molecules into smaller ones. Some of the products of digestion are used by the body to get energy. Others become building blocks for muscle, bone, skin, and other organs.

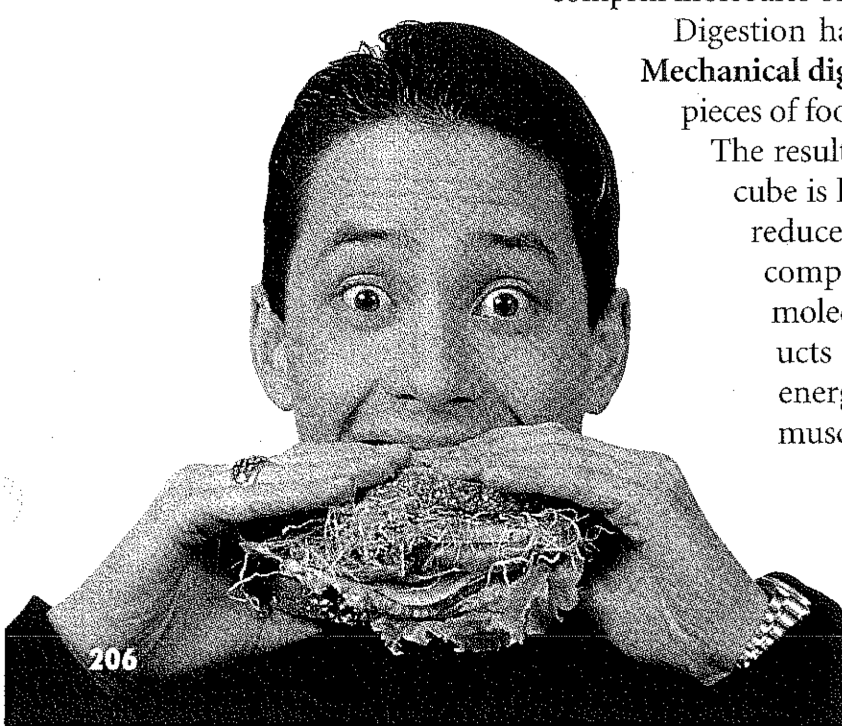


Figure 30 The foods in this sandwich will move through areas of the digestive system that have different pH values.

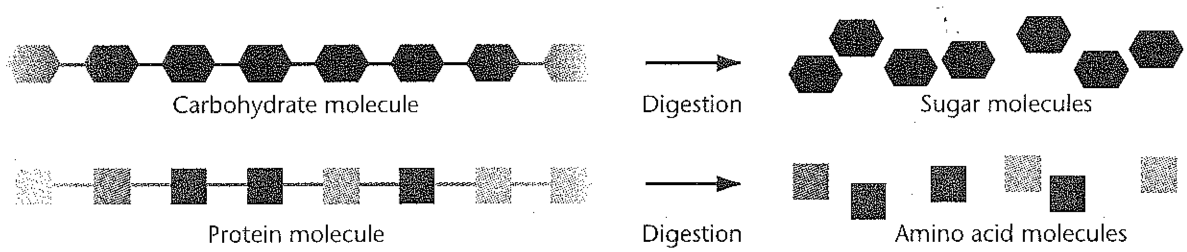


Figure 31 Carbohydrates and proteins are large molecules that must be broken down by digestion. ***Interpreting Diagrams*** *What smaller molecules result in each case?*

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

☑ *Checkpoint* *What happens to foods in your body?*

pH in the Digestive System

A bite of sandwich is about to take a journey through your digestive system. What pH changes will affect the food molecules along the way? Figure 32 shows the main parts of the human digestive system. As you read, trace the food's pathway through the body.

Your Mouth The first stop in the journey is your mouth. Immediately, 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 carbohydrate is broken into sugars. This makes the bread taste sweet.

Your Stomach Next, the food is swallowed and arrives in your stomach. This muscular organ starts the chemical digestion of foods that contain protein, such as meat, fish, and beans. Cells in the lining of your stomach release enzymes and hydrochloric acid. Rather than the near-neutral pH of your mouth, the pH drops to a very acidic level of about 2. This pH is even more acidic than the juice of a lemon.

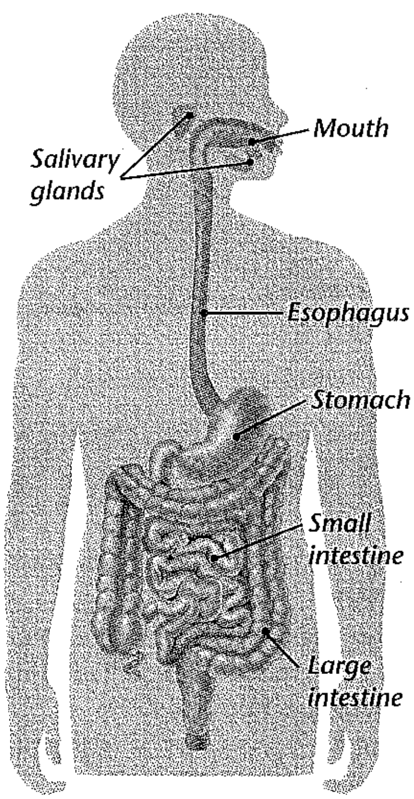


Figure 32 The pH changes as food moves through the digestive system.

Figure 33 Shrimp contains protein. Rice and pea pods contain carbohydrates.

The low pH in your stomach helps digestion take place. One enzyme that works in your stomach is pepsin. It 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, other digestive fluids surround the food. One fluid contains the bicarbonate ion (HCO_3^-). This ion creates a slightly basic solution, with a pH of about 8. In the small intestine, other enzymes complete the breakdown of carbohydrates, fats, and proteins. All of these enzymes work best in a slightly basic solution. Most chemical digestion ends in the small intestine.

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

Figure 34 The pH varies greatly throughout 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

Section 5 Review

1. How are foods changed by your digestive system?
2. How does pH differ in your mouth, your stomach, and your small intestine? Why are the differences important?
3. What two processes of digestion begin in the mouth? How do they differ?
4. **Thinking Critically Predicting** How would the digestion of food be affected if your stomach did not produce hydrochloric acid?

CHAPTER PROJECT

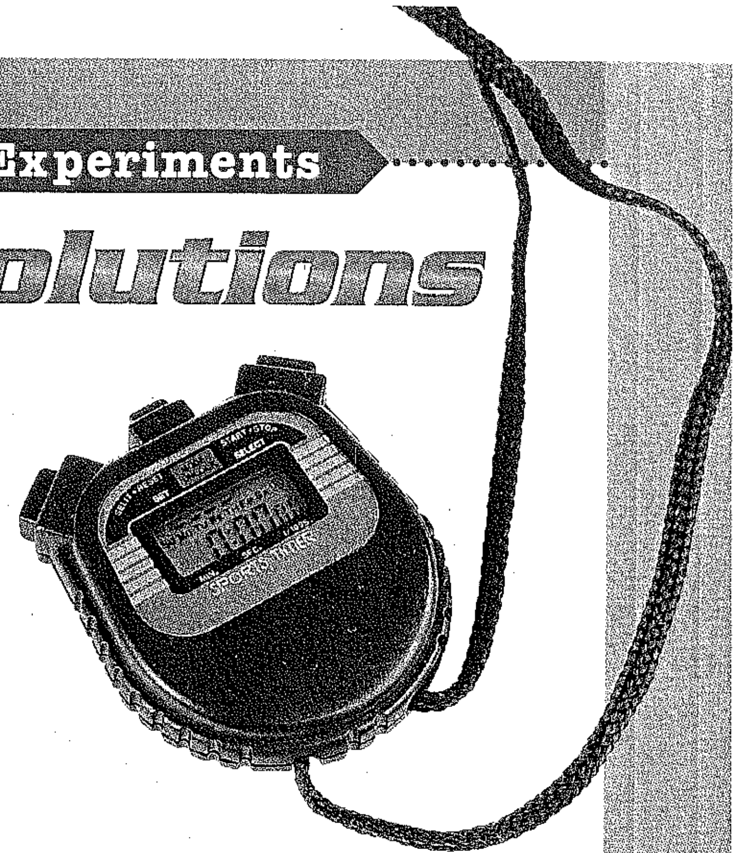
Check Your Progress

Use indicator paper to find the pH of each substance you tested earlier with homemade indicators. Add these pH values to your data table. Compare the data you collected with your indicators with the data from the pH tests.

Skills Lab

Designing Experiments

Speedy Solutions



In this lab, you will design an experiment to find out how a chosen variable affects the speed at which salt dissolves in water.

Problem

How can you control the rate at which salt dissolves in water?

Materials

spoon
thermometers
balance
ice
test tube rack
solid stoppers, #4
hot plate
stirring rods
timer or watch
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 with which salt 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 your manipulated variable and the responding variable. (*Hint:* Remember to include units.)
9. Have your teacher approve your procedure, safety guidelines, and data table.
10. Perform the experiment.

DATA TABLE

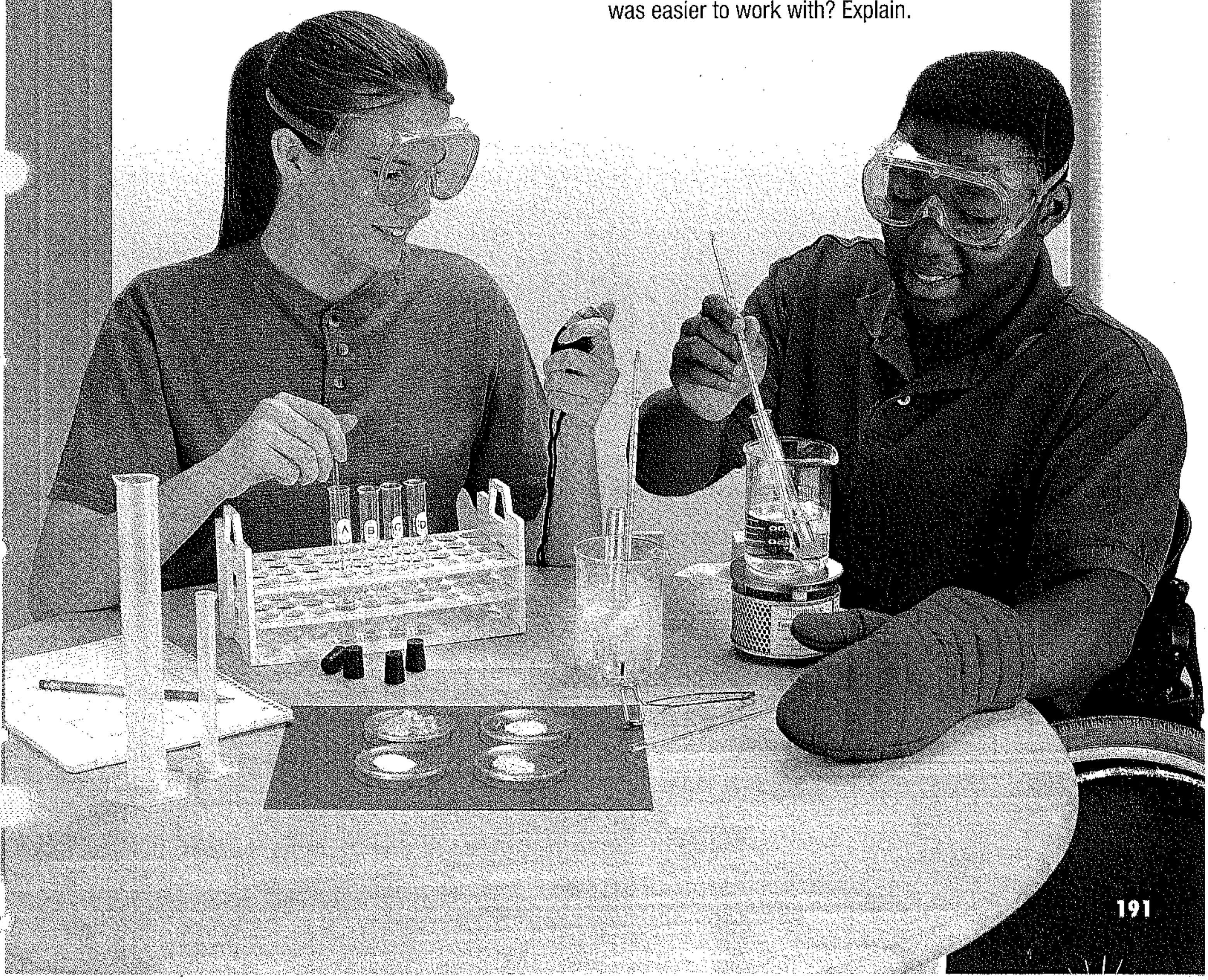
Manipulated Variable	Dissolving Time		
	Test 1	Test 2	Test 3

Analyze and Conclude

1. Which is the manipulated variable in your experiment? Which is the responding variable? How do you know which is which?
2. List three variables you held constant in your procedure. Explain why controlling these variables makes your data more reliable.
3. 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. Study the shape of your graph. Write a conclusion about the effect of the variable you tested on the speed of salt dissolving in water.
5. Does your conclusion support the hypothesis you wrote in Step 4? Explain.
6. How do your results relate to what you have learned about particles and solubility?
7. What advantage would there be in running your tests a second or third time?
8. **Think About It** 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.

More to Explore

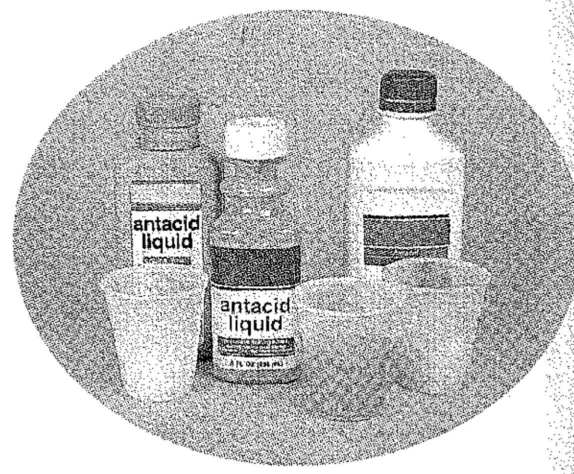
Choose another variable from the list you made in Steps 1 and 2. Repeat the process with that variable. Of the two variables you chose, which was easier to work with? Explain.



Real-World Lab

You, the Consumer

The Antacid Test



Consumers see or hear ads for antacids on television, radio, and in magazines. Each product claims to "neutralize excess stomach acid" best. You can experiment to see whether some antacids really do work better than others.

Problem

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

Skills Focus

designing experiments, measuring, interpreting data

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.
4. Add two 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.

DATA TABLE

Substance	Original Color	Color With Indicator
HCl		
Antacid Brand A		
Antacid Brand B		

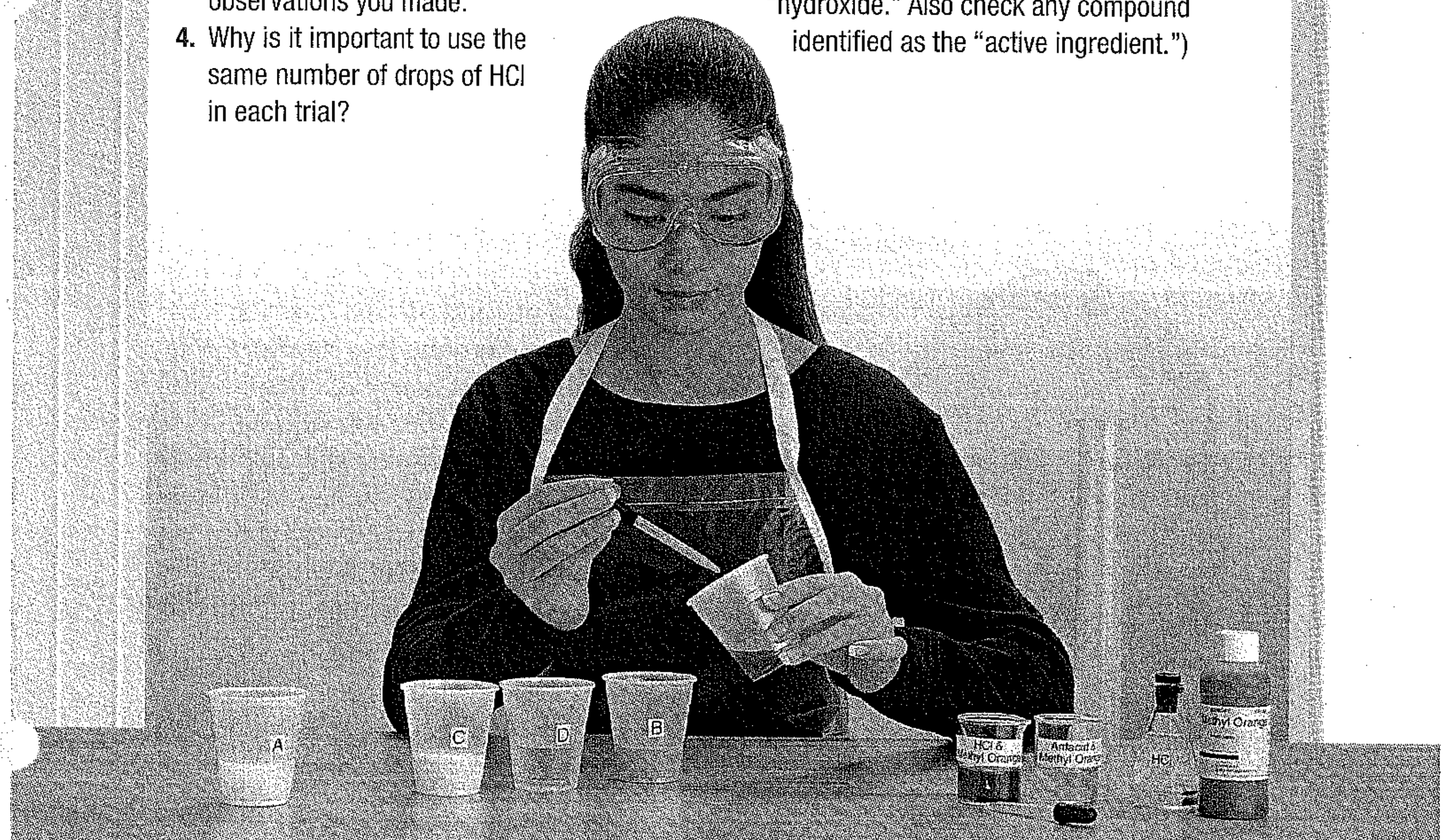
8. Devise a plan for adding the antacid so that you can detect when a change occurs. Decide how much antacid to add each time and how to mix the solutions to be sure the indicator is giving accurate results.
9. Make a second data table to record your observations.
10. Carry out your procedure and record 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. What is the function of the methyl orange solution?
2. Do your observations support your predictions from Step 6? Explain why or why not.
3. Why do you think antacids reduce stomach acid? Explain your answer, using the observations you made.
4. Why is it important to use the same number of drops of HCl in each trial?
5. Which antacid neutralized the HCl with the smallest number of drops? Give a possible explanation for the difference.
6. If you have the same volume (number of drops) of each antacid, which one can neutralize the most acid?
7. 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. **Apply** If you want to buy an antacid, what information do you need in order to decide which brand is the best buy?

Getting Involved

Compare the advertised strengths of several brands of antacids. Look for antacids in a local grocery store or drug store. Check the ingredient lists of several brands. What are some of the different bases used in commercial antacids? (*Hints:* Look for compounds containing "hydroxide." Also check any compound identified as the "active ingredient.")



CHAPTER 6 STUDY GUIDE

SECTION 1 Understanding Solutions

Key Ideas

- A solution is a well-mixed mixture, having smaller particles than a suspension or a colloid.
- When a solution forms, particles of solute are surrounded by particles of solvent.
- Solutes lower the freezing point and raise the boiling point of a solvent.

Key Terms

suspension
solution
solvent
solute
colloid

SECTION 2 Concentration and Solubility

Key Ideas

- Concentration compares the amount of solute to the amount of solvent or amount of solution.
- Solubility can be affected by temperature, pressure, and type of solvent.

Key Terms

dilute solution
concentrated solution
solubility
saturated solution
unsaturated solution
supersaturated solution

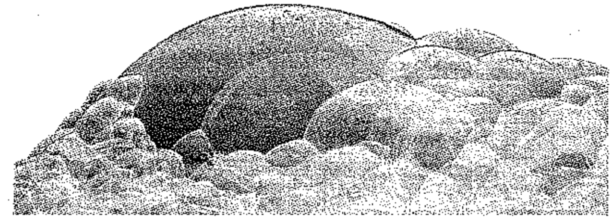
SECTION 3 Describing Acids and Bases

Key Ideas

- An acid tastes sour, reacts with metals and carbonates, and turns litmus red.
- A base tastes bitter, feels slippery, and turns litmus blue.
- An indicator is a substance that turns different colors in an acid or a base.

Key Terms

acid
indicator
base



SECTION 4 Acids and Bases in Solution

Key Ideas

- An acid produces hydrogen ions (H^+) when it dissolves in water.
- A base produces hydroxide ions (OH^-) when it dissolves in water.
- pH describes the acidity of a solution. The lower the pH, the higher the concentration of hydrogen ions.
- When a base reacts with an acid, water and a salt form.

Key Terms

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

SECTION 5 Digestion and pH

INTEGRATING LIFE SCIENCE

Key Ideas

- Digestion breaks down foods into small molecules that are used for energy and raw materials.
- The pH at which digestive enzymes work best varies from very acidic to slightly basic.

Key Terms

digestion
mechanical digestion
chemical digestion

Organizing Information

Concept Map Use key terms and ideas you learned in this chapter to construct a concept map about solutions. (For more on concept maps, see the Skills Handbook.)

Reviewing Content

For more review of key concepts, see the Interactive Student Tutorial CD-ROM.

Multiple Choice

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 is a(n)
a. neutral solution.
b. supersaturated solution.
c. unsaturated solution.
d. saturated solution.

3. When salt is added to an ice and water mixture at 0°C,
a. the temperature of the mixture drops.
b. more of the water freezes.
c. more of the water evaporates.
d. there is no noticeable change.

4. Bubbles form when washing soda (Na_2CO_3) is mixed with
a. tap water.
b. salt water.
c. ammonia cleaner.
d. lemon juice.

5. Which of the following compounds is a base?
a. HNO_3 **b.** $MgCl_2$
c. $Ca(OH)_2$ **d.** CH_4

True or False

If the statement is true, write true. If it is false, change the underlined word or words to make the statement true.

6. The solubility of a gas in water goes up if you <u>increase</u> the temperature.

7. The slightly sour taste of lemonade tells you that it may contain <u>a base</u>.

8. The gas produced when an acid reacts with a carbonate is <u>oxygen</u>.

9. Dilute hydrochloric acid is an example of a <u>strong</u> acid.

10. Amylase, the enzyme in saliva that helps break down carbohydrates into simple sugars, works best in a <u>neutral</u> solution.

Checking Concepts

11. Describe at least two differences between a dilute solution and a concentrated solution of sugar water.

12. The concentration of an alcohol and water solution is 25% alcohol by volume. What is the volume of alcohol in 200 mL of the solution?

13. Explain how you could tell the difference between a solution and a clear colloid.

14. Explain how an indicator helps you distinguish between an acid and a base.

15. What combination of acid and base can be used to make the salt potassium chloride, KCl?

16. Writing to Learn Some of the limestone on the outside of buildings in an area looks as if it is being gradually eaten away. As an investigator for the local air pollution agency, write a brief memo explaining what may be causing the problem.

Thinking Critically

17. Developing Hypotheses Some power plants release hot wastewater into nearby rivers or streams. Fish living in these waters sometimes die from lack of oxygen. Write a hypothesis to explain what has happened to the oxygen in the water.

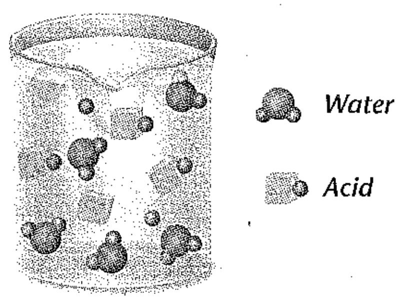
18. Drawing Conclusions You have two clear liquids. One turns litmus red and one turns litmus blue. If you mix them and retest with litmus, no color changes occur. Describe the reaction that took place.

19. 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.

20. 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.

Applying Skills

The diagram below shows the particles of an unknown acid in a water solution. Use the diagram to answer Questions 21–23.



21. Interpreting Data How can you tell from the diagram that the solution contains a weak acid?

22. Making Models Suppose another unknown acid is a strong acid. Make a diagram to show the particles of this acid dissolved in water.

23. Drawing Conclusions Explain how the pH of a strong acid compares with the pH of a weak acid of the same concentration.

Performance CHAPTER PROJECT Assessment

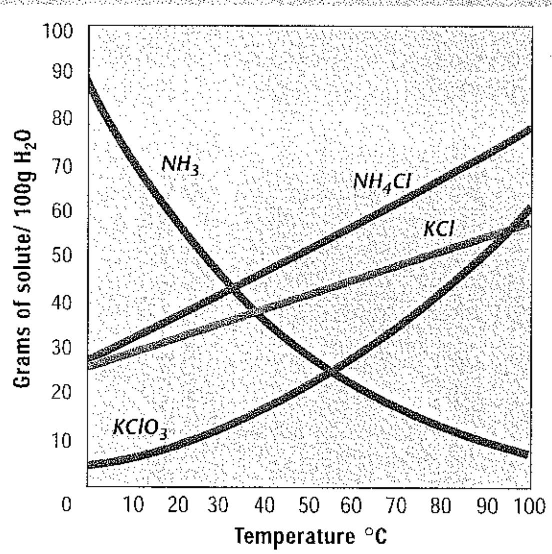
Present Your Project Demonstrate the indicators you prepared. Make a list of the substances you tested in order from most acidic to least acidic.

Reflect and Record In your journal, discuss whether or not you would use the same materials as indicators if you did this project again. Explain why. Describe how acid-base indicators could be useful for farmers and gardeners. Would you recommend that they use any of the indicators you made? Why or why not?

Test Preparation

Use these questions to prepare for standardized tests.

Study the graph showing solubilities of four compounds. Then answer Questions 24–27.



24. At 70°C, about how many grams of ammonium chloride (NH_4Cl) can dissolve in 100 grams of water?
a. 40 g **b.** 50 g
c. 60 g **d.** 70 g

25. If 30 grams of potassium chloride (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

26. Which one of the compounds becomes less soluble with increasing temperature?
a. NH_4Cl **b.** NH_3
c. KCl **d.** $KClO_3$

27. At about what temperature is the solubility of ammonia (NH_3) the same as the solubility of potassium chlorate ($KClO_3$)?
a. 0°C **b.** 55°C
c. 85°C **d.** 100°C