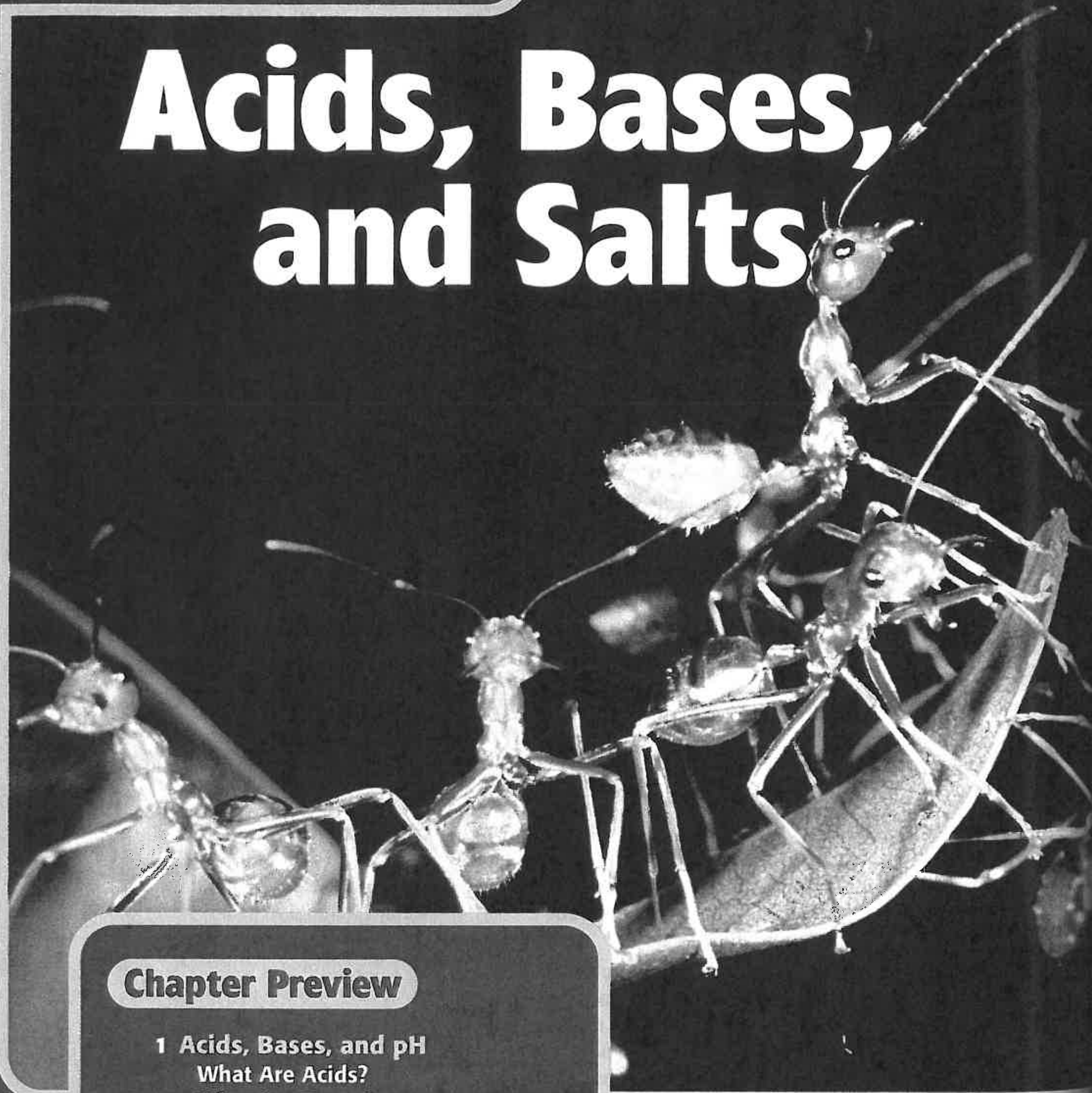
CHAPTER 8

Acids, Bases, and Salts



Chapter Preview

Some species of ants produce formic acid and inject it into their victims when they bite. The helicopter is adding a base to an acidic lake to neutralize it.

Focus ACTIVITY

Background Some kinds of ants can defend themselves with a quick squirt of highly irritating formic acid solution. These ants are often called *stinging ants,* but in fact the ants bite and then squirt the acid into the wound. Formic acid was identified in 1670 by a chemist who heated ants in a flask and collected the vapors given off. The name *formic acid* is from the Latin *formica,* meaning ant. Many other acids are also found in living things.

Acids also react with a type of chemical called *bases.* In many ways, acids and bases are chemical opposites. For example, the base calcium hydroxide can be used to treat lakes that are too acidic. The reaction that neutralizes the lake is similar to the reaction that happens when you take an antacid for an upset stomach.

Activity 1 Cut a lemon in half. Squeeze the lemon over a clean dish to get about a teaspoon of juice. Dip a clean finger into the juice, and taste it. Describe the taste. Do you think that lemon juice is acidic or basic? Give reasons for your decision.

Activity 2 After you have tasted the lemon juice in Activity 1, add a teaspoon of water to it, and stir with your finger. With a clean, dry spoon, add 1/2 teaspoon of baking soda to the diluted lemon juice. What happens to the juice and baking soda? Baking soda is a basic substance. What evidence do you see that a chemical reaction takes place?

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Pre-Reading Questions

1. The orange is known as a citrus fruit because it contains *citric acid*. What other foods may contain citric acid?
2. Bee venom is also acidic. How might a solution of baking soda in water reduce the pain of a bee sting?

SECTION 1

Acids, Bases, and pH

KEY TERMS

acid
indicator
electrolyte
base
pH

OBJECTIVES

- **Describe** the ionization of strong acids in water and the dissociation of strong bases in water.
- **Distinguish** between solutions of weak acids or bases and solutions of strong acids or bases.
- **Relate** pH to the concentration of hydronium ions and hydroxide ions in a solution.

Does the thought of eating a lemon make your mouth pucker and your saliva flow? You know to expect that sour, piercing taste that can sometimes make you shudder. Eating a lime or a dill pickle may cause you to have a similar response.

What Are Acids?

Each of the foods shown in ***Figure 1*** tastes sour because it contains an **acid.** Several fruits, including lemons and limes, contain citric acid. Dill pickles are soaked in vinegar, which contains acetic acid. Other acidic foods include apples, which contain malic acid, and grapes, which contain tartaric acid.

acid any compound that increases the number of hydronium ions when dissolved in water

indicator a compound that can reversibly change color depending on the pH of the solution or other chemical change

When acids dissolve in water, they *ionize*, which means that they form ions. Hydrogen ions, H^+, attach to water molecules to form hydronium ions, H_3O^+. These hydronium ions are responsible for the sour taste you experience. **Indicators** respond to the concentration of hydronium ions in water by changing color. Blue litmus paper contains an indicator that can help you determine if a substance is an acid. Acids turn blue litmus paper red, as shown in ***Figure 1.***

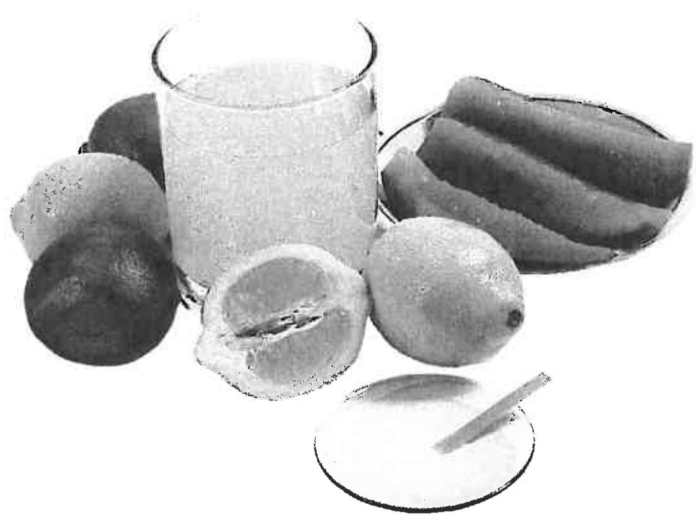
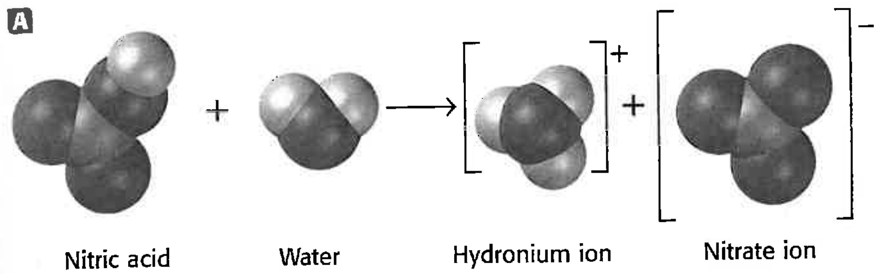
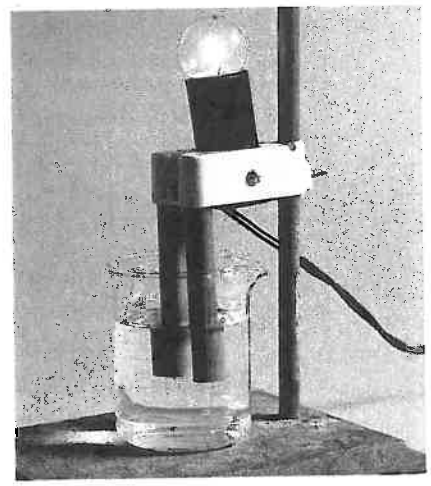


Figure 1
Lemons, limes, and dill pickles taste sour because they contain acids. Acids, such as the citric acid in lemon juice, turn blue litmus paper red.

Figure 2





B Nitric acid, HNO_3, is a strong electrolyte and a strong acid because it ionizes completely in water to form hydronium, ions H_3O^+, and nitrate ions, NO_3^-.

Strong acids ionize completely

All acids ionize when dissolved in water. The ionization process shown in ***Figure 2A*** occurs when nitric acid is added to water. The single arrow pointing to the right shows that nitric acid ionizes completely in water. When the acid ionizes, it forms hydronium ions and nitrate ions. These charged ions are able to move around in the solution and conduct electricity, as you see in ***Figure 2B.*** A substance that conducts electricity when dissolved in water is an **electrolyte.**

Solutions of some acids, such as nitric acid, conduct electricity well. Nitric acid, HNO_3, is a *strong acid* because it ionizes completely in water. Other strong acids behave similarly to nitric acid when dissolved in water. A solution of sulfuric acid in water, for example, conducts electric current in car batteries. Strong acids are strong electrolytes because solutions of these acids have as many hydronium ions as the acid can possibly form.

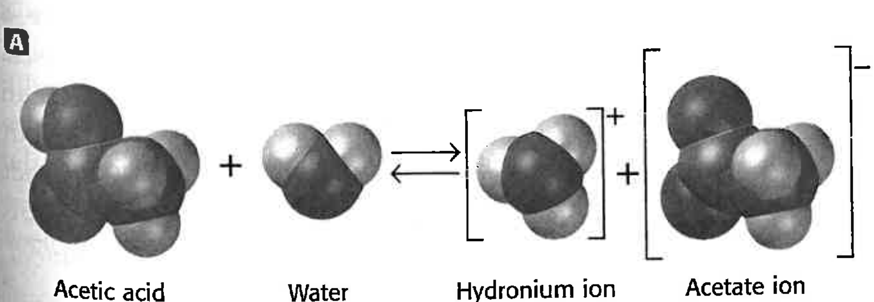
electrolyte a substance that dissolves in water to give a solution that conducts an electric current

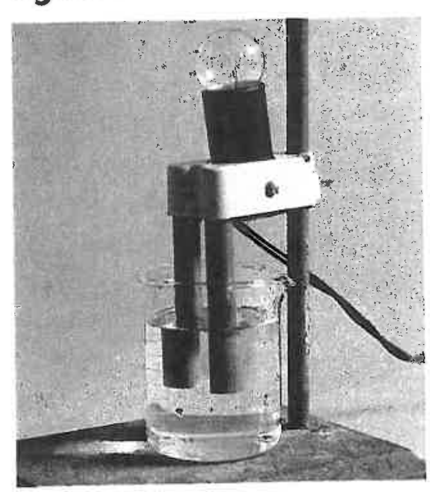
Weak acids do not ionize completely

Solutions of *weak acids,* such as acetic acid, CH_3COOH, do not conduct electricity as well as nitric acid. When acetic acid is added to water, the equilibrium shown in ***Figure 3A*** is reached.

When acetic acid is dissolved in water, some molecules of acetic acid combine with water molecules to form ions. Many of the ions then recombine to form molecules of acetic acid. Because there are fewer charged ions in a solution of acetic acid, it does not conduct electricity very well, as shown in ***Figure 3B.*** Acetic acid and other weak acids are weak electrolytes.

Figure 3





B Acetic acid, CH_3COOH, is a weak acid and a weak electrolyte because it ionizes only partially in water to form hydronium ions, H_3O^+, and acetate ions, CH_3COO^-.

Table 1 **Some Common Acids**

Acid	Formula	Strength	Uses for the acid
Hydrochloric acid	HCl	strong	cleaning masonry; treating metal before plating or painting; adjusting the pH of swimming pools
Sulfuric acid	H_2SO_4	strong	manufacturing fertilizer and chemicals; most used industrial chemical; the electrolyte in car batteries
Nitric acid	HNO_3	strong	manufacturing fertilizers and explosives
Acetic acid	CH_3COOH	weak	manufacturing chemicals, plastics, and pharmaceuticals; the acid in vinegar
Formic acid	$HCOOH$	weak	dyeing textiles; the acid in stinging ants
Citric acid	$H_3C_6H_5O_7$	weak	manufacturing flavorings and soft drinks; the acid in citrus fruits (oranges, lemons, limes)

Any acid can be dangerous in a concentrated form

Some examples of common strong and weak acids and their uses are listed in ***Table 1.*** Acids are used in many manufacturing processes and are necessary to many organisms even though strong acids can damage living tissue. For example, your stomach normally contains a dilute solution of hydrochloric acid that helps you digest food, but concentrated hydrochloric acid can burn your skin.

Even weak acids are not always safe to handle. Most vinegar is a 5% solution of acetic acid in water, but concentrated acetic acid can damage the skin, and the vapors are harmful to the eyes, mouth, and lungs. To be safe, always wear safety goggles, gloves, and a laboratory apron when working with acids.

Figure 4
These household items are bases because they produce OH^- ions in water solution.

base any compound that increases the number of hydroxide ions when dissolved in water

What Are Bases?

Like acids, all **bases** share common properties. Bases have a bitter, soapy taste, and solutions of bases feel slippery. ***Figure 4*** shows some common household substances that contain bases. Like solutions of acids, solutions of bases contain ions and can conduct electricity. Some bases contain hydroxide ions, OH^-, but others do not. Bases that do not contain hydroxide ions will react with water molecules to form hydroxide ions. Bases cause indicators to change color, such as turning red litmus paper blue.

Table 2 **Some Common Bases**

Base	Formula	Strength	Uses for the base
Potassium hydroxide (potash)	KOH	strong	manufacturing soap; absorbing carbon dioxide from flue gases; dyeing products
Sodium hydroxide (lye)	$NaOH$	strong	manufacturing soap; refining petroleum; cleaning drains; manufacturing synthetic fibers
Calcium hydroxide	$Ca(OH)_2$	strong	treating acidic soil; treating lakes polluted by acid precipitation; making mortar, plaster, and cement
Ammonia	NH_3	weak	fertilizing soil; manufacturing other fertilizers; manufacturing nitric acid; making cleaning solutions
Methylamine	CH_3NH_2	weak	manufacturing dyes and medicines; tanning leather
Aniline	$C_6H_5NH_2$	weak	manufacturing dyes and varnishes; used as a solvent

Many common bases contain hydroxide ions

Strong bases are ionic compounds that contain a metal ion and a hydroxide ion. These strong bases are also known as *metal hydroxides*. When a metal hydroxide is dissolved in water, the metal ions and the hydroxide ions *dissociate*, or separate.

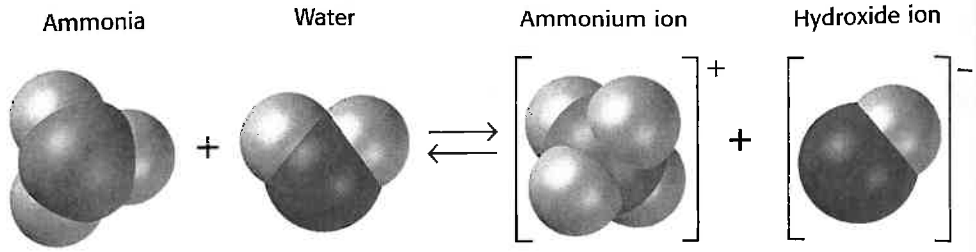
For example, sodium hydroxide, NaOH, is a metal hydroxide that is found in some drain cleaners. Solutions of sodium hydroxide conduct electricity well, so sodium hydroxide is a strong electrolyte. The dissociation of sodium hydroxide in water is shown below.

$$NaOH \rightarrow Na^+ + OH^-$$

Some metal hydroxides, such as calcium hydroxide and magnesium hydroxide, are not very soluble in water, but the ions in the part of the metal hydroxide that does dissolve separate completely. Calcium hydroxide is used to treat soil that is too acidic. Other useful bases are listed in ***Table 2.***

Like acids, bases can be very dangerous in concentrated form, and in the case of bases such as sodium hydroxide and potassium hydroxide, bases can be dangerous even in fairly dilute form. Because bases attack living tissue very rapidly, bases are in some ways more dangerous than acids. To protect yourself when working with bases in the laboratory, always wear safety goggles, gloves, and a laboratory apron. If possible, work with very dilute bases instead of concentrated ones.

Figure 5
Ammonia produces hydroxide ions in water through ionization. An ammonia molecule accepts H^+ ions from water to form ammonium ions, NH_4^+, and hydroxide ions, OH^-.



Other bases ionize in water to form hydroxide ions

Ammonia, like other bases, forms hydroxide ions when it dissolves in water. But ammonia does not contain hydroxide ions. Instead, it forms hydroxide ions with water through an ionization process, shown in ***Figure 5.*** In this process, water acts as an acid and donates a hydrogen ion to ammonia to form an ammonium ion, NH_4^+, and leaves a hydroxide ion, OH^-, behind.

A solution of ammonia in water is a poor conductor of electricity. This shows that only some of the ammonia molecules actually become ammonium ions when the ammonia dissolves. So, an ammonia solution consists mostly of water and dissolved ammonia, along with a few ammonium ions and hydroxide ions. Ammonia is a much weaker base than potassium hydroxide, which is a metal hydroxide that dissociates completely.

Quick Lab

Which household substances are acidic, which are basic, and which are neither?

Materials

- *baking powder*
- *baking soda*
- *several 50 mL beakers*
- *pipet bulbs*
- *milk*
- *mineral water*
- *bleach*
- *blue litmus paper*
- *white vinegar*
- *dishwashing liquid*
- *soft drinks*
- *mayonnaise*
- *red litmus paper*
- *disposable pipets or eyedroppers*
- *laundry detergent*
- *tap water*

SAFETY CAUTION Wear safety goggles, gloves, and a laboratory apron. Never pipet anything by mouth.

1. Prepare a sample of each substance you will test. If the substance is a liquid, pour about 5 mL of it into a small beaker. If the substance is a solid, place a small amount of it in a beaker, and add about 5 mL of water. Label each beaker clearly with the name of the substance that is in the beaker.
2. Use a pipet to transfer a drop of liquid from one of the samples to red litmus paper. Then transfer another drop of liquid from the same sample to blue litmus paper. Record your observations.
3. Repeat step 2 for each sample. Be sure to use a clean pipet to transfer each sample.

Analysis

1. Which substances are acidic? Which are basic? How did you determine this?
2. Which substances are not acids or bases? How did you determine this?

What Is pH?

You can tell if a solution is acidic or basic by using an indicator, such as litmus paper. But to determine exactly how acidic or basic a solution is, you must measure the concentration of hydronium (H_3O^+) ions. The **pH** of a solution indicates its concentration of H_3O^+ ions. The pH of a solution is often critical. For example, enzymes in your body work only in a narrow pH range.

VOCABULARY Skills Tip

The term pH *originates from the French words* pouvoir Hydrogène, *which means "the power of hydrogen."*

pH values correspond to the concentration of hydronium ions

pH is a measure of the H_3O^+ concentration in a solution, but pH also indicates hydroxide ion (OH^-) concentration. So a pH value can tell you how acidic or basic a solution is. A pH value can even tell you if a solution is neutral, or neither an acid nor a base.

pH a value used to express the acidity or alkalinity of a solution

Typically, the pH of solutions ranges from 0 to 14, as shown in ***Figure 6.*** In neutral solutions, or in substances such as pure water, the concentration of hydronium ions equals the concentration of hydroxide ions, and the pH is 7. Solutions that have a pH of less than 7 are acidic. In acidic solutions, such as apple juice, the concentration of hydronium ions is greater than the concentration of hydroxide ions. Solutions that have a pH of greater than 7 are basic. In basic solutions, the concentration of hydroxide ions is greater than the concentration of hydronium ions.

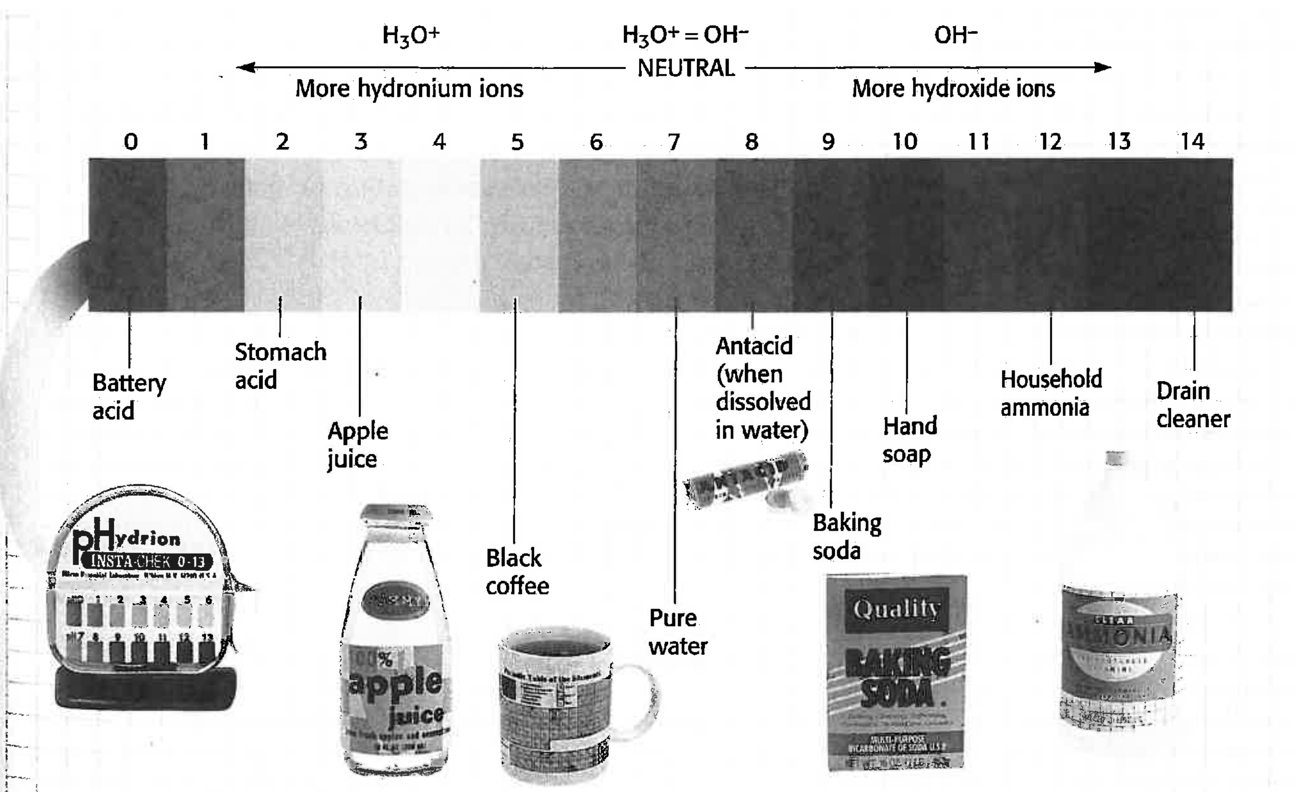


Figure 6

The pH of a solution is easily measured by moistening a piece of pH paper with the solution and then comparing the color of the pH paper with the color scale on the dispenser of the pH paper.

The concentration of a strong acid allows you to calculate pH

When you describe the concentration of a substance in a solution, you probably write the concentration as a *molarity* (M), or the number of moles of the substance per liter of solution. For example, the hydronium ion (H_3O^+) concentration of pure water at 25°C is 0.000 000 1 mol/L, or 10^{-7} M.

When the H_3O^+ concentration of a solution can be written as a power of 10, the pH is the negative of the power of 10 used to describe the concentration of hydronium ions. For example, the pH of pure water is 7, so the concentration of hydronium ions in water is 10^{-7} M. The pH of apple juice is about 3, so the concentration of H_3O^+ in apple juice is 10^{-3} M.

If you know the concentration of a solution of a strong acid, you can calculate the pH of the solution. When a strong monoprotic acid ionizes in a solution, one hydronium ion is formed for each particle of acid that dissolves. So the concentration of hydronium ions in a solution of strong acid is the same as the concentration of the acid itself, and this information allows you to find the pH of the solution.

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Did You Know?

Did you know that the concentration of hydronium ions and the concentration of hydroxide ions are related? In any solution made with water, the more hydronium ions there are (the more acidic the solution is), the fewer hydroxide ions there are (the less basic the solution is).

Math Skills

Determining pH Determine the pH of a 0.0001 M solution of the strong acid HCl dissolved in water.

1 List the given and unknown values.

Given: *concentration of HCl in solution* = 0.0001 M
Unknown: pH

2 Determine the molar concentration of hydroxide ions.

concentration of HCl in solution = 0.0001 M
HCl is completely ionized into H_3O^+ and Cl^- ions.
concentration of H_3O^+ ions in solution = 0.0001 M = 1×10^{-4} M

3 Convert the H_3O^+ concentration to pH.

concentration of H_3O^+ ions = 1×10^{-4} M
pH = $-(-4) = 4$

Practice HINT

- If a solution contains a base, you should expect the pH to be greater than 7. If the solution contains an acid, the pH will be less than 7.
- To find the concentration of a solution of strong acid from its pH, multiply the pH value by –1. Then use the result as a power of 10. The result is the concentration of the acid in moles per liter (mol/L).

Practice

Determining pH

1. Calculate the pH of a 1×10^{-4} M solution of HBr, a strong acid.
2. Determine the pH of a 0.01 M solution of HNO_3, a strong acid.
3. Nitric acid, HNO_3, is a strong acid. The pH of a solution of HNO_3 is 3. What is the concentration of the solution?

Small differences in pH mean larger differences in acidity

Because pH is the negative of the power of 10 of hydronium ion concentration, small differences in pH mean larger differences in the hydronium ion concentration. For example, the pH of apple juice differs from the pH of coffee by two pH units, so apple juice is 10^2, or 100 times, more acidic than coffee. Likewise, coffee is about 10^3, or 1000 times, more acidic than antacid tablets, which form a base with a pH of about 8 when dissolved in water.

pH can be measured in more than one way

pH paper contains several indicators that change color at different pH values. pH may also be measured with a pH meter, as shown in ***Figure 7.*** Because ions in a solution have an electric charge, a pH meter can measure pH by determining the electric current created by the movement of the ions in the solution. If you use a pH meter properly, you can determine the pH of a solution more precisely than is possible if you use pH paper.

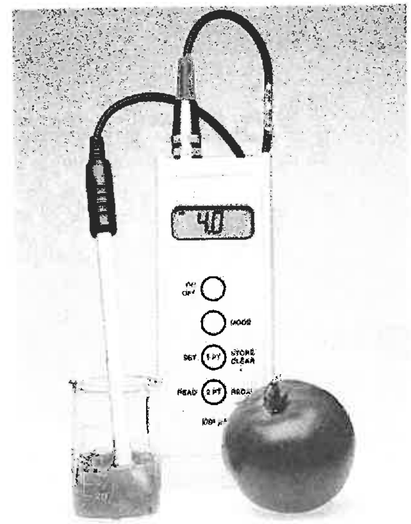


Figure 7

A pH meter measures an electric current that results from differences in H_3O^+ concentrations.

SECTION 1 REVIEW

SUMMARY

- Acids are substances that taste sour, turn blue litmus paper red, and form hydronium ions when they dissolve in water.
- Strong acids are strong electrolytes because they ionize completely in water.
- Weak acids are weak electrolytes because they ionize only slightly in water.
- Bases have a slippery feel, have a bitter taste, turn red litmus paper blue, and produce hydroxide ions when they dissolve in water.
- The pH of a solution of a strong acid can be found if you know the concentration of the solution.

1. **Explain** how a strong acid and a weak acid behave differently when each is dissolved in water.
2. **Compare** the ionization of a weak acid in water to the ionization of a weak base in water.
3. **Write** the chemical equation for the self-ionization of water.
4. **Classify** the following solutions as acidic, basic, or neutral.
   - **a.** a soap solution, pH = 9
   - **b.** a sour liquid, pH = 5
   - **c.** a solution that has four times as many hydronium ions as hydroxide ions
   - **d.** pure water
5. **Arrange** the following substances in order of increasing acidity: vinegar (pH = 2.8), gastric juices from inside your stomach (pH = 2.0), and a soft drink (pH = 3.4).
6. **Critical Thinking** A solution of an acid in water has a pH of 4, which is slightly acidic. Is this a solution of a weak acid? Explain your answer.

Math Skills

7. What is the pH of a 0.01 M solution of the strong acid $HClO_4$, perchloric acid?

SECTION 2

Reactions of Acids with Bases

KEY TERMS

neutralization reaction

salt

OBJECTIVES

- **Write** ionic equations for neutralization reactions.
- **Identify** the products of a neutralization reaction.
- **Describe** the composition of a salt.

Have you ever used an antacid to relieve the symptoms of an upset stomach or so-called heartburn? Heartburn has nothing to do with your heart. Heartburn occurs when the stomach's natural solution of hydrochloric acid (HCl) irritates the lining of the esophagus. The antacid contains a base that reacts with the acid to reduce the acidity of the solution and soothe your stomach.

neutralization reaction the reaction of the ions that characterize acids (hydronium ions) and the ions that characterize bases (hydroxide ions) to form water molecules and a salt

Acid-Base Reactions

A reaction between an acid and a base is a **neutralization reaction.** An example of neutralization is the reaction of HCl and magnesium hydroxide, which is an antacid and a base.

Neutralization is an ionic reaction

A solution of a strong acid, such as hydrochloric acid, ionizes completely, as shown below.

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

In a similar way, a solution of a strong base, such as sodium hydroxide, dissociates completely, as shown below.

$$NaOH \rightarrow Na^+ + OH^-$$

If the two solutions of equal concentrations and equal volumes are combined, the following neutralization reaction takes place:

$$H_3O^+ + Cl^- + Na^+ + OH^- \rightarrow Na^+ + Cl^- + 2H_2O$$

The Na^+ and Cl^- ions are called *spectator ions* because they are like spectators watching on the sidelines. These ions do not change during the reaction between H_3O^+ and OH^-. As you can see in ***Figure 8,*** energy is also released in the reaction of Na and Cl_2.

Figure 8
When Na reacts with Cl_2, sodium chloride is produced and energy is released.

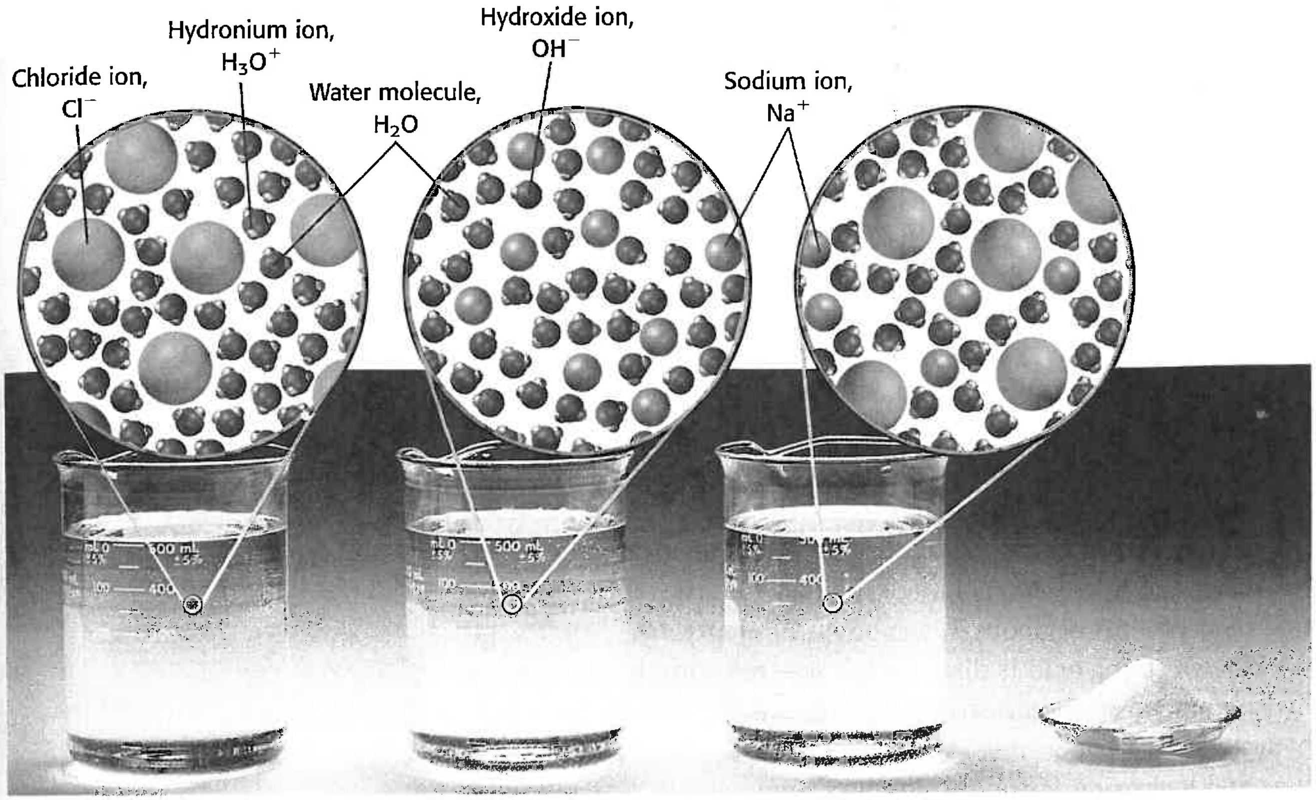


Figure 9

When a solution of HCl reacts with a solution of NaOH, the reaction produces water and leaves sodium and chloride ions in solution. When the water is evaporated, the sodium and chloride ions crystallize to form pure sodium chloride.

Strong acids and bases react to form water and a salt

If you include only the substances that react during neutralization, the equation can be written as follows:

$$H_3O^+ + OH^- \rightarrow 2H_2O$$

When an acid reacts with a base, hydronium ions react with hydroxide ions to form water. The other ions—positive ions from the base and negative ions from the acid—form an ionic compound called a **salt,** such as sodium chloride. Salts are ionic compounds that are often soluble in water, as you can see in ***Figure 9.***

salt an ionic compound that forms when a metal atom or a positive radical replaces the hydrogen of an acid

Not all neutralization reactions produce neutral solutions

Reactions between acids and bases do not always produce neutral solutions. The final pH of the solution depends on the amounts of acid and base that are combined. The pH also depends on whether the acid and base are strong or weak.

If a strong acid, such as nitric acid, reacts with an equal amount of a weak base, such as sodium hydrogen carbonate from an antacid tablet, the resulting solution will still be acidic. A similar situation occurs when a strong base reacts with a weak acid. When a strong acid reacts with an equal amount of a weak base, the resulting solution will be acidic.

Titrations are neutralization reactions

When an acid solution is added to a basic solution, a neutralization reaction occurs. If you know the concentration of the acid solution or the basic solution, a *titration* can help you determine the concentration of the other solution. A titration is the process of gradually adding one solution to another solution in the presence of an indicator to determine the concentration of one of the solutions.

In a titration, an indicator is used that changes color when the original amount of the base in solution is equal to the amount of the acid added to the solution. For example, when a strong acid is titrated with a strong base, an indicator called *bromthymol blue* is used because bromthymol blue changes color when the solution reaches a pH of about 7, as shown in ***Figure 10***.

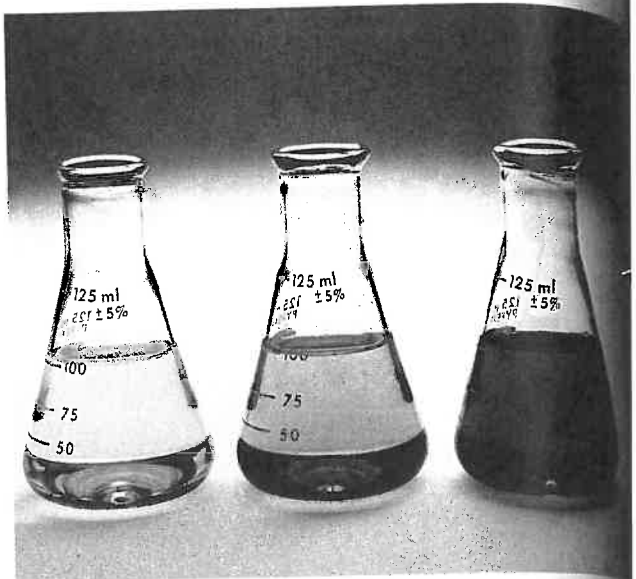


Figure 10

Bromthymol blue is an indicator that changes color between a pH of 6.0 and 7.6. It is ideal for a titration involving a strong acid and a strong base.

When a strong acid is dissolved, it ionizes completely to form hydronium ions. When a strong base dissolves, it forms as many hydroxide ions as possible. And as you have learned, hydronium ions and hydroxide ions combine in a neutralization reaction. If the number of hydronium ions is equal to the number of hydroxide ions in a solution, the product of the reaction will be neutral. The *equivalence point* in a titration of a strong acid with a strong base is reached when the original amount of the acid equals the original amount of the base and occurs at pH 7. ***Figure 11*** shows the change in pH during the titration of nitric acid with sodium hydroxide.

The equivalence point is not always neutral

Titrations can also be carried out with a strong acid and a weak base, or with a weak acid and a strong base. In these cases, however, the equivalence point will not be at pH 7. For example, when 1 mol of acetic acid, a weak acid, reacts in water with 1 mol of sodium hydroxide, a strong base, 1 mol of sodium acetate should form. However, some of the acetate ions react with water molecules. As a result, OH^- ions ions are formed.

When there are OH^- ions left over, a neutralization reaction does not produce a neutral solution. Neutralization occurs when water is formed from H_3O^+ ions and OH^- ions, but if there are any hydroxide ions left over, the solution will still be basic. A similar situation occurs when a strong acid is titrated with a weak base, but in this case the product is acidic and has a pH of less than 7.

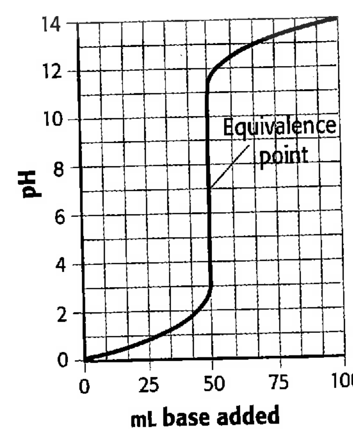


Figure 11

When a strong acid, such as nitric acid, is titrated with a strong base, the pH of the solution changes rapidly when the equivalence point is reached.

Salts

When you hear the word *salt,* you probably think of white crystals that you sprinkle on food. But to a chemist, a salt can be almost any combination of cations and anions, except for hydroxides and oxides, which are bases.

Sodium chloride has many different uses

Common table salt contains sodium chloride, NaCl, which is an ionic compound that can be formed from the reaction of hydrochloric acid with sodium hydroxide. NaCl is the source of most of the sodium in your diet. It is widely used to season and preserve food. Most NaCl in the United States comes from underground deposits that were left when ancient seas dried up.

NaCl is also used in ceramic glazes, soap manufacturing, home water softeners, highway de-icing, and fire extinguishers. Many other salts also contain sodium, as you can see in ***Table 3*** below.

Salts are all around us

Salts can be formed by acid-base neutralization, but more often, they are formed from other salts. Another familiar example of a salt is baking soda, sodium hydrogen carbonate. Photographic film contains the salts silver bromide and silver iodide, which are sensitive to light. Ordinary soaps and detergents are also examples of salts. ***Figure 12*** shows a salt that is used in medical diagnosis.

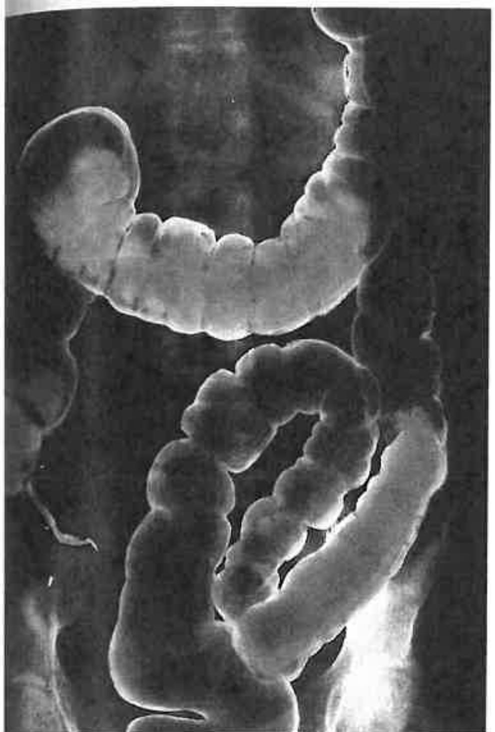


Figure 12

The salt barium sulfate, $BaSO_4$, is a highly insoluble salt that blocks X rays. After barium sulfate is placed into the large intestine, the form of the intestine shows up lighter on an X-ray photo.

Table 3 **Some Common Salts**

Salt	Formula	Uses
Aluminum sulfate	$Al_2(SO_4)_3$	purifying water; used in antiperspirants
Ammonium sulfate	$(NH_4)_2SO_4$	flameproofing fabric; used as fertilizer
Calcium chloride	$CaCl_2$	de-icing streets and highways; used in some kinds of concrete
Potassium chloride	KCl	treating potassium deficiency; used as table-salt substitute
Sodium carbonate	Na_2CO_3	manufacturing glass; added to wash to soften water
Sodium hydrogen carbonate	$NaHCO_3$	treating upset stomach; ingredient in baking powder; used in fire extinguishers
Sodium stearate	$NaOOCC_{17}H_{34}$	typical example of a soap
Sodium lauryl sulfonate	$NaSO_3C_{12}H_{25}$	typical example of a detergent

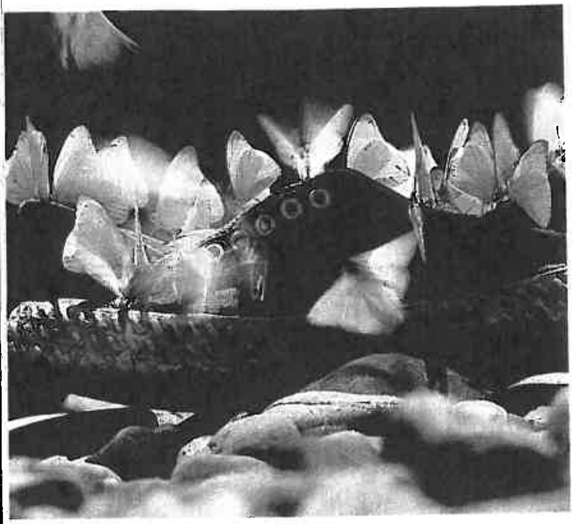


Figure 13

These butterflies can obtain the salt they need from the dried sweat on an old sneaker.

Salts are useful substances

You have probably seen a lot of chalk since you entered school, but did you know that chalk is a salt? Chalk is one form of the salt calcium carbonate, $CaCO_3$, which also makes up limestone and marble. It is likely that the walls in your house are made of slabs of gypsum, which is one form of the salt calcium sulfate, $CaSO_4$.

You often hear that a healthful diet should include minerals such as potassium, sodium, calcium, magnesium, iron, phosphorus, and iodine. However, ingesting these nutrients in the form of free elements is not very common. Instead, you get ions of these elements in their ionic form from salts. You need calcium ions, Ca^{2+}, for strong bones and teeth and for proper function of nerves and muscles. The correct proportion of potassium ions, K^+, and sodium ions, Na^+, is crucial for transmission of nerve impulses, even in insects, such as those shown in ***Figure 13.*** Phosphorus, in the form of phosphate ions, PO_4^{3-}, is needed for many processes in living cells, from transporting energy to the reproduction of the genetic code.

SECTION 2 REVIEW

SUMMARY

- Acids and bases react with each other in a process called *neutralization*.
- Neutralization is a reaction between an acid and a base to form water and a salt.
- Neutralization reactions between weak acids and strong bases result in basic solutions.
- Neutralization reactions between strong acids and weak bases result in acidic solutions.
- Salts are ionic substances composed of cations and anions other than oxide or hydroxide.

1. **Write** the chemical equation for the neutralization of nitric acid, HNO_3, with magnesium hydroxide, $Mg(OH)_2$, first with spectator ions and then without spectator ions.
2. **Determine** which acid and which base you would combine to form the salt aluminum sulfate, $Al_2(SO_4)_3$.
3. **Identify** the spectator ions in the neutralization of lithium hydroxide, LiOH, with hydrobromic acid, HBr.
4. **Predict** whether the reaction of each of the following acids and bases will yield an acidic, a basic, or a neutral solution. Explain your answer for each.
   a. sulfuric acid, H_2SO_4, and ammonia, NH_3
   b. formic acid, HCOOH, and potassium hydroxide, KOH
   c. nitric acid, HNO_3, and calcium hydroxide, $Ca(OH)_2$
5. **Critical Thinking** A classmate observes a neutralization reaction between an acid and a base. After the reaction is complete, your classmate is surprised to find that the pH of the resulting solution is 4, not 7, the pH of a neutral solution. What can you tell your classmate to help them understand what happened?

SECTION 3

INTEGRATING TECHNOLOGY and Society

Acids, Bases, and Salts in the Home

OBJECTIVES

- **Describe** the chemical structures of soaps and detergents and explain how they work.
- **Describe** the chemical composition of bleach and its uses.
- **Describe** how an antacid reduces stomach acid.
- **Identify** acidic and basic household products and their uses.

KEY TERMS

soap
detergent
disinfectant
bleach
antacid

As you have seen, you won't find acids, bases, and salts only in a laboratory. Many items in your own home, such as soaps, detergents, shampoos, antacids, vitamins, sodas, and juices in your kitchen are examples of household products that contain acids, bases, and salts.

soap a substance that is used as a cleaner and that dissolves in water

Cleaning Products

If you work on an oily bicycle chain or if you've been eating potato chips, water alone will not remove the greasy film from your hands. Water will not work because it doesn't mix with grease or oil. Something else must be added to water to improve its ability to clean.

Soaps allow oil and water to mix

Soap improves water's ability to clean because it can dissolve in both oil and in water. This property allows oil and water to form an emulsion that can be washed away by rinsing. For example, when you are washing your face with soap, as the girl in ***Figure 14*** is, the oil on your face is emulsified by the soapy water. The water you rinse with carries away both the soap and unwanted oil to leave your face clean.

Soaps are salts of sodium or potassium and fatty acids, which have long hydrocarbon chains. Soaps are made through a reaction of animal fats or vegetable oils with a solution of sodium hydroxide or potassium hydroxide. The products of the reaction are soap and an alcohol called *glycerol.*

Figure 14
When you wash with soap, you create an emulsion of oil droplets spread throughout water.

Connection to SOCIAL STUDIES

People have used soap for thousands of years. Ancient Egyptians took baths regularly with soap made from animal fats or vegetable oils and basic solutions of alkali-metal compounds. According to Roman legend, people discovered that the water in the Tiber River near Mount Sapo was good for washing. Mount Sapo was used for elaborate animal-sacrifice rituals, and the combination of animal fat and the basic ash that washed down the mountain made the river soapy.

Making the Connection

1. The process of making soap is sometimes referred to as *saponification*. How does this word relate to the Roman soap legend?
2. Homemade soap can be made from hog fat and ashes. Which material provides the base needed to make the soap?

How soap removes grease

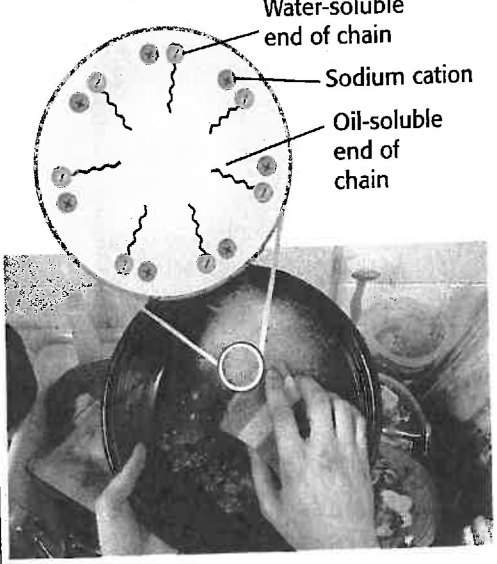
Soap is an ionic compound. Its negative ion is a long hydrocarbon chain of the soap anion with a carboxylate group ($-COO^-$) at one end. For every negatively charged end, there is a positive sodium or potassium ion.

Soap is able to remove grease and oil because the cations and the negatively charged ends of the chains ($-COO^-$) dissolve in water, while the hydrocarbon chains dissolve in oil. Soap acts as an emulsifier by surrounding droplets of oil, as shown in ***Figure 15.*** This action causes the droplets of oil to stay suspended in water. When you are washing your hands with soap, you probably rub them together. Rubbing your hands together actually helps clean them. When you do this, you lift most of the emulsion of grease and water into the lather where it can be rinsed into the sink.

detergent a water-soluble cleaner that can emulsify dirt and oil

Figure 15

The charged ends of soap or detergent dissolve in water, and the hydrocarbon chains dissolve in oil, keeping the oil droplet in suspension.



Detergents have replaced soap in many uses

As useful as soap is for cleaning, it does not work well in hard water, that is, water containing the dissolved ions Mg^{2+}, Ca^{2+}, and Fe^{3+}. These cations combine with the fatty acid anions of soap to form an insoluble salt called *soap scum*. This soap scum settles out on clothing, dishes, your skin, and your hair. The scum also makes a ring around the bathtub or washbasin. To prevent this problem, **detergents** are used instead of soap to wash clothes and dishes. Most shampoos, liquid hand soaps, and body washes are actually detergents, not soap.

Detergents are sodium, potassium, and sometimes ammonium salts. Like anions in soaps, the anion in detergents are composed of a long hydrocarbon chain that has a negatively charged end. But the charged end of a detergent is a sulfonate group ($-SO_3^-$), not a carboxylate group. These sulfonate ions do not form scum with the ions in hard water. Detergents are also different from soaps because their hydrocarbon chains are made from petroleum products instead of from animal fats or plant oils.

Because soaps and detergents act in the same way, ***Figure 15*** represents detergents as well as soaps. The long hydrocarbon chains are soluble in oil or grease. The sulfonate ends are highly soluble in water. Water molecules attract the charged sulfonate group and keep the oil droplet suspended among the water molecules.

Many household cleaners contain ammonia

Ammonia solutions, such as the ones shown in ***Figure 16,*** are also effective cleaners. Household ammonia is a solution of ammonia gas in water. Recall that ammonia is a weak base because it ionizes only slightly in water to form ammonium ions and hydroxide ions. The hydroxide ions make the ammonia solution basic, as shown in the reaction below.

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

Although the concentration of hydroxide ions is very low in an ammonia solution, enough of the ions are available to help emulsify thin layers of oily dirt, such as fingerprints and oily smears. In addition, many ammonia cleaners contain alcohols, detergents, and other cleaning agents.

Figure 16

Basic solutions of ammonia, such as these, can clean away light grease smears, such as fingerprints.

Bleach can eliminate stains

A **disinfectant** is a substance that kills bacteria and viruses. Household **bleach,** a very strong disinfectant, is a basic solution of sodium hypochlorite, NaOCl. You are probably familiar with the ability of bleach to remove colors and stains.

Bleach does not actually remove the substance causing the stain. Instead, it changes the substance to a colorless form. This bleaching action is carried out by the oxygen atom in the hypochlorite ion, ClO^-.

If an acid is added to a bleach solution, the acid reacts with the hydroxide ions, and the reaction reverses, giving off deadly chlorine gas. For this reason, you should never mix bleach with an acid, such as vinegar. Also, ammonia and bleach should not be mixed because noxious chloramine gas, NH_2Cl, is formed.

disinfectant a chemical substance that kills harmful bacteria or viruses

bleach a chemical compound used to whiten or make lighter, such as hydrogen peroxide or sodium hypochlorite

Quick ACTIVITY

Detergents

Detergents help break up oil into droplets that can be washed away by water. Detergents also break up the surface tension of water so that it can wet materials more easily. In this activity, you will demonstrate this effect using a piece of wax paper, a drop of water, a toothpick, and liquid detergent.

1. Lay some wax paper on a flat surface, and put a drop of water on it. Does the water wet the surface of the wax paper? How can you tell?
2. Gently touch the drop of water with the tip of the toothpick. What happens to the drop of water?
3. Now dip the tip of the toothpick in liquid detergent.
4. Gently touch the drop of water with the tip of the toothpick after it has been dipped in detergent. What happens to the drop of water? How could this action help water clean away dirt?

Acids, Bases, and Salts in the Household

You probably have taken many of the acidic and basic materials in your home for granted. For example, many of the clothes in your closet get their color from acidic dyes. These dyes are sodium salts of organic compounds that contain the sulfonic acid group ($-SO_3H$) or the carboxylic acid group ($-COOH$). If you have ever had an upset stomach because of excess stomach acid, you may have taken an antacid tablet to feel better. The antacid made you feel better because it neutralized the excess stomach acid. Many other useful products in your home are also acids or bases.

Many healthcare products are acids or bases

In the morning before school, you may drink a glass of orange juice that contains vitamin C. Ascorbic acid is the chemical name for vitamin C, which your body needs to grow and repair bone and cartilage. Both sodium hydrogen carbonate and magnesium hydroxide (milk of magnesia) can be used as **antacids.** Antacids are basic substances that you swallow to neutralize stomach acid when you have an upset stomach. ***Figure 17*** shows how adding an antacid tablet to an acidic solution changes the pH of the solution. A similar reaction (without the color change) takes place in your stomach when you take an antacid.

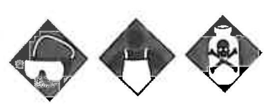
■ **antacid** a weak base that neutralizes stomach acid

Quick Lab

What does an antacid do?

Materials

- *plastic stirrer*
- *wax paper*
- *several varieties of antacid tablets*
- *red litmus paper*
- *150 to 200 mL beakers (2)*
- *pipet bulbs*
- *vinegar*
- *spoon*
- *blue litmus paper*
- *disposable pipets*



1. Pour 100 mL of water in a beaker. Add vinegar one drop at a time while stirring. Test the solution with litmus paper after each drop is added. Record the number of drops it takes for the solution to turn blue litmus paper bright red.
2. Use the back of a spoon to crush an antacid tablet to a fine powder on a piece of wax paper. Pour 100 mL of water in the second beaker, add the powdered tablet, and stir until a suspension forms.
3. Use litmus paper to find out whether the mixture is acidic, basic, or neutral. Record your results.
4. Now add vinegar to the antacid mixture. Record the number of drops it takes to react with the antacid and turn the blue litmus paper bright red. Compare this solution with the solution that has only vinegar and water. Compare the brand of antacid you tested with the brands of other groups.

Analysis

1. How does an antacid work to relieve the pain caused by excess stomach acid?
2. Of the brands that were tested, which brand worked the best? Explain your reasoning.

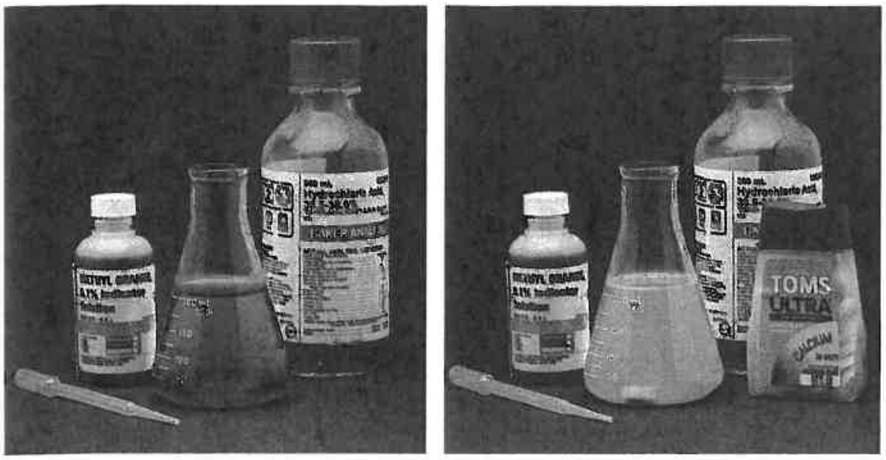


Figure 17

Stomach acid has about the same concentration of HCl as the solution in the flask in the left photo. When an antacid tablet reacts with the acid, the pH increases to a less acidic level, as shown in the photo on the right.

Shampoos are adjusted for an ideal pH

Shampoos can be made from soap. But if they are, they can leave sticky soap scum on your hair if you happen to live in an area that has hard water. Most shampoos today are made from detergents and are able to remove dirt as well as most of the oil from your hair without leaving soap scum, even when they are used with hard water. Shampoo is not meant to remove all of the oil from your hair. Some oil is needed to give your hair shine and to keep it from becoming dry and brittle.

The appearance of your hair is greatly affected by the pH of the shampoo you use. Hair—which consists of strands of a protein called *keratin*—looks best when it is kept at either a slightly acidic pH or very close to neutral. If a shampoo is too basic, it can cause strands of hair to swell, which gives them a dull, lifeless appearance. Shampoos are usually pH balanced, which means that they are made to be in a specific pH range. The pH of most shampoos is between 5 and 8. Shampoos that have higher pH values are more effective in cleaning oil from your hair. Shampoos that have lower pH values protect dry hair.

Acids keep fruit fresh longer

Some cut fruits slowly turn brown when they are exposed to air, such as the right side of the cut apple shown in ***Figure 18.*** This happens because certain molecules in the apple are oxidized to form darker substances. Both sides of the apple in ***Figure 18*** were cut at the same time, so why does the left side of the apple look like it was just cut? The left side was moistened with lemon juice shortly after it was cut. The citric acid in lemon juice helps *antioxidants* in the apple that react with oxygen before the oxygen can react with other substances in the apple. Vitamin C is another example of a natural antioxidant.

Did You Know?

The fibrous protein keratin builds up in the outermost cells of your epidermis, the outer layer of your skin. Keratin in these cells makes the skin tough and almost completely waterproof. Keratin forms callouses in places on the skin where it is rubbed.

The horns, hoofs, claws, feathers, and scales of animals grow from the same type of tissue that makes up your epidermis and also consist mainly of keratin.

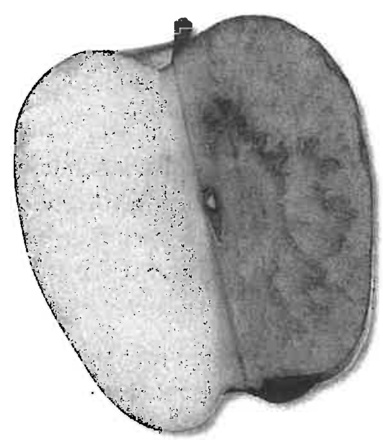


Figure 18

The left side of this cut apple was coated with lemon juice. Citric acid in the lemon juice kept the surface of the apple looking fresh.

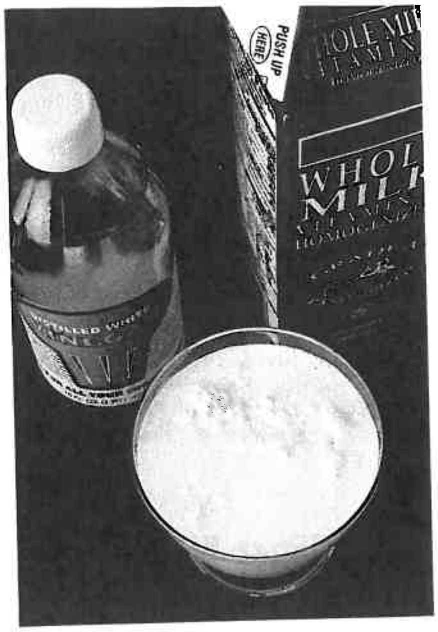


Figure 19

Adding vinegar to milk causes the milk to curdle, because casein, the main protein in milk, becomes denatured by the acid.

Acids, bases, and salts in the kitchen

Acids have other uses in the kitchen. Acidic marinades made of vinegar or wine can be used to tenderize meats because they can *denature* proteins in the meat. That is, the acids cause the protein molecules to unravel and lose their characteristic shapes. As a result, the meat becomes more tender.

Figure 19 shows that milk curdles if you add vinegar to it. This reaction may seem undesirable, but a similar reaction occurs in the formation of yogurt. Bacteria convert lactose, a sugar in milk, into lactic acid. The lactic acid denatures the protein casein in milk and changes the milk into a thick gel known as yogurt.

There are many bases and salts in the kitchen. You can unclog a drain by using the strong base sodium hydroxide, also called *lye.* Baking soda, or sodium hydrogen carbonate, is a salt that forms carbon dioxide gas at high temperatures, which makes cookies rise when they are baked. Baking powder consists of baking soda and an acidic substance that react to release CO_2, which makes light, fluffy batter for cakes.

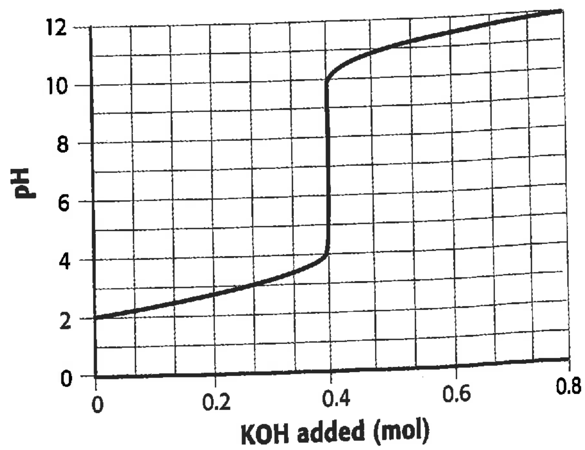
SECTION 3 REVIEW

SUMMARY

- Soaps and detergents can dissolve in oil and water. They are usually sodium or potassium salts of carboxylic or sulfonic acids, which have long hydrocarbon chains.
- Detergents do not form an insoluble scum in hard water as soap does.
- Bleach is an alkaline solution of sodium hypochlorite, NaOCl. Bleach is a disinfectant and oxidizes stains to a colorless form.
- Antacids are basic substances that react with hydrochloric acid in the stomach.
- Acids, bases, and salts have many practical uses in the kitchen, both in cleaning and cooking.

1. **Describe** how soap can dissolve in both oil and water. How does soap work with water to remove oily dirt?
2. **Explain** why soap scum might form in hard water that contains Mg^{2+} ions when soap is used instead of detergent to wash dishes.
3. **Explain** why the agitation of a washing machine helps a detergent clean your clothes. (**Hint:** Compare this motion to rubbing your hands together when you wash them.)
4. **Explain** why it is not necessary for bleach to actually remove the substance that causes a stain.
5. **Explain** how milk of magnesia, an antacid, can reduce acidity in stomach acid.
6. **List** three acidic household substances and three basic household substances. How are the substances most often used?
7. **Critical Thinking** Crayon companies recommend treating wax stains on clothes by spraying the stains with an oily lubricant, applying dishwashing liquid, and then washing the clothes. Explain in a paragraph why this treatment would remove the stain.

Graphing Skills



Examine the above graph, and answer the following questions. (See Appendix A for help interpreting a graph.)

1. Does the solution's acidity increase or decrease as potassium hydroxide is added? Explain your answer.
2. Identify the independent and dependent variables. What is the relationship between the two variables?
3. At what point on the graph are there equal moles of acid and base? Explain your answer.
4. Use your answer to the previous question to calculate the number of moles of acid present before the potassium hydroxide is added to the solution.
5. What is the pH of the potassium hydroxide solution added to the acid? How did you reach this conclusion?
6. A person who has a stomach disorder is advised to avoid acidic foods. Construct the type of graph best suited for the data given in the table below. Which substance is most acidic? Which substance has a pH closest to the pH of pure water?

Substance	Average pH
Bananas	4.6
Dill pickles	3.4
Eggs	7.8
Salmon	6.2
Soda crackers	7.5

CHAPTER 8 REVIEW

Chapter Highlights

Before you begin, review the summaries of key ideas of each section, found at the end of each section. The vocabulary terms are listed on the first page of each section.

UNDERSTANDING CONCEPTS

1. Which ions does an acid form in solution?
   a. oxygen
   b. hydronium
   c. hydroxide
   d. sulfur

2. Which ions does a base form in solution?
   a. oxygen
   b. hydronium
   c. hydroxide
   d. sulfur

3. A substance with a pH of 9 has
   a. the same number of H_3O^+ ions and OH^- ions.
   b. more H_3O^+ ions than OH^- ions.
   c. no H_3O^+ ions, but many OH^- ions.
   d. more OH^- ions than H_3O^+ ions.

4. When a solution of nitric acid is added to a solution of calcium hydroxide, the salt formed has the formula
   a. $Ca(NO_3)_2$.
   b. $Ca(OH)_2$.
   c. H_2O.
   d. CaH.

5. An antacid relieves an overly acidic stomach because antacids are
   a. acidic.
   b. neutral.
   c. basic.
   d. dilute.

6. Any substance that conducts electricity when it dissolves in water is called a(n)
   a. salt.
   b. antacid.
   c. electrolyte.
   d. weak base.

7. Detergents have replaced soap in many uses because detergents
   a. are made from animal fat.
   b. do not form insoluble substances.
   c. are milder than soap.
   d. contain ammonia.

8. Compared to strong acids, weak acids
   a. ionize more completely in water.
   b. are less soluble in water.
   c. do not react with bases.
   d. ionize only slightly in water.

9. Which of the following ions could be present in a salt?
   a. Br^-
   b. OH^-
   c. H_3O^+
   d. H^+

10. Which of the following ionic equations best represents a neutralization reaction?
    a. $Na + H_2O \rightarrow Na^+ + OH^- + H_2$
    b. $HNO_3 + H_2O \rightarrow H_3O^+ + NO_3^-$
    c. $2OH^- + NH_4Cl \rightarrow Cl^- + H_2O + NH_3$
    d. $OH^- + H_3O^+ \rightarrow 2H_2O$

11. An increase in the hydronium ion concentration of a solution ______ the pH.
    a. raises
    b. lowers
    c. does not affect
    d. doubles

12. A complete neutralization of a weak acid by a strong base yields a solution that is
    a. basic.
    b. neutral.
    c. acidic.
    d. saturated.

13. Bleach removes stains by
    a. changing the color of the stain.
    b. covering the stain.
    c. removing the stain-causing substances.
    d. disinfecting the stain.

14. Which of the following is *not* a property of soap?
    a. It is a salt.
    b. It is made from petroleum.
    c. It dissolves in both oil and water.
    d. It is an ionic substance.

15. Which of the following is *not* an acidic material found in the kitchen?
    a. baking soda
    b. lemon juice
    c. vinegar
    d. vitamin C

USING VOCABULARY

16. Explain how the *ionization* of a strong acid differs from the ionization of a weak acid in a solution. Give an example of a strong acid and a weak acid. Show which ions form when each is dissolved in water.

17. Give both the name and the formula of the salt produced in the following *neutralization reaction*:

$$2H_3O^+ + 2Br^- + Ca^{2+} + 2OH^- \rightarrow Ca^{2+} + 2Br^- + 4H_2O$$

18. Explain how you can use the *indicator* litmus, in the form of litmus paper, to determine whether a solution is *acidic, basic,* or *neutral.*

19. List the two kinds of ions that are in greatest concentration in a solution of a strong *base.*

20. How is the pH of a solution related to its *hydronium ion* concentration? What happens to pH as this concentration changes?

21. Explain how the molecular structure of *soaps* and *detergents* can cause water to wash away oil and grease.

22. What is the active substance in *bleach*? How is bleach made?

23. Why are most shampoos made from *detergents* rather than *soaps*?

24. Microbiologists often wipe down work areas with a *bleach* solution before working with bacterial cultures. What is the purpose of using bleach in this way?

25. Explain why a solution of a *strong acid* is a good conductor of electricity.

26. What is a *neutralization reaction*? How might the product of a neutralization reaction have a pH of less than 7?

27. How would you find the concentration of a strong acid in a *titration*? Use the terms *indicator* and *equivalence point* in your answer.

BUILDING MATH SKILLS

28. **Determining pH** What is the pH of a 0.001 M solution of hydrobromic acid, HBr, a strong acid?

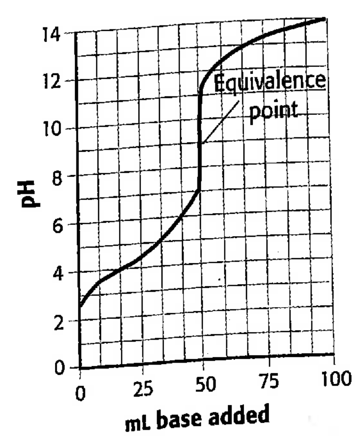
29. **Determining pH** What is the pH of a solution that contains 0.10 mol of HCl in a volume of 100.0 L?

30. **Using pH** What is the molar concentration of hydronium ions in a solution with a pH of 6?

31. **Determining pH** The concentration of hydronium ions in a certain acid solution is 100 times the concentration of hydronium ions in a second acid solution. If the second solution has a pH of 5, what is the pH of the first solution?

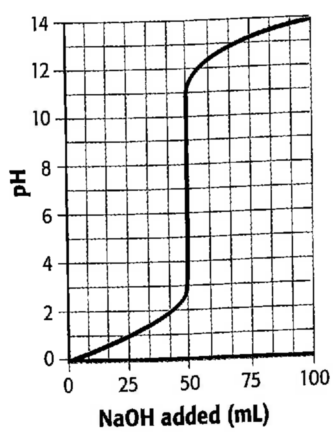
BUILDING GRAPHING SKILLS

32. **Interpreting Graphs** The point at which equal amounts of an acid and a base have reacted in a neutralization reaction is called the equivalence point. Study the graph of pH versus volume of base added below, and note the pH at the equivalence point. Classify both the acid and the base in this neutralization reaction as either weak or strong. Explain your answer.



CHAPTER 8 REVIEW

33. **Interpreting Graphs** The graph below shows how pH changes as a 0.1 M solution of NaOH is added to 50 mL of a 0.1 M solution of HCl. Use the graph to answer the following questions.
   a. Describe how pH changes as the first 30 mL of NaOH solution is added. What takes place in the solution during this addition?
   b. What is happening in the solution just as 50 mL of NaOH has been added? Why is the pH changing so rapidly at this point? (**Hint:** When 50 mL of the NaOH solution has been added, equal amounts of acid and base have combined.)
   c. What is happening in the solution as more than 50 mL of NaOH solution is added?



THINKING CRITICALLY

34. **Applying Knowledge** Baking soda, sodium hydrogen carbonate ($NaHCO_3$), is useful in the kitchen for baking and to absorb odors in the refrigerator. Baking soda can also be tossed onto a grease fire to extinguish it. How can baking soda extinguish fires?

35. **Creative Thinking** If you wish to change the pH of a solution very slightly, should you add a strong acid or a weak acid? Explain your answer.

36. **Problem Solving** Insect bites hurt because the insect injects a toxin into the victim. When certain kinds of ants bite, they inject a small amount of highly irritating formic acid. Suggest a treatment that might stop an ant bite from itching or hurting.

37. **Designing Systems** Suppose you measure the pH of a clear solution in a beaker and find that it has a pH of 3. You are asked to determine whether the solution is a very dilute solution of a strong acid or a stronger solution of a weak acid. Propose a method to answer the question.

38. **Creative Thinking** You need several grams of the substance ammonium bromide, NH_4Br, for an experiment, but you do not have any. You do, however, have a solution of hydrobromic acid, HBr, and a solution of ammonia. Suggest a way to use an acid-base reaction to make a small quantity of NH_4Br.

39. **Applying Knowledge** Pure water is a poor conductor of electricity. But it is still dangerous to have any sort of plugged-in appliances near the bathtub or shower. Why does this danger exist? Explain your reasoning by discussing the composition of tap water.

BUILDING LIFE/WORK SKILLS

40. **Communicating Effectively** When there is an oil spill in the ocean, emergency-response teams use the properties of oil and water along with solubility principles to clean spills and prevent them from spreading. Describe the research behind these techniques, and evaluate the impact this research has had on the environment.

41. **Locating Information** Research the invention of the pH meter by Dr. Arnold O. Beckman. Why was the pH meter invented? How does it work? Prepare a poster to present your results.

42. Applying Knowledge Design an experiment to measure the pH of four types of shampoo: baby shampoo, shampoo for extra body, shampoo for oily hair, and shampoo that contains conditioner. Also compare two brands of pH-balanced shampoo. Write a paragraph summarizing your results.

INTEGRATING CONCEPTS

43. Connection to Biology The pH of human blood is about pH 7.4 and must be kept within a few tenths of a pH unit of the normal pH. Reactions within the human body ensure that a proper pH is maintained. The equilibrium shown below between carbonic acid, H_2CO_3, and the hydrogen carbonate ion, HCO_3^-, is important to maintain the blood's pH.

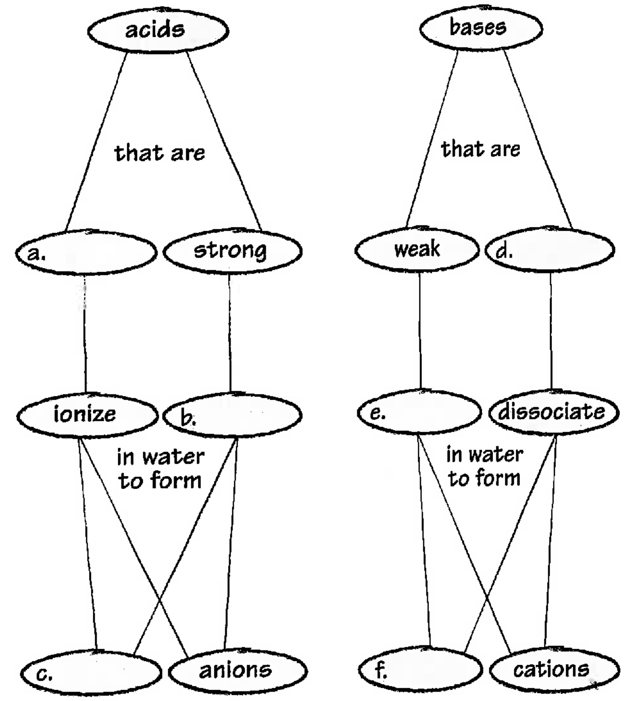
$$H_2CO_3 + H_2O \rightleftharpoons HCO_3^- + H_3O^+$$

Find out what happens to keep the pH from decreasing as extra hydronium ions enter the blood. Also find out how the pH is kept from increasing as extra OH^- ions enter the blood.

44. Connection to History In the 18th century, the French chemist Antoine Lavoisier experimented with substances containing oxygen, such as CO_2 and SO_2, that formed acidic solutions when dissolved in water. His observations led him to infer that for a solution to be acidic, it must contain oxygen. Provide evidence to disprove Lavoisier's conclusion.

45. Locating Information A reaction between baking soda and a baking batter that is made of acidic ingredients produces CO_2 gas. The reaction makes the batter fluffier. Some recipes call for baking powder instead of baking soda. Find out what regular baking powder and double-acting baking powder are made of. How do they each differ from baking soda?

46. Concept Mapping Copy the unfinished concept maps below onto a sheet of paper. Complete the maps by writing the correct word or phrase in the lettered boxes.



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