Chapter 7

Acids, Bases, and Solutions

CALIFORNIA Standards Preview

S 8.5 Chemical reactions are processes in which atoms are rearranged into different combinations of molecules. As a basis for understanding this concept:

- **d.** Students know physical processes include freezing and boiling, in which a material changes form with no chemical reaction.
- **e.** Students know how to determine whether a solution is acidic, basic, or neutral.

S 8.9 Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content in the other three strands, students should develop their own questions and perform investigations. Students will:

- **c.** Distinguish between variable and controlled parameters in a test.

Solutions containing transition metal compounds are often very colorful. ▶

Video Preview

Discovery Channel School

Acids, Bases, and Solutions

Focus on the

BIG Idea

S 8.5.e

What are some characteristics of acids and bases?

Check What You Know

Suppose you dissolve a teaspoon of salt in a glass of water. Is it possible to recover the salt from the water? Explain.

Build Science Vocabulary

The images shown here represent some of the key terms in this chapter. You can use this vocabulary skill to help you understand the meaning of some key terms in this chapter.

Vocabulary Skill

Identify Related Word Forms

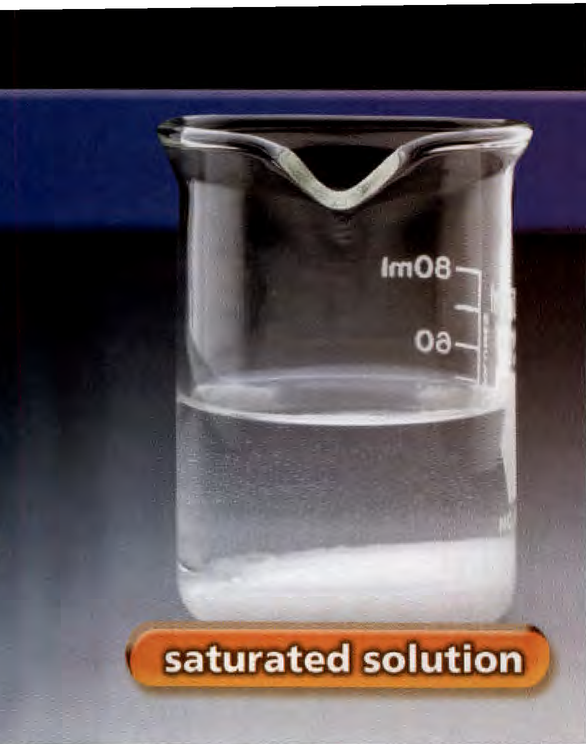
You can expand your vocabulary by learning the related forms of a word. For example, the common verb *to bake* is related to the noun *baker* and the adjective *baked*. As you read this chapter, look for related forms of the verbs *indicate*, *saturate,* and *suspend.*

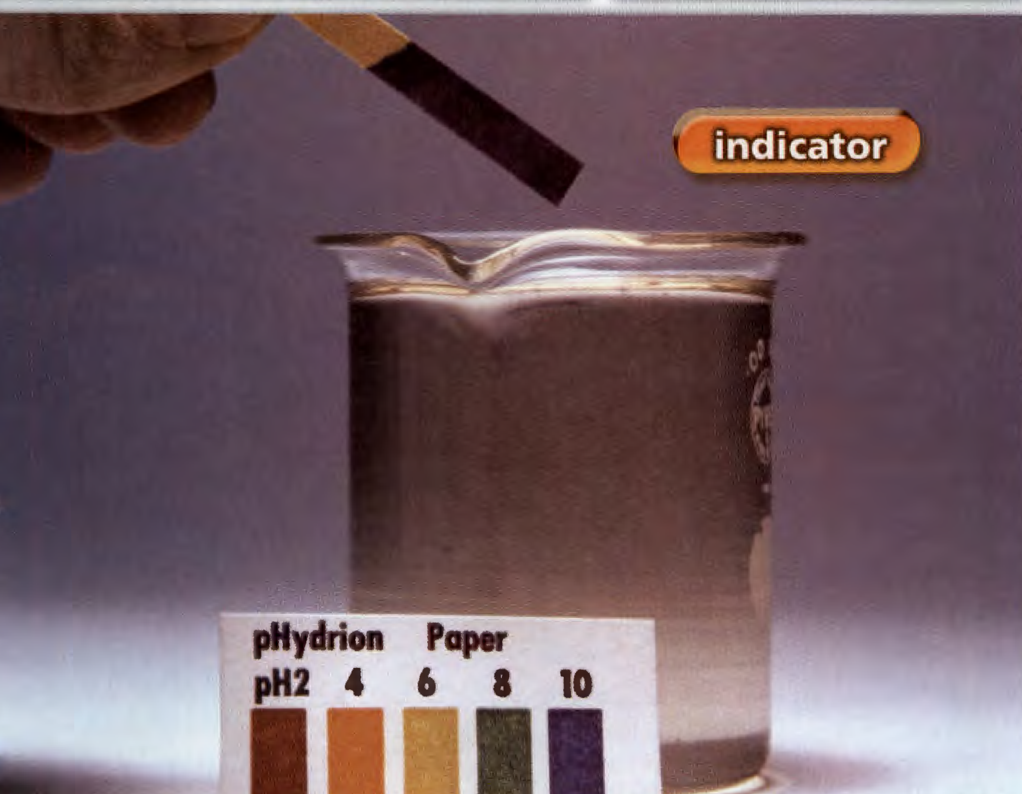
Verb	Noun	Adjective
indicate To show; to point to	**indicator** Something that shows or points to	**indicative** Serving as a sign; showing
saturate To fill up as much as is possible	**saturation** The condition of holding as much as is possible	**saturated** To be full; to hold as much as is possible
suspend To hang so as to allow free movement	**suspension** The condition of hanging or moving freely	**suspended** Hanging so as to allow free movement

Apply It!

Review the words related to *saturate.* Complete the following sentences with the correct form of the word.

1. The __________ sponge could hold no more water.
2. He continued to add water to the point of ______.





Chapter 7 Vocabulary

Section 1 (page 256)
solution
solvent
solute
colloid
suspension

Section 2 (page 262)
dilute solution
concentrated solution
solubility
saturated solution
unsaturated solution
supersaturated solution

Section 3 (page 268)
acid
corrosive
indicator
base

Section 4 (page 274)
hydrogen ion (H^+)
hydroxide ion (OH^-)
pH scale
neutral
neutralization
salt

Interactive Textbook
Build Science Vocabulary *Online*
Visit: PHSchool.com
Web Code: cxj-2070

How to Read Science

Reading Skill

Create Outlines

An outline shows the relationship between main ideas and supporting ideas. An outline usually is set up like the one shown below. Roman numerals show the main topics. Capital letters show the subtopic. Use the headings, subheadings, Key Terms, and Key Concepts to help you decide what information to include in your outline. Here is a sample for the beginning of Section 1.

Title → **Understanding Solutions**

I. What Is a Solution?
   - A. A mixture with the same properties throughout that contains a solvent and at least one solute ← Subheading
     1. Solvent—the largest portion ← Key terms and definitions
     2. Solute—the substance dissolved in the solvent ← Key terms and definitions
   - B. Solutions with water—the "universal solvent" ← Subheadings
   - C. Solutions without water—may contain solids, liquids, or gases ← Subheadings

II. Colloids and Suspensions
   - A. Colloids

Main topics → I, II

Apply It!

1. What are the two main topics in this outline?

2. Compare the definition of *solvent* in the outline with the definition on page 256. How are they different?

In your notebook, complete the outline for Section 1. As you read Section 4, write an outline to help you understand the relationship among topics in the section.

Lab zone

Standards Investigation

S 8.5.e

Make Your Own Indicator

As you learn about acids and bases in this chapter, you can make your own solutions that will let you determine if something is acidic, basic, or neutral. Such solutions change color in an acid or a base and are called acid-base indicators. 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 investigation, you must

- make 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 based on their pH values
- 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

CALIFORNIA Standards Focus

S 8.5.d Students know physical processes including freezing and boiling, in which a material changes form with no chemical reaction.

- 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

Lab zone Standards Warm-Up

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?

You're really thirsty, so you drink a tall, cool glass of tap water. But exactly what is tap water? 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 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 uniform 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.**

Dissolving one substance into another is an example of a physical change. In a physical change, neither substance changes into a new substance. Physical changes can often be undone to recover the original materials. Solutes and solvents have different physical properties such as boiling and melting points. You can use these different properties to recover the solute from the solvent. Suppose you dissolve salt in water. Water has a lower boiling point than salt. If you boil salt water, the water will vaporize first, leaving the salt behind.

Solutions With Water In many common solutions, the solvent is water. Sugar in water, for example, is the starting solution for flavored soda water. 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. Water is the solvent in blood, saliva, and tears.

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. Some solutions, such as air or brass, don't have liquid solvents at all. A solution may be a combination of gases, liquids, or solids.

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

Video Field Trip
Discovery Channel School
Acids, Bases, and Solutions

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	Stainless steel (chromium, nickel, and carbon in iron)

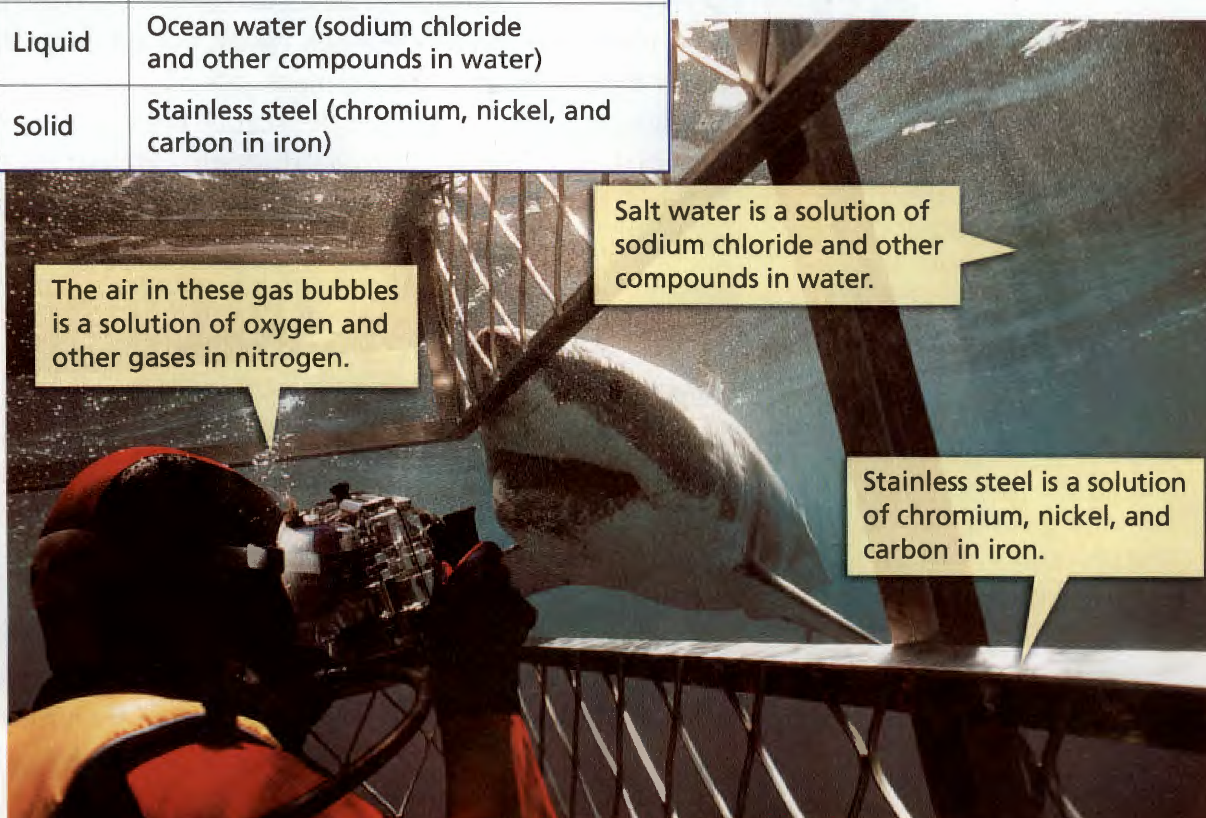


FIGURE 1
Solutions can be formed from any combination of solids, liquids, and gases.
Interpreting Photos *What are the solutes and solvent for stainless steel?*

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

Colloids and Suspensions

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

Colloids Look at Figure 2. The glass cleaner is a solution. You can see through solutions because light passes through them without being scattered in all directions. Have you ever tried to look through a glass of milk? Milk is a colloid. A **colloid** is a mixture that contains small, undissolved particles that do not settle out. **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.** Milk contains fats and proteins that form globular particles. These particles scatter light in different directions, making it impossible to see through a glass of milk.

Fog is a colloid that consists of water droplets in air. Fog scatters the headlight beams of cars, reducing visibility for drivers. Gelatin, mayonnaise, shaving cream, and whipped cream are other examples of colloids.

Suspensions If you did the Standards Warm-Up, 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 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. **A suspension does not have the same properties throughout. It contains visible particles that are larger than the particles in solutions or colloids.** The snow globe in Figure 2 is another example of a suspension.

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 does salt seem to disappear when you mix it with water? 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 solvent surround and separate the particles of the solute.**

Ionic and Molecular Compounds in Solution Figure 3 shows what happens when the ionic compound, salt, mixes with water. The positive and negative ions are attracted to the polar water molecules. Water molecules surround each ion as the ions leave the surface of the compound. As each layer of the compound is exposed, more ions can dissolve.

However, not every substance breaks into ions when it dissolves in water. A molecular compound, 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. The covalent bonds within the molecules remain unbroken.

Solutes and Conductivity Suppose 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 electric current, but a water solution of molecular compounds normally does not. You could test the electrical conductivity of the solution. If no ions are present (as in a sugar solution), current will not flow.

Reading Checkpoint **Which kind of solution conducts an electric current?**

Go Online
active art
For: Salt Dissolving in Water activity
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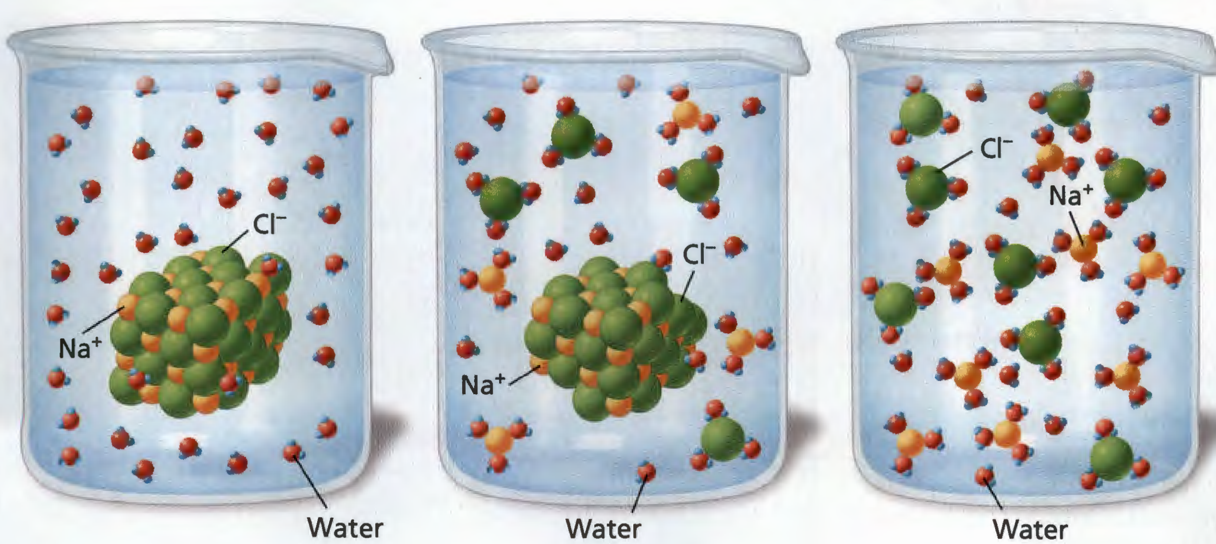
FIGURE 3
Salt Dissolving in Water
When an ionic compound —like salt—dissolves, water molecules surround and separate the positive and negative ions. Notice that the sodium ions attract the oxygen ends of the water molecules.



Lab zone Skills Activity

Designing Experiments

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

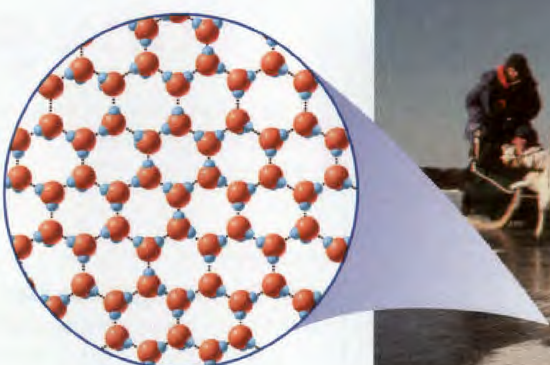
What variables should remain constant in your experiment? What is the manipulated variable? What will be the responding variable?

With approval from your teacher, do the experiment.

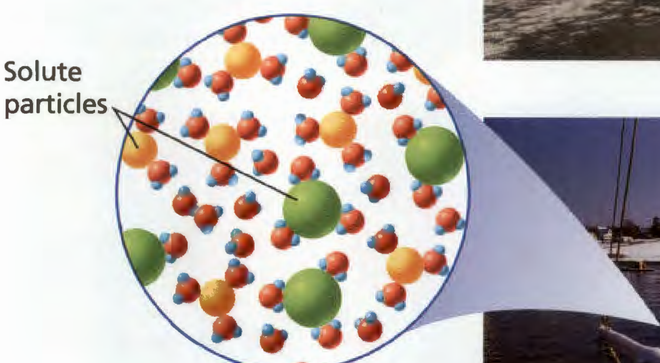
Effects of Solutes on Solvents

Ordinarily, the freezing point of pure water is 0°C, and the boiling point is 100°C. The addition of solutes to water changes these properties. **Solutes lower the freezing point and raise the boiling point of a solvent.**

Lower Freezing Points Pure water is made only of water molecules that freeze at 0°C. When liquid water freezes, water molecules join together to form crystals of solid ice. 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. The presence of a solute lowers the freezing point of water. Figure 4 illustrates the particles in pure water and in a saltwater solution.




Freshwater lake ▶



Saltwater bay ▶

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

Higher Boiling Points The directions for cooking pasta often advise adding salt to the water. Why? 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 water molecules need more energy to escape when a solute is present. The temperature must go higher than 100°C for water to boil. Solutes raise the boiling point of the solvent. Adding salt to the water decreases cooking time for the pasta because the water is hotter.

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. This solution can absorb more of the heat given off by the running engine. This reduces the risk of damage to the car from overheating. The freezing point of this solution is lower than the lowest temperature the car is likely to be exposed to. This reduces the risk of damage from freezing in very cold weather.

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

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

Section 1 Assessment

S 8.5.d, E-LA: Reading 8.1.0

Vocabulary Skill **Identify Related Word Forms**
Complete the sentence by using *solute* and *solution* correctly. A _______ is a mixture that contains at least one _______.

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.

Section 2

Concentration and Solubility

CALIFORNIA Standards Focus

S 8.5.d Students know physical processes including freezing and boiling, in which a material changes form with no chemical reaction.

- 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

Lab zone Standards Warm-Up

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 is able to dissolve 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

You must collect approximately 43 gallons of maple sap to make one gallon of maple syrup. 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). You make maple syrup by evaporating the water from the maple sap. By removing the water, you are left with a sweeter solution.

Making Maple Syrup ▼

Changing Concentration A **concentrated solution** has a lot of solute dissolved in a certain amount of solvent. You can make a concentrated solution by adding more solute 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. A **dilute solution** has only a little solute dissolved in a certain amount of solvent. You can make a dilute solution by increasing the amount of solvent in a solution. When you make juice from concentrate, you add water, making a more dilute solution.

Measuring Concentration You know that maple syrup is more concentrated than maple sap. But how could you find the actual concentration of either solution? **To measure concentration, you compare the amount of solute to the total amount of solution.** 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 measure 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, you might ask, "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.

If you can continue to dissolve more solute, you still have an **unsaturated solution.** 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.

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 *When the boy cannot dissolve any more sugar in his tea, what term describes the solution?*

Solubility in 100 g of Water at 0°C	
Compound	**Solubility (g)**
*Carbon dioxide (CO_2)	0.335
Baking soda ($NaHCO_3$)	6.9
Table salt (NaCl)	35.7
Table sugar ($C_{12}H_{22}O_{11}$)	180

*CO_2 at 101 kPa total pressure

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?*

Working With Solubility The solubility of a substance tells you how much solute you can dissolve before a solution becomes saturated. For solids, solubility is given for a particular solvent (such as water) at a particular temperature. For gases, the pressure is also given. 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 100 grams of water will dissolve 6.9 grams of baking soda. But the same mass of water will dissolve 180 grams of table sugar!

Using Solubility Suppose you had a white powder. You can't tell for sure whether the white powder is table salt or sugar. How could you identify it? You could measure its solubility in water at 0°C and compare the results to the data in Figure 7. **You can identify a substance by its solubility because it is a characteristic property of matter.**

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

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 becomes saturated when no more sugar will dissolve. 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.**

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.

Pressure Increasing the pressure increases the solubility of gases. Soda water contains dissolved carbon dioxide gas. To increase the carbon dioxide concentration in soda water, 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 must be 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."

Solvents Some solvents and solutes are not compatible. Have you ever tried to mix vinegar, which is mostly water, and oil 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 do not mix 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 you can use soap and water to clean up water-based (latex) paints. But cleaning up oil-based paints may require a nonpolar solvent, such as turpentine.

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

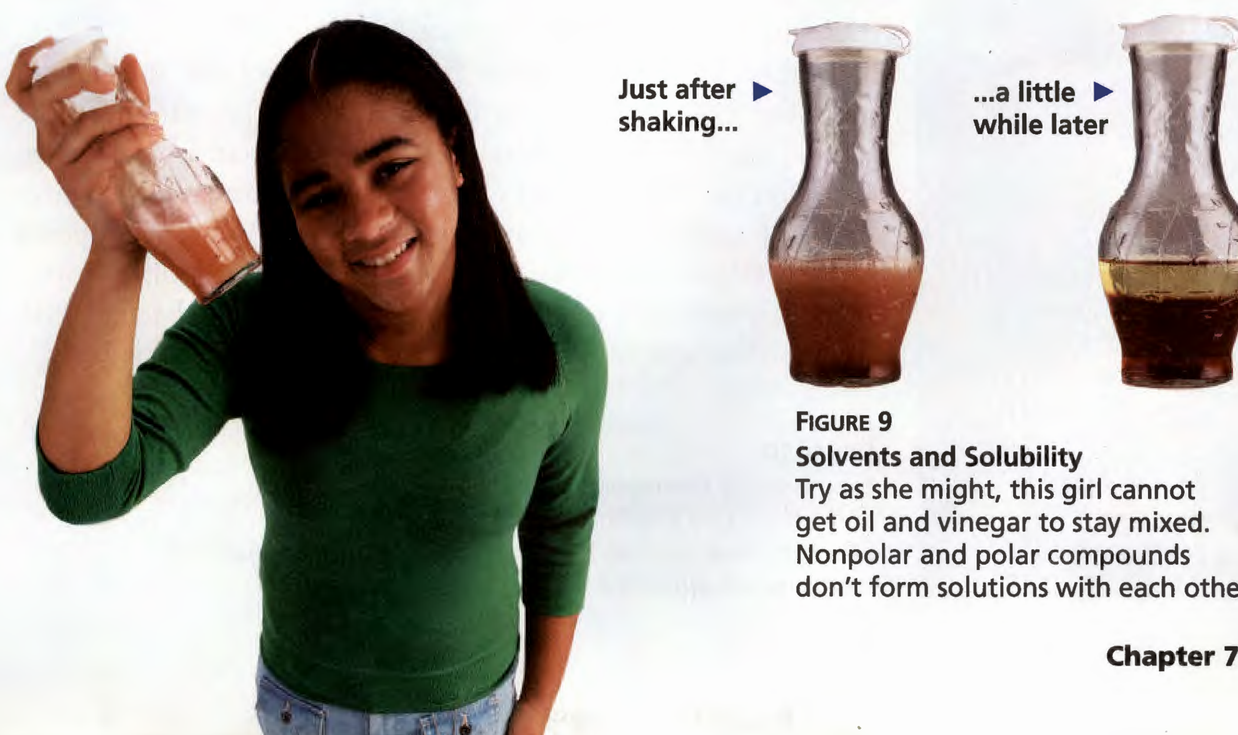


FIGURE 9
Solvents and Solubility
Try as she might, this girl cannot get oil and vinegar to stay mixed. Nonpolar and polar compounds don't form solutions with each other.

Reviewing Math: Algebra and Functions 7.1.5

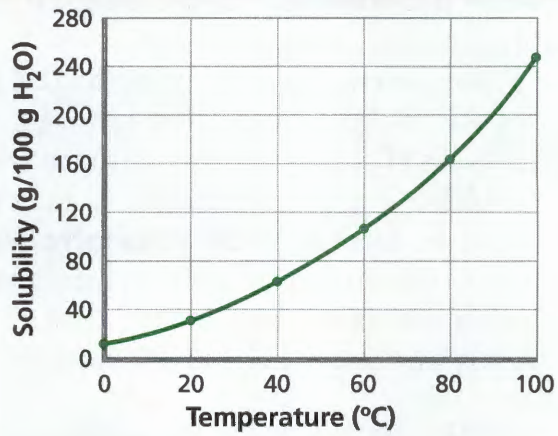
Math Analyzing Data

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.

Solubility of KNO_3



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 the increased solubility of sugar when they make treats 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 much sugar can dissolve in the water. The mixture must be heated until it begins to boil. Nuts and other ingredients are added while the mixture is still hot. 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 in a liquid when the temperature of the liquid goes up. For example, more carbon dioxide will dissolve in cold water than in hot water. Have you ever noticed that warm soda water tastes "flat"? Warm soda water contains less carbon dioxide gas. When you open a warm bottle of soda water, carbon dioxide escapes from the soda water in greater amounts than if the soda water had been chilled. So 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 immediately come out of solution (center). Soon, the precipitation 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. Look at Figure 11. When you drop a crystal of solute into a supersaturated solution, the extra solute will come out of the 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

S 8.5.d; Math: 7 NS 1.3
E-LA: Reading 8.1.0

Vocabulary Skill Identify Related Word Forms
Compare the meaning of the noun *solution* with the meaning of the adjective *solubility*. How are they similar? How are they different?

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

CALIFORNIA Standards Focus

S 8.5.e Students know how to determine whether a solution is acidic, basic, or neutral.

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

Key Terms

- acid
- corrosive
- indicator
- base

Lab zone Standards Warm-Up

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 observe other substances in the same way. You might observe 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 an orange, an apple, or fruit juice for breakfast today? 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

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 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. You should never taste a substance unless you know that it is safe to eat.

Reactions With Metals Acids react with certain metals, such as magnesium, zinc, and iron, to produce hydrogen gas. When they react, the metals seem to disappear in the solution. This observation is one reason acids are described as **corrosive**, meaning they "wear away" 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. The metal still covered with wax remains intact. 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 uses 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 Standards Warm-Up, 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. Litmus is a kind of dye derived from plants called lichens (LY kens). Litmus paper is made by coating strips of paper with litmus. Look at Figure 13 to see what happens to litmus paper as it is dipped in a solution containing acid. Acids turn blue litmus paper red. 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.

Reading Checkpoint How is litmus paper made?

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?*

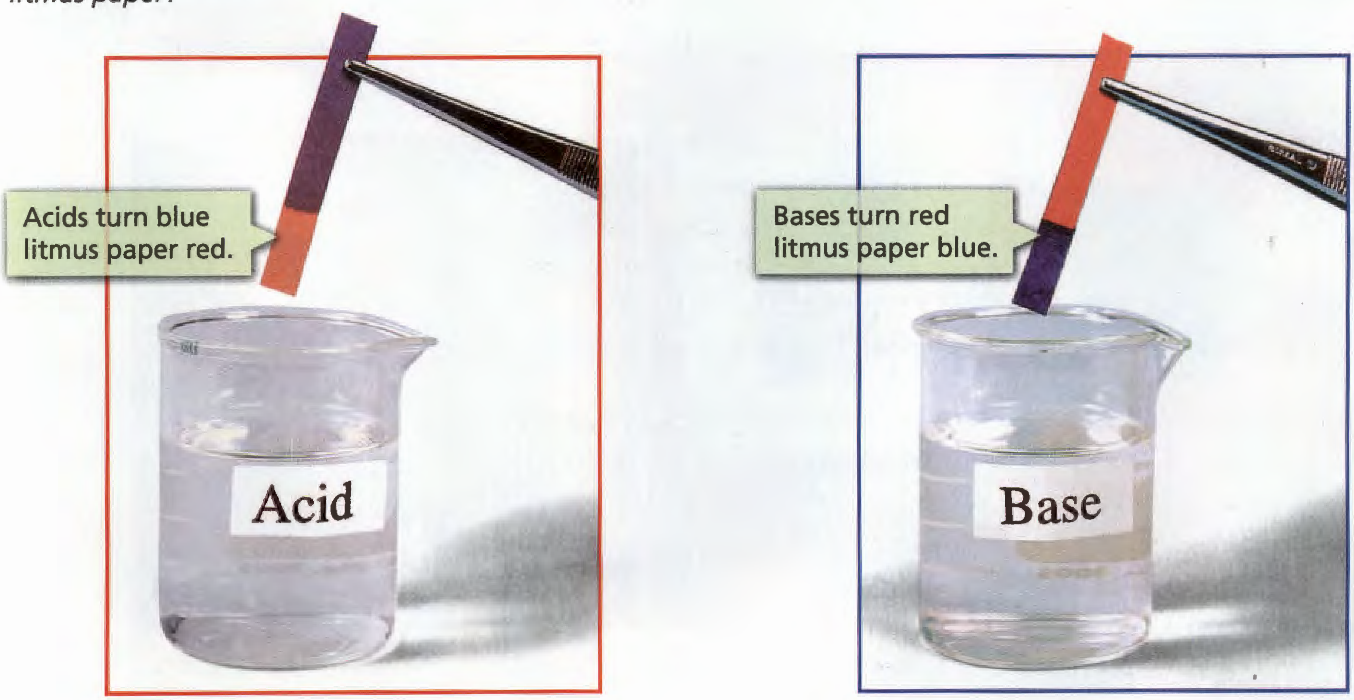


FIGURE 14
Bases in Soaps
If you give a dog a sudsy bath, bases in the soap could make your hands feel slippery.

Properties of Bases

Bases are another group of compounds that can be identified by their common properties. **A base tastes bitter, feels slippery, and turns red litmus paper blue.** Common bases include sodium hydroxide, calcium hydroxide, and ammonia.

Bitter Taste Bases taste bitter. The slightly bitter taste of soda water is caused by the base quinine. Soaps, some shampoos, and detergents taste bitter too, but they are not safe to taste. You should never taste a substance unless you know that it is safe to eat.

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 Since 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 how litmus works is to remember the letter *b*. Bases turn litmus paper **b**lue.

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

FIGURE 15
Uses of Acids
Acids are found in vegetables and 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.

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

Sulfuric acid reacts with lead and lead sulfate in a battery to produce an electric current.

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, some acids are vitamins, including ascorbic acid, or vitamin C, and folic acid. Vitamins are essential in small amounts to normal growth and functioning of the body. 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 vitamins are acids?

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 you must wear gloves 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.

Bases and Food ▼
Baking soda reacts with acids such as lemon juice and buttermilk to produce carbon dioxide gas in baked goods. Without these gas bubbles, breads, biscuits, cakes, and cookies would not be light and fluffy.

Section 3 Assessment

S 8.5.e, E-LA: Writing 8.2.0, Reading 8.1.0

Vocabulary Skill **Identify Related Word Forms** Look up the verb *corrode* in a dictionary. How does knowing the meaning of *corrode* help you understand the adjective *corrosive*?

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

CALIFORNIA Standards Focus

S 8.5.e Students know how to determine whether a solution is acidic, basic, or neutral.

- 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
- neutral
- neutralization
- salt

Lab zone Standards Warm-Up

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! How could these two harmful chemicals react to 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 the list of acids in Figure 17 begins with hydrogen. The acids you will learn about in this section all 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.

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 common 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:

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

An acid produces hydrogen ions (H^+) in water. These hydrogen ions cause the properties of acids. For instance, when you add acid to certain metals, 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 acids turn litmus paper red.

Reading Checkpoint **Why do acids turn litmus paper red?**

Bases in Solution

Look at the table in Figure 17. Many of the 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 at what happens to sodium hydroxide in water:

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

Not all bases contain 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.

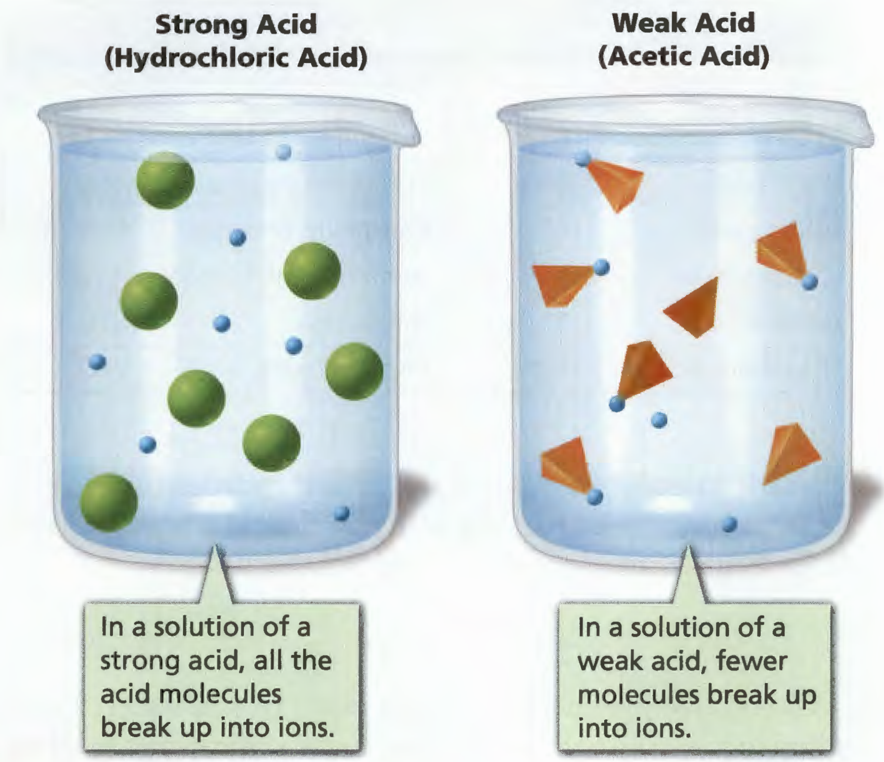
$$NH_3 + H_2O \longrightarrow NH_4^+ + OH^-$$

Notice that both reactions produce negative hydroxide ions in the product. **A base 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.

Key
- Chloride ion (Cl^-)
- Hydrogen ion (H^+)
- Acetic acid ($HC_2H_3O_2$)
- Acetate ion ($C_2H_3O_2^-$)



Lab zone Try This Activity

pH Predictions

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. Use what you already know to predict which materials are acidic or basic.
3. Using a plastic dropper, transfer a drop of one sample onto a fresh strip of pH paper.
4. Compare the color of the strip to the pH 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 ions form in solution. 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 ions (OH^-) 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 the pH scale and some common items. Notice that the most acidic items are at the low end of the scale. A pH lower than 7 is acidic. The most basic items are at the high end of the scale. 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 low pH indicates that the concentration of hydrogen ions is big. In contrast, a high pH indicates 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 using indicators. The student in Figure 20 is using pH paper. pH paper turns a different color for each pH value. Matching the color of the paper with the colors on the test scale indicates how acidic or basic the solution is.

You can also use an indicator solution to find the pH of a solution. Some indicator solutions will change color over the entire pH scale. Other indicator solutions only change color within a range of approximately two pH units. Knowing the pH range over which this color change occurs gives you a rough estimate of pH. Most chemistry laboratories contain a pH meter. A pH meter is an electronic device that makes rapid, accurate pH measurements.

Using Acids and Bases Safely 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 strength and their concentration.

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

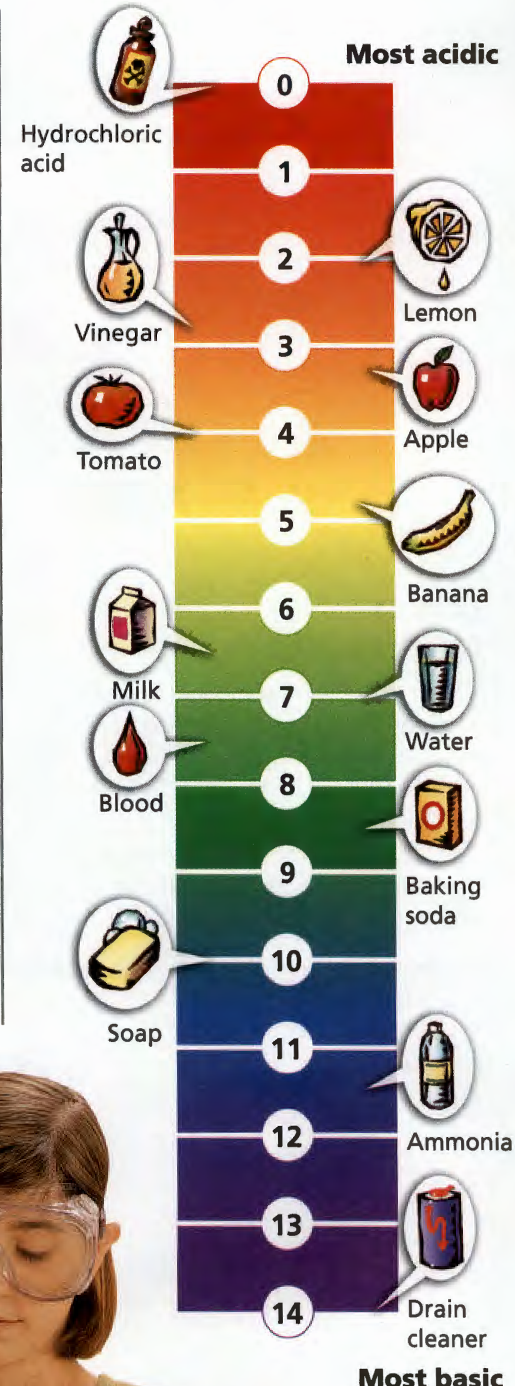


FIGURE 20
The pH Scale
The pH scale classifies solutions as acidic or basic. pH paper turns a different color for each pH value.
Interpreting Diagrams *If a solution has a pH of 9, is it acidic or basic?*

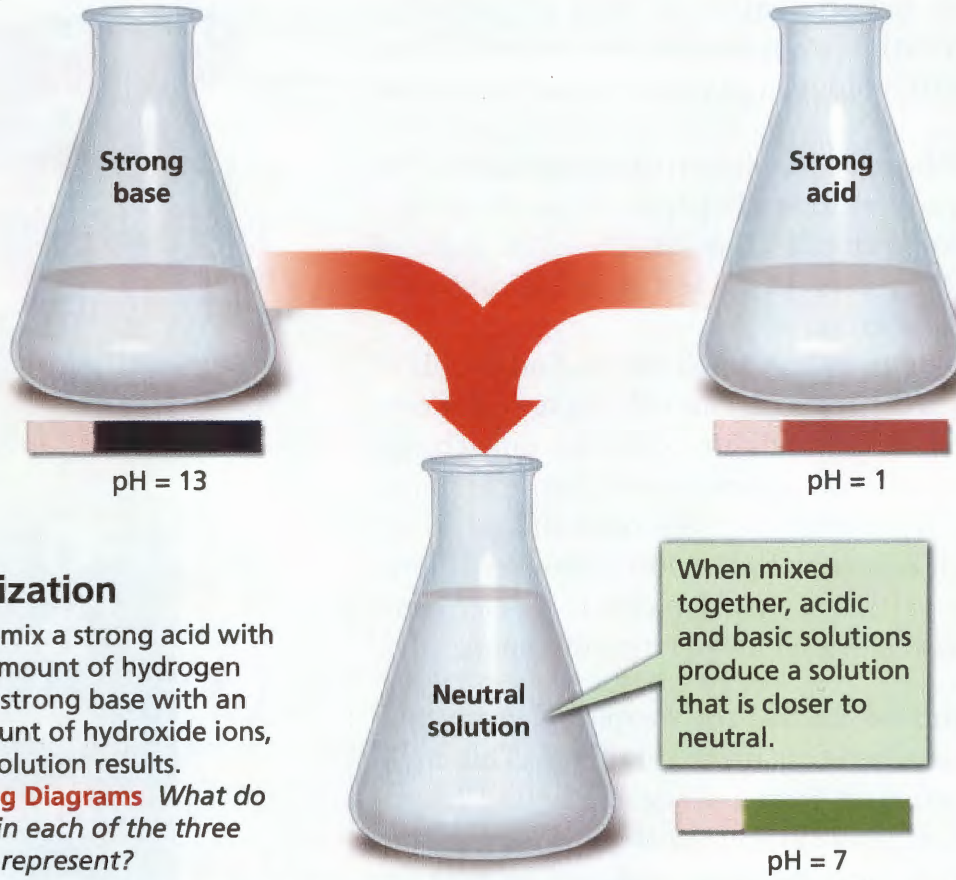


FIGURE 21
Neutralization
When you mix a strong acid with a certain amount of hydrogen ions and a strong base with an equal amount of hydroxide ions, a neutral solution results.
Interpreting Diagrams *What do the colors in each of the three rectangles represent?*

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. A reaction between an acid and a base is called **neutralization** (noo truh lih ZAY shun).

Reactants After neutralization, an acid-base mixture is less acidic or basic than either of the individual starting solutions. The pH depends on the identities, the volumes, and the concentrations of the reactants. If a small amount of strong base reacts with a much larger amount of strong acid, the solution will remain acidic. Look at Figure 21. A solution of strong acid contains a certain amount of hydrogen ions. A solution of strong base contains an equal amount of hydroxide ions. If you mix them together, a neutral solution results.

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

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:

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

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

S 8.5.e, E-LA: Reading 8.2.0

Target Reading Skill **Create Outlines** Complete your outline for Strength of Acids and Bases. Use your outline to help answer the following questions.

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

S 8.5.e, 8.9.c

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 is an indicator solution that 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** What variables are controlled? Why? What are the manipulated and responding variables?
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.*

Chapter 7 Study Guide

The BIG Idea Acids taste sour, turn blue litmus paper red, and produce hydrogen ions (H^+) in water. Bases taste bitter, turn red litmus paper blue, and produce hydroxide ions (OH^-) in water.

1 Understanding Solutions

Key Concepts S 8.5.d

- 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.
- 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 solvent surround and separate the particles of the solute.
- 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 S 8.5.d

- To measure concentration, you compare the amount of solute to the amount of solvent or to the total amount of solution.
- You can identify a substance by its solubility 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 S 8.5.e

- An acid tastes sour, reacts with metals and carbonates, and turns blue litmus paper red.
- A base 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 S 8.5.e

- An acid produces hydrogen ions (H^+) in water.
- A base 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
neutral
neutralization
salt

Review and Assessment

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Target Reading Skill

Create Outlines To help review Section 3, copy the incomplete outline for the section. Complete the outline by adding subtopics and details. Be sure to include Key Concepts and Key Terms.

Describing Acids and Bases

I. Properties of acids
  A. Taste sour
  B. React with metals
  C.
  D.
II. Properties of bases

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.

Complete the following sentences so that your answers clearly explain the Key Terms.

6. A **solution** is a mixture that contains __________ .
7. Pepper and water make a **suspension** because __________ .
8. An **acid** is a substance that tastes sour, reacts with metals and carbonates, and __________ .
9. Soap is an example of a **base** because __________ .
10. Litmus is an example of an **indicator** because __________ .

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.

Video Assessment
Discovery Channel School
Acids, Bases, and Solutions

Review and Assessment

Checking Concepts

11. Explain how you can tell the difference between a solution and a clear colloid.

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

13. Tomatoes are acidic. Predict two properties of tomato juice that you would be able to observe.

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

15. Give an example of a very acidic pH value.

16. What combination of acid and base can be used to make the salt sodium chloride?

Thinking Critically

17. 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.

18. 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.

19. 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.

20. 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.

21. Problem Solving Fill in the missing salt product in the reaction below.

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

22. Predicting What ions are formed when the base CaO is dissolved in water?

Math Practice

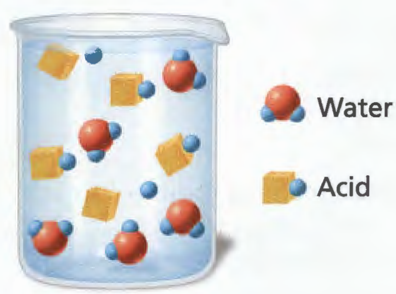
23. Calculating a Concentration If you have 1,000 grams of a 10-percent solution of sugar water, how much sugar is dissolved in the solution?

24. 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 25–28.

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



25. Interpreting Diagrams How can you tell that the solution contains a weak acid?

26. Inferring Which shapes in the diagram represent ions?

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

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

Lab zone Standards Investigation

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 investigation again? Explain.

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Standards Practice

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Choose the letter of the best answer.

1. 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. **S 8.5.e**

2. 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 **S 8.5.e**

3. A base is defined as strong if it has a pH value in the range of

A 0-3.
B 4-7.
C 8-11.
D 12-14. **S 8.5.e**

4. Dissolving salt in water is an example of a physical change because

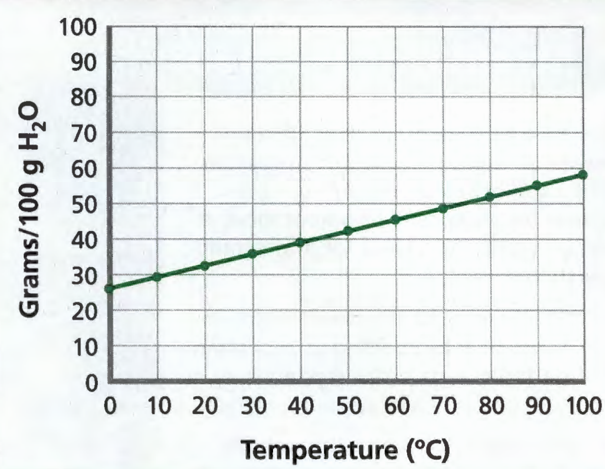
A neither of the substances changes into a new substance.
B the salt cannot be separated from the water.
C the water cannot become saturated with salt.
D a physical change occurs whenever a substance is mixed with water. **S 8.5.d**

5. Which of the following things could be used to determine whether a substance is an acid or a base?

A pH paper
B litmus paper
C pH meter
D all of the above **S 8.5.e**

Use the graph below and your knowledge of science to answer Question 6.

Solubility of Potassium Chloride (KCl)



6. A student makes a saturated solution of KCl and 100 g of water at 20°C. If the student leaves the solution and all of the water evaporates, how many grams of KCl will be left in the container?

A 0 g
B 16 g
C 32 g
D 40 g **S 8.5.d**

7. Which of the following is an example of a base?

A tomatoes
B lemons
C vitamin C
D soap **S 8.5.e**

Apply the BIG Idea

8. You have an unknown solution. You want to know whether the solution is an acid or a base. First list some of the known properties of acids and bases. Then describe a method of determining whether the solution is an acid or a base. **S 8.5.e**