chapter 23

Acids, Bases, and Salts

BIG Idea
Some substances can be classified as acids, bases, or salts.

23.1 Acids and Bases

MAIN Idea Acids produce hydronium ions (H_3O^+) in water, and bases produce hydroxide ions (OH^-) in water.

23.2 Strength of Acids and Bases

MAIN Idea Acid strength describes the ease with which an acid dissociates into ions. Acid concentration describes the amount of acid dissolved in water.

23.3 Salts

MAIN Idea An acid and a base react to form a salt and water.

The Well-Seasoned You

Salt is essential for most animals, including humans. Birds, such as these macaws, arrive each day to eat the clay at Macaw Clay Lick in Peru. In this chapter, you'll learn about salts and about the acids and bases that react to form them.

Science Journal

Research to find out why your body needs salt, then write a brief summary and identify several ways that you can safely get the salt you need.

Frans Lanting/Minden Pictures

Start-Up Activities

Launch LAB

The Effects of Acid Rain

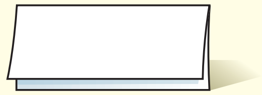
Many limestone caves and rock formations are shaped by water containing carbon dioxide. Higher levels of carbon dioxide in acid rain can damage marble structures. Observe this reaction using soda water to represent acid rain and chalk, which like limestone and marble, is calcium carbonate.

1. Measure approximately 5 g of classroom chalk.
2. Crush it slightly and place it in a 100-mL beaker.
3. Add 50 mL of plain, bottled, carbonated water to the beaker.
4. After several minutes, stir the mixture.
5. When the mixture stops reacting, filter it using a paper filter in a glass funnel.
6. Dry the residue overnight and determine its mass.
7. **Think Critically** Record your observations in your Science Journal. How did the mass change? Write your conclusions about the effect of acid rain on marble buildings and monuments.

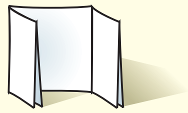
FOLDABLES™ Study Organizer

Acids, Bases, and Salts The very essence of life, DNA, is an acid. You also may be familiar with ascorbic acid, or vitamin C. Make the following Foldable to compare and contrast the characteristics of acids, bases, and salts.

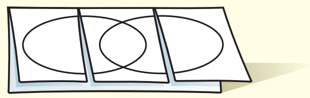
STEP 1 **Fold** one sheet of paper lengthwise.



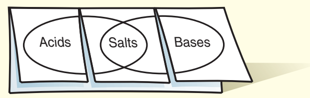
STEP 2 **Fold** into thirds.



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



STEP 4 **Label** the ovals *Acids, Salts,* and *Bases.*



Construct a Venn Diagram As you read the chapter, list the characteristics of acids, bases, and salts under the appropriate tabs.

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

Frans Lanting/Minden Pictures

section 1

Acids and Bases

Reading Guide

What You'll Learn

- **Compare and contrast** acids and bases and identify the characteristics they have.
- **Examine** some formulas and uses of common acids and bases.
- **Determine** how the process of ionization and dissociation apply to acids and bases.

Why It's Important

Acids and bases are found almost everywhere—from fruit juice and gastric juice to soaps.

Review Vocabulary

electrolyte: compound that breaks apart in water, forming charged particles (ions) that can conduct electricity

New Vocabulary

- acid
- hydronium ion
- indicator
- base

Figure 1 The acids in these common foods give each their distinctive sour taste.

Acids

What comes to mind when you hear the word *acid?* Do you think of a substance that can burn your skin or even burn a hole through a piece of metal? Do you think about sour foods like those shown in **Figure 1?** Although some acids can burn and are dangerous to handle, most acids in foods are safe to eat. What acids have in common, however, is that they contain at least one hydrogen atom that can be removed when the acid is dissolved in water.

Properties of Acids When an acid dissolves in water, some of the hydrogen is released as hydrogen ions, H^+. An **acid** is a substance that produces hydrogen ions in a water solution. It is the ability to produce these ions that gives acids their characteristic properties. When an acid dissolves in water, H^+ ions interact with water molecules to form H_3O^+ ions, which are called **hydronium ions** (hi DROH nee um • I ahnz).

Acids have several common properties. For one thing, all acids taste sour. The familiar, sour taste of many foods is due to acids. However, taste never should be used to test for the presence of acids. Some acids can damage tissue by producing painful burns. Acids are corrosive. Some acids react strongly with certain metals, seeming to eat away the metals as metallic compounds and hydrogen gas form. Acids also react with indicators to produce predictable changes in color. An **indicator** is an organic compound that changes color in acid and base. For example, the indicator litmus paper turns red in acid.

KS Studios

Common Acids Many foods contain acids. In addition to citric acid in citrus fruits, lactic acid is found in yogurt and buttermilk, and any pickled food contains vinegar, also known as acetic acid. Your stomach uses hydrochloric acid to help digest your food. At least four acids (sulfuric, phosphoric, nitric, and hydrochloric) play vital roles in industrial applications.

Reading Check *Which four acids are important for industry?*

Table 1 lists the names and formulas of a few acids, their uses, and some properties. Three acids are used to make fertilizers—most of the nitric acid and sulfuric acid and approximately 90 percent of phosphoric acid produced are used for this purpose. Many acids can burn, but sulfuric acid can burn by removing water from your skin as easily as it takes water from sugar, as shown in **Figure 2.**

Figure 2 When sulfuric acid is added to sugar the mixture foams, removing hydrogen and oxygen atoms as water and leaving air-filled carbon.

Table 1 Common Acids and Their Uses

Name, Formula	Use	Other Information
Acetic acid, CH_3COOH	Food preservation and preparation	When in solution with water, it is known as vinegar.
Acetylsalicylic acid, $HOOC–C_6H_4–OOCCH_3$	Pain relief, fever relief, to reduce inflammation	Known as aspirin
Ascorbic acid, $H_2C_6H_6O_6$	Antioxidant, vitamin	Called vitamin C
Carbonic acid, H_2CO_3	Carbonated drinks	Involved in cave, stalactite, and stalagmite formation and acid rain
Hydrochloric acid, HCl	Digestion as gastric juice in stomach, to clean steel in a process called pickling	Commonly called muriatic acid
Nitric acid, HNO_3	To make fertilizers	Colorless, yet yellows when exposed to light
Phosphoric acid, H_3PO_4	To make detergents, fertilizers and soft drinks	Slightly sour but pleasant taste, detergents containing phosphates cause water pollution
Sulfuric acid, H_2SO_4	Car batteries, to manufacture fertilizers and other chemicals	Dehydrating agent, causes burns by removing water from cells

Mini LAB

Observing Acid Relief

WARNING: *Do not eat antacid tablets.*

Procedure

1. Add 150 mL of **water** to a **250-mL beaker.**
2. Add three drops **1*M* HCl** and 12 drops of **universal indicator.**
3. Observe the color of the solution.
4. Add an **antacid tablet** and observe for 15 minutes.

Analysis

1. Describe any changes that took place in the solution.
2. Explain why these changes occurred.

Bases

You might not be as familiar with bases as you are with acids. Although you can eat some foods that contain acids, you don't consume many bases. Some foods, such as egg whites, are slightly basic. Other examples of basic materials are baking powder and amines found in some foods. Medicines, such as milk of magnesia and antacids, are basic, too. Still, you come in contact with many bases every day. For example, each time you wash your hands using soap, you are using a base. One characteristic of bases is that they feel slippery, like soapy water. Bases are important in many types of cleaning materials, as shown in **Figure 3.** Bases are important in industry, also. For example, sodium hydroxide is used in the paper industry to separate fibers of cellulose from wood pulp. The freed cellulose fibers are made into paper.

Bases can be defined in two ways. Any substance that forms hydroxide ions, OH^-, in a water solution is a **base.** In addition, a base is any substance that accepts H^+ from acids. The definitions are related, because the OH^- ions produced by some bases do accept H^+ ions.

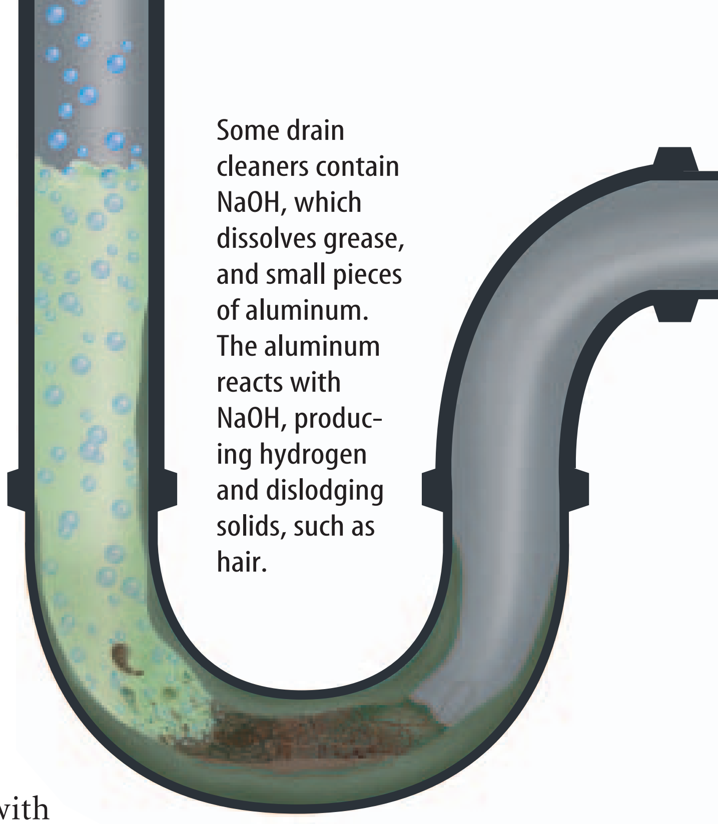
Properties of Bases One way to think about bases is as the complements, or opposites, of acids. Although acids and bases share some common features, the bases have their own characteristic properties. In the pure, undissolved state, many bases are crystalline solids. In solution, bases feel slippery and have a bitter taste. Like strong acids, strong bases are corrosive, and contact with skin can result in severe burns. Therefore, taste and touch never should be used to test for the presence of a base. Finally, like acids, bases react with indicators to produce changes in color. The indicator litmus turns blue in bases.

Figure 3 Bases are commonly found in many cleaning products used around the home.
Identify *the property of bases evident in soaps.*

Geoff Butler

Figure 4 Two applications of bases are shown here.

Aluminum hydroxide is a base used in water-treatment plants. Its sticky surface collects impurities, making them easier to filter from the water.



Some drain cleaners contain NaOH, which dissolves grease, and small pieces of aluminum. The aluminum reacts with NaOH, producing hydrogen and dislodging solids, such as hair.

Common Bases You probably are familiar with many common bases because they are found in cleaning products used in the home. These and some other bases are shown in **Table 2,** which also includes their uses and some information about them. **Figure 4** shows two uses of bases that you might not be familiar with.

Table 2 Common Bases and Their Uses

Name, Formula	Use	Other Information
Aluminum hydroxide, $Al(OH)_3$	Color-fast fabrics, antacid, water purification as shown in **Figure 4**	Sticky gel that collects suspended clay and dirt particles on its surface
Calcium hydroxide, $Ca(OH)_2$	Leather-making, mortar and plaster, lessen acidity of soil	Called caustic lime
Magnesium hydroxide, $Mg(OH)_2$	Laxative, antacid	Called milk of magnesia when in water
Sodium hydroxide, NaOH	To make soap, oven cleaner drain cleaner, textiles, and paper	Called lye and caustic soda; generates heat (exothermic) when combined with water, reacts with metals to form hydrogen
Ammonia, NH_3	Cleaners, fertilizer, to make rayon and nylon	Irritating odor that is damaging to nasal passages and lungs

INTEGRATE Life Science

Acidic Stings *Some ants add sting to their bite by injecting a solution of formic acid.* In fact, *formic acid was named for ants, which make up the genus Formica.* Still, ants are considered tasty treats by many animals. For example, one woodpecker called a *flicker has saliva that is basic enough to take the sting out of ants.*

Solutions of Acids and Bases

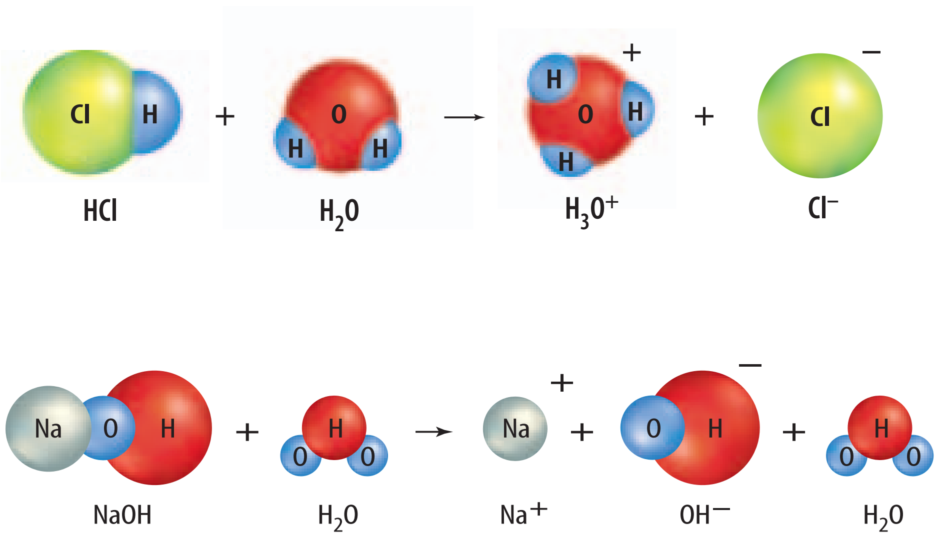
Many of the products that rely on the chemistry of acids and bases are solutions, such as the cleaning products and food products mentioned previously. Because of its polarity, water is the main solvent in these products.

Dissociation of Acids You have learned that substances such as HCl, HNO_3, and H_2SO_4 are acids because of their ability to produce hydrogen ions (H^+) in water. *When an acid dissolves in water, the negative areas of nearby water molecules attract the positive hydrogen in the acid.* The acid dissociates—or separates—into ions and the hydrogen atom combines with a water molecule to form hydronium ions (H_3O^+). Therefore, an acid can more accurately be described as a compound that produces hydronium ions when dissolved in water. This process is shown in **Figure 5.**

Dissociation of Bases Compounds that can form hydroxide ions (OH^-) in water are classified as bases. If you look at **Table 2,** you will find that most of the substances listed contain –OH in their formulas. *When bases that contain –OH dissolve in water, the negative areas of nearby water molecules attract the positive ion in the base.* The positive areas of nearby water molecules attract the –OH of the base. *The base dissociates into a positive ion and a negative ion—a hydroxide ion (OH^-).* This process also is shown in **Figure 5.** Unlike acid dissociation, *water molecules do not combine with the ions formed from the base.*

$$NaOH(s) \xrightarrow{H_2O} Na^+(aq) + OH^-(aq)$$

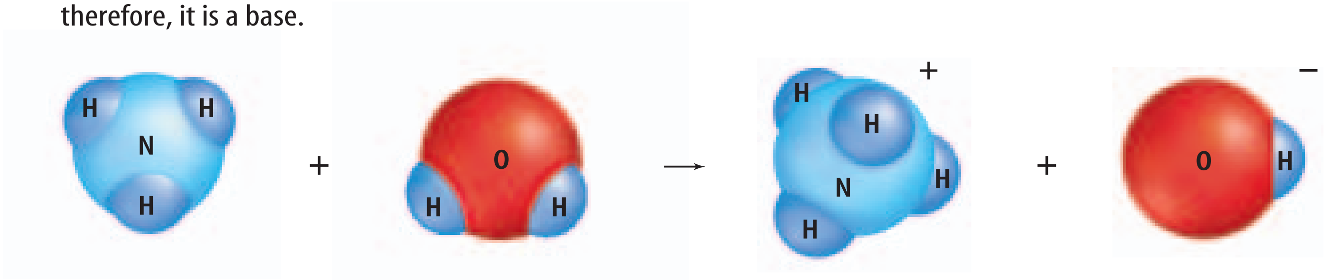
Figure 5 Acids and bases are classified by the ions they produce when they dissolve in water. Acids produce hydronium ions in water. Bases produce hydroxide ions in water.



When hydrogen chloride dissolves in water, a hydronium ion and a chloride ion are produced.

When sodium hydroxide dissolves in water, a sodium ion and a hydroxide ion are produced.

Figure 6 Ammonia reacts with water to produce some hydroxide ions, therefore, it is a base.



Ammonia Ammonia is a base that does not contain —OH. In a water solution, dissociation takes place when the ammonia molecule attracts a hydrogen ion from a water molecule, forming an ammonium ion (NH_4^+). This leaves a hydroxide ion (OH^-), as shown in **Figure 6.**

Reading Check *How does ammonia react in a water solution?*

Ammonia is a common household cleaner. However, products containing ammonia never should be used with other cleaners that contain chlorine (sodium hypochlorite), such as some bathroom bowl cleaners and bleach. A reaction between sodium hypochlorite and ammonia produces the toxic gases hydrazine and chloramine. Breathing these gases can severely damage lung tissues and cause death.

Solutions of both acids and bases produce some ions that are capable of carrying electric current to some extent. Thus, they are said to be electrolytes.

Science Online

Topic: Cleaner Chemistry

Visit gpscience.com for Web links to information about the dangers of mixing ammonia cleaners with chlorine or hydrochloric acid cleaners.

Activity Visit the cleaning products and laundry sections of the grocery store. Read the labels on several products. Make a list of products that include warnings on the labels and those that do not. Share your findings with the class.

section 1 review

Summary

Acids

- Acids, when dissolved in water, release H^+, which forms hydronium ions (H_3O^+).
- Acids are sour tasting, corrosive, and reactive with indicators.

Bases

- Bases, when dissolved in water, form OH^-.
- Bases exist as crystals in the solid state, are slippery, have a bitter taste, are corrosive, and are reactive with indicators.

Solutions of Acids and Bases

- The polar nature of water allows acids and bases to dissolve in water.
- Dissociation is the separation of substances, such as acids and bases, into ions in water.

Self Check

1. **Identify** three important acids and three important bases and describe their uses.
2. **Describe** an indicator.
3. **Predict** what metallic compound forms when sulfuric acid reacts with magnesium metal.
4. **Infer** If an acid donates H^+ and a base produces OH^-, what compound is likely to be produced when acids react with bases?
5. **Think Critically** Vinegar contains acetic acid, CH_3COOH. Is acetic acid organic or inorganic? How do you know?

Applying Math

6. **Calculate** the molecular weight of acetylsalicylic acid, $C_9H_8O_4$.

section 2

Strength of Acids and Bases

Reading Guide

What You'll Learn

- **Determine** what is responsible for the strength of an acid or a base.
- **Compare and contrast** strength and concentration.
- **Examine** the relationship between pH and acid or base strength.
- **Examine** electrical conductivity.

Why It's Important

Understanding the strength of acids and bases helps you use them safely.

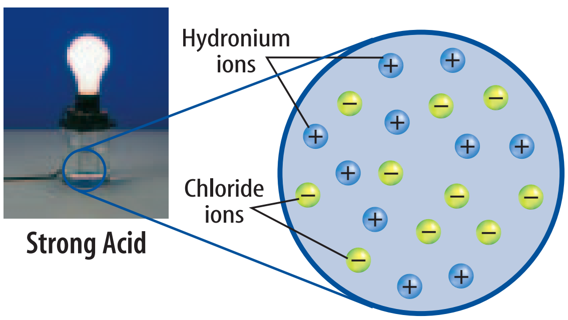
Review Vocabulary

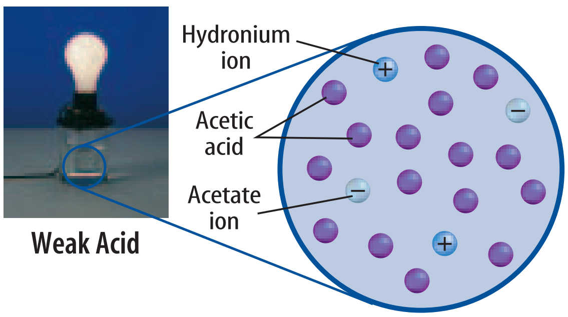
acid strength: the ability of an acid to dissociate completely

New Vocabulary

- strong acid
- weak acid
- strong base
- weak base
- pH
- buffer

Figure 7 Nearly all molecules of HCl, a strong acid, dissociate into ions in water. The bulb burns brightly. Only a few molecules of acetic acid, a weak acid, dissociate. The bulb is dimmer.





Strong and Weak Acids and Bases

Some acids must be handled with great care. For example, sulfuric acid found in car batteries can burn your finger, yet you drink acids such as citric acid in orange juice and carbonic acid in soft drinks. Obviously, some acids are stronger than others. One measure of acid strength is the ability to dissociate in solution.

The strength of an acid or base depends on how many acid or base particles dissociate into ions in water. When a **strong acid** dissolves in water, nearly all the acid molecules dissociate into ions. HCl, HNO_3, and H_2SO_4 are examples of strong acids. When a **weak acid** dissolves in water, only a small fraction of the molecules dissolve in water. Acetic acid and carbonic acid are examples of weak acids.

Ions in solution can conduct an electric current. The more ions a solution contains, the more current it can conduct. The ability of a solution to conduct a current can be demonstrated using a lightbulb connected to a battery with leads placed in the solution, as shown in **Figure 7.** The strong acid solution conducts more current and the lightbulb burns brightly. The weak acid solution does not conduct as much current as a strong acid solution and the bulb burns less brightly.

Strong and Weak Acids Equations describing dissociation can be written in two ways. In strong acids, such as HCl, nearly all the acid dissociates. This is shown by writing the equation using a single arrow pointing toward the ions that are formed.

$$HCl(g) + H_2O(l) \rightarrow H_3O^+(aq) + Cl^-(aq)$$

Almost 100 percent of the particles in solution are H_3O^+ and Cl^- ions, and only a negligible number of HCl molecules are present.

Equations describing the dissociation of weak acids, such as acetic acid, are written using double arrows pointing in opposite directions. This means that only some of the CH_3COOH dissociates and the reaction does not go to completion.

$$CH_3COOH(l) + H_2O(l) \rightleftharpoons H_3O^+(aq) + CH_3COO^-(aq)$$

In an acetic acid solution, most of the particles are CH_3COOH molecules, and only a few CH_3COO^- and H^+ ions are in solution.

Strong and Weak Bases Remember that many bases are ionic compounds that dissociate to produce ions when they dissolve. A **strong base** dissociates completely in solution. The following equation shows the dissociation of sodium hydroxide, a strong base.

$$NaOH(s) \rightarrow Na^+(aq) + OH^-(aq)$$

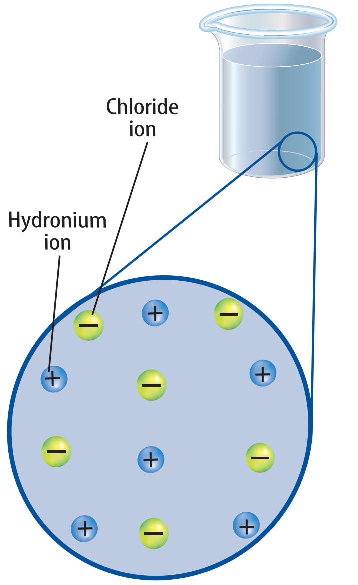
The dissociation of ammonia, which is a weak base, is shown using double arrows to indicate that not all the ammonia ionizes. A **weak base** is one that does not dissociate completely.

$$NH_3(aq) + H_2O(l) \rightleftharpoons NH_4^+(aq) + OH^-(aq)$$

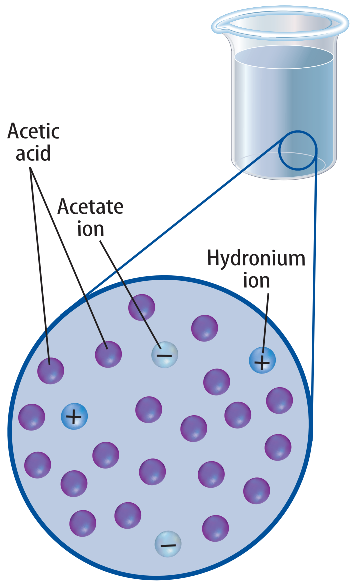
Because ammonia produces only a few ions and most of the ammonia remains in the form of NH_3, ammonia is a weak base.

Strength and Concentration Sometimes, when talking about acids and bases, the terms *strength* and *concentration* can be confused. The terms *strong* and *weak* are used to classify acids and bases. The terms refer to the ease with which an acid or base dissociates in solution. *Strong* acids and bases dissociate completely; *weak* acids and bases dissociate only partially. In contrast, the terms *dilute* and *concentrated* are used to indicate the concentration of a solution, which is the amount of acid or base dissolved in the solution. It is possible to have dilute solutions of strong acids and bases and concentrated solutions of weak acids and bases, as shown in **Figure 8.**

Figure 8 You can have a dilute solution of a strong acid and a concentrated solution of a weak acid.



This is a dilute solution of HCl.



This is a concentrated solution of acetic acid.

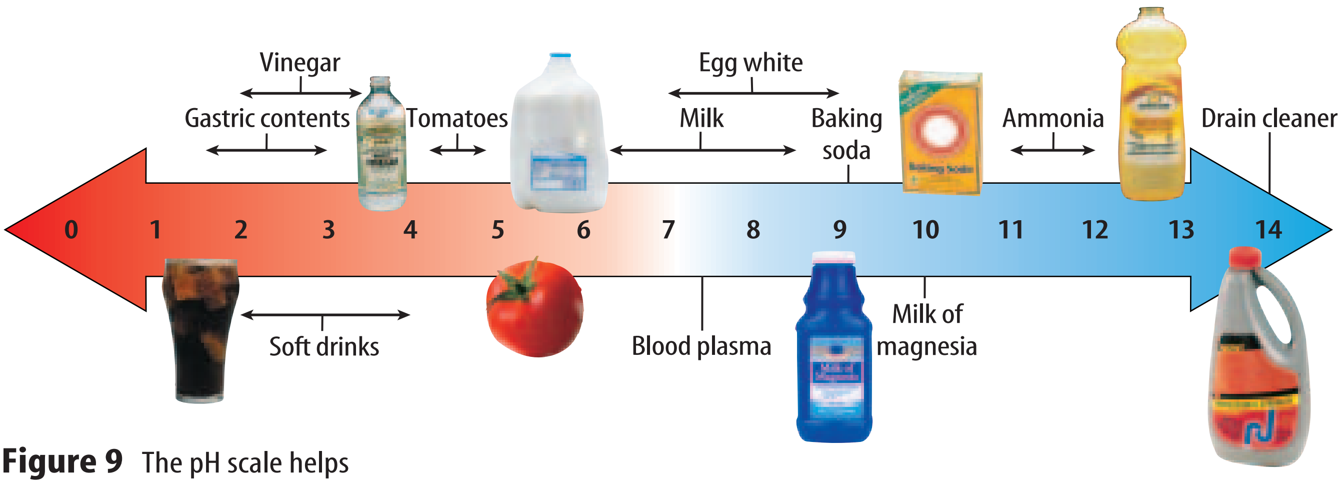


Figure 9 The pH scale helps classify solutions as acidic or basic.

pH of a Solution

If you have a swimming pool or keep tropical fish, you know that the pH of the water must be controlled. Also, many products such as shampoos claim to control pH so it suits your type of hair. The **pH** of a solution is a measure of the concentration of H^+ ions in it. The greater the H^+ concentration is, the lower the pH is and the more acidic the solution is. The pH measures how acidic or basic a solution is. To indicate pH, a scale ranging from 0 to 14 has been devised, as shown in **Figure 9.**

As the scale shows, solutions with a pH lower than 7 are described as acidic, and the lower the value is, the more acidic the solution is. Solutions with a pH greater than 7 are basic, and the higher the pH is, the more basic the solution is. A solution with a pH of exactly 7 indicates that the concentrations of H^+ ions and OH^- ions are equal. These solutions are considered neutral. Pure water at 25°C has a pH of 7.

One way to determine pH is by using a universal indicator paper. This paper undergoes a color change in the presence of H_3O^+ ions and OH^- ions in solution. The final color of the pH paper is matched with colors in a chart to find the pH, as shown in **Figure 10.** Is this an accurate way to determine pH?

An instrument called a pH meter is another tool to determine the pH of a solution. This meter is operated by immersing the electrodes in the solution to be tested and reading the dial. Small, battery-operated pH meters with digital readouts are precise and convenient for use outside the laboratory when testing the pH of soils and streams, as shown in **Figure 10.**

Figure 10 The pH of a sample can be measured in several ways. Indicator paper gives an approximate value quickly, however, a pH meter is quick and more precise.

(cw from tl)Elaine Shay, Brent Turner/BLT Productions, Matt Meadows, Elaine Shay, StudiOhio, Icon Images, CORBIS, CORBIS, (c)Dominic Oldershaw, (bl)Mark Burnett/Stock Boston/PictureQuest, (br)Matt Meadows

Blood pH Your blood circulates throughout your body carrying oxygen, removing carbon dioxide, and absorbing nutrients from food that you have eaten. In order to carry out its many functions properly, the pH of blood must remain between 7.0 and 7.8. The main reason for this is that enzymes, the protein molecules that act as catalysts for many reactions in the body, cannot work outside this pH range. Yet you can eat foods that are acidic without changing the pH of your blood. How can this be? The answer is that your blood contains compounds called buffers that enable small amounts of acids or bases to be absorbed without harmful effects.

Buffers are solutions containing ions that react with additional acids or bases to minimize their effects on pH. One buffer system in blood involves bicarbonate ions, HCO_3^-. Because of these buffer systems, small amounts of even concentrated acid will not change pH much, as shown in **Figure 11.** Buffers help keep your blood close to a nearly constant pH of 7.4.

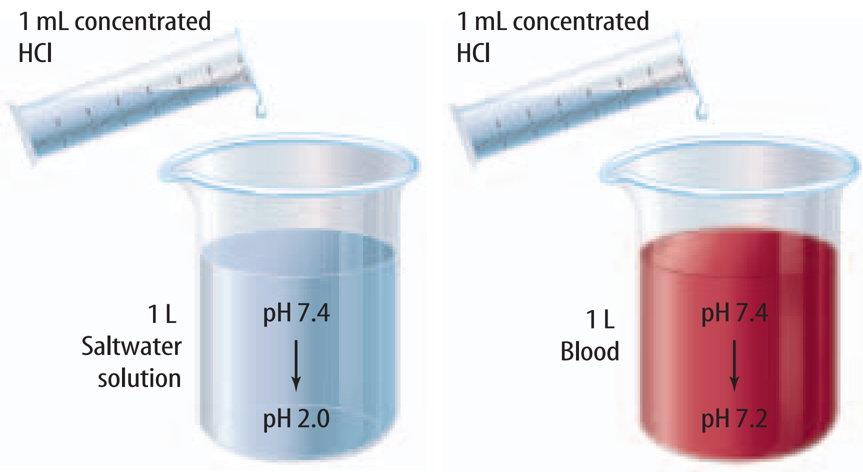


Figure 11 This experiment shows how well blood plasma acts as a buffer. Adding 1 mL of concentrated HCl to 1 L of salt water changes the pH from 7.4 to 2.0. Adding the same amount of concentrated HCl to 1 L of blood plasma changes the pH from 7.4 to 7.2.

Reading Check *What are buffers and how are they important for health?*

section 2 review

Summary

Strong and Weak Acids and Bases

- When strong acids dissolve in water, nearly all the acid molecules dissociate into ions. When weak acids dissolve in water, few molecules dissociate.
- When strong bases dissolve in water, nearly all base particles dissociate. When weak bases dissove, only a few particles dissociate.
- Ions in solution can conduct electricity.
- Strength refers to the ability of an acid or base to dissociate in water; concentration refers to how much acid or base is in solution.

pH of a Solution

- pH describes a substance as acidic or basic.
- Buffers are substances that minimize the effects of an acid or base on pH.

Self Check

1. **Describe** what determines the strength of an acid. A base?
2. **Explain** how to make a dilute solution of a strong acid.
3. **Explain** how electricity can be conducted by solutions.
4. **Describe** pH values of 9.1, 1.2, and 5.7 as basic, acidic, or very acidic.
5. **Think Critically** The proper pH range for a swimming pool is between 7.2 and 7.8. Most pools use two substances, Na_2CO_3 and HCl, to maintain this range. How would you adjust the pH if you found it was 8.2? 6.9?

Applying Math

6. **Use Equations** To determine the difference in pH strength, calculate 10^n, where n = difference between pHs. How much more acidic is a solution of pH 2.4 than a solution of pH 4.4?

LAB

Acid Concentrations

Real-World Question

The science of acids and bases is not practiced only in a high-tech laboratory by degreed scientists. You can investigate the acidic concentrations of things in your own home using a simple home-made indicator solution. How can you tell if a substance is a strong or weak acid?

Goals

- **Determine** the relative concentrations of common acid substances.

Materials

home-made cabbage indicator (indicates both acids and bases)
coffee filter
wax paper
grease pencil or masking tape
teaspoons (3)
alum
cream of tartar
fruit preservative

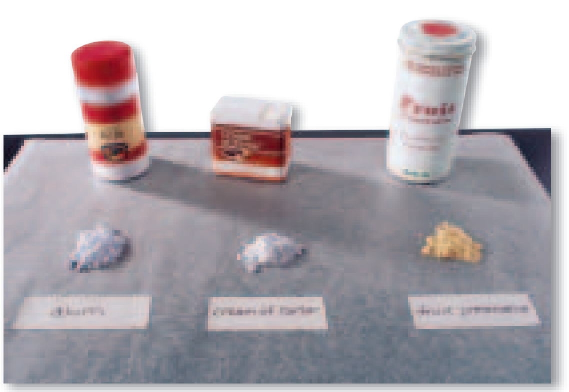
Safety Precautions

Procedure

1. Use the grease pencil or masking tape and a pencil to label three areas on the wax paper *alum, cream of tartar,* and *fruit preservative.* These areas should be about 8 cm apart.
2. Place approximately 1/2 teaspoon of each of the three powders on the wax paper where labeled. Use a separate teaspoon for each substance.
3. Cut three strips from the coffee filter, about 1 cm wide by 8 cm long.
4. Dip the end of one of the strips into the cabbage indicator solution, then lay the wet end on top of the alum.
5. Wet a second strip and lay it in on top of the cream of tartar.
6. Wet the third strip and lay on top of the fruit preservative.
7. Wait 5 minutes, then check the indicator strips and record your observations.

Conclude and Apply

1. Determine if all three substances were acids. Did the indicator strips turn a similar color?
2. Explain why each substance produced a different color.
3. Propose a possible rank of the concentrations.
4. Predict what you would have observed if you used sodium hydroxide instead of alum.



Communicating Your Data

Compare your results with other groups in the class. Discuss any differences in the results you obtained.

Tim Courlas/Horizons Companies

section 3

Salts

Reading Guide

What You'll Learn

- **Identify** a neutralization reaction.
- **Determine** what a salt is and how salts form.
- **Compare and contrast** soaps and detergents.
- **Examine** how esters are made and what they are used for.

Why It's Important

You need salt to live and soaps and detergents to keep yourself and your clothing clean.

Review Vocabulary

ester: organic compounds made from acids and alcohols

New Vocabulary

- neutralization
- salt
- titration
- soap

Neutralization

Advertisements for antacids claim that these products neutralize the excess stomach acid that causes indigestion. Normally, gastric juice contains a dilute solution of hydrochloric acid. Too much acid can produce discomfort. Antacids contain bases or other compounds containing sodium, potassium, calcium, magnesium, or aluminum that react with acids to lower acid concentration. **Figure 12** shows what happens when you take an antacid tablet containing sodium bicarbonate—$NaHCO_3$. The equation is:

$$HCl(aq) + NaHCO_3(s) \rightarrow NaCl(aq) + CO_2(g) + H_2O(l)$$

In this case, the acid (HCl) is neutralized by the base ($NaHCO_3$).

Neutralization is a chemical reaction between an acid and a base that takes place in a water solution. For example, when HCl is neutralized by NaOH, hydronium ions from the acid combine with hydroxide ions from the base to produce neutral water.

$$H_3O^+(aq) + OH^- \rightarrow 2H_2O(l)$$

Salt Formation The equation above accounts for only half of the ions in the solution. The remaining ions react to form a salt. A **salt** is a compound formed when the negative ions from an acid combine with the positive ions from a base. In the reaction between HCl and NaOH the salt formed in water solution is sodium chloride.

$$Na^+(aq) + Cl^-(aq) \rightarrow NaCl(aq)$$

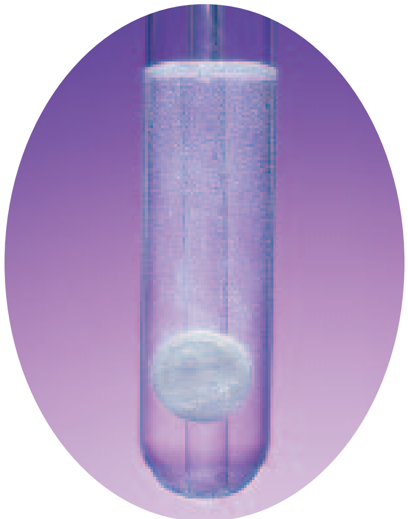


Figure 12 An antacid tablet reacts in your stomach much as it does in this dilute HCl. Usually, people chew antacid tablets before swallowing them. **Explain** *how this would affect the rate of the reaction.*

Figure 13 Like many animals, elephants get salt from natural deposits. Salt helps to maintain body processes.

Acid-Base Reactions The following general equation represents acid-base reactions in water.

Acid-Base Reactions

acid + base → salt + water

Another neutralization reaction occurs between HCl, an acid, and $Ca(OH)_2$, a base producing water and the salt $CaCl_2$.

$$2HCl(aq) + Ca(OH)_2(aq) \rightarrow CaCl_2(aq) + 2H_2O(l)$$

Salts

Salt is essential for many animals large and small. Some animals find it at natural deposits, as shown in **Figure 13.** Even insects, such as butterflies, need salt and often are found clustered on moist ground. You need salt too, especially because you lose salt in perspiration. How humans obtain one salt—sodium chloride—is shown in **Figure 14.**

There are many other salts, however, a few of which are shown in **Table 3.** Most salts are composed of a positive metal ion and an ion with a negative charge, such as Cl^- or CO_3^{2-}. Ammonium salts contain the ammonium ion, NH_4^+, rather than a metal.

Table 3 Some Common Salts and Their Uses

Name, Formula	Common Name	Uses
Sodium chloride, NaCl	Salt	Food, manufacture of chemicals
Sodium hydrogen carbonate, $NaHCO_3$	Sodium bicarbonate Baking soda	Food, antacids
Calcium carbonate, $CaCO_3$	Calcite, chalk	Manufacture of paint and rubber tires
Potassium nitrate, KNO_3	Saltpeter	Fertilizers
Potassium carbonate, K_2CO_3	Potash	Manufacture of soap and glass
Sodium phosphate, Na_3PO_4	TSP	Detergents
Ammonium chloride, NH_4Cl	Sal ammoniac	Dry-cell batteries

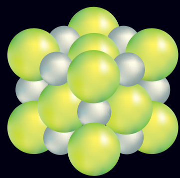
VISUALIZING SALT

Figure 14

The salt you use every day comes from both the land and the sea. Some salt can be mined from the ground in much the same way as coal, or salt can be obtained by the process of evaporation in crystallizing ponds.

EVAPORATION PROCESS Workers fill evaporation ponds, like these near San Francisco Bay, California, with salt water, or brine. They move the brine from pond to pond as it becomes saltier through evaporation. (Red-tinted ponds have a higher salt content.) The saltiest water is then pumped from evaporation ponds into crystallizing ponds, where the remaining water is drained off. In the five years it takes to produce a crop of salt, brine may move through as many as 23 different ponds.

MINING SALT Underground salt deposits are found where there was once a sea. Salt mines can be located deep underground or near Earth's surface in salt domes. Salt domes, such as the one above on Avery Island, Louisiana, form when pressure from Earth pushes buried salt deposits close to the surface, where they are easily mined.



Unit cell of sodium chloride (NaCl)

TABLE SALT Raw sodium chloride is washed in chemicals and water to remove impurities before it appears on your dining-room table as salt. Iodine is added to table salt to ensure against iodine deficiency in the diet.

SALT MOUNDS When the crystallizing ponds are drained, the result is huge piles of salt, like these on the Caribbean island of Bonaire.

Titration

Sometimes you need to know the concentration of an acidic or basic solution; for example, to determine the purity of a commercial product. This can be done using a process called **titration** (ti TRAY shun), in which a solution of known concentration is used to determine the concentration of another solution. **Figure 15** shows a titration experiment.

Titration involves a solution of known concentration, called the standard solution. This is added slowly and carefully to a solution of unknown concentration to which an acid/base indicator has been added. If the solution of unknown concentration is a base, a standard acid solution is used. If the unknown is an acid, a standard base solution is used.

Science Online

Topic: Acid/Base Indicators
Visit gpscience.com for Web links to information about acids, bases, and indicators.

Activity Obtain several strips of pH indicator paper and test various liquids around your house to determine if they are acidic, basic, or neutral. You might try the liquids in your refrigerator, rain from a puddle, or swimming pool water.

The Endpoint Has a Color The titration shown in **Figure 15** shows how you could find the concentration of an acid solution. First, you would add a few drops of an indicator, such as phenolphthalein (fee nul THAY leen), to a carefully measured amount of the solution of unknown concentration. Phenolphthalein is colorless in an acid but turns bright pink in the presence of a base.

Then, you would slowly and carefully add a base solution of known concentration to this acid-and-indicator mixture. Toward the end of the titration you must add a base drop by drop until one last drop of the base turns the solution pink and the color persists. The point at which the color persists is known as the end point, the point at which the acid is completely neutralized by the base. When you know what volume of base was used, you use that value and the known concentration of the base to calculate the concentration of the acid solution.

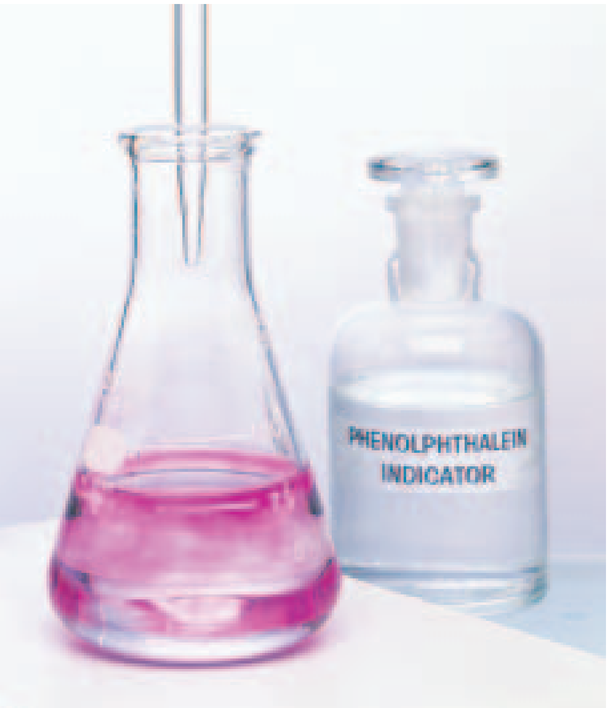


Figure 15 In this titration, a base of known concentration is being added to an acid of unknown concentration. The swirl of pink color shows that the end point is near.
Explain *How do you know when the endpoint has been reached?*

Figure 16 Natural indicators include red cabbage, radishes, and roses.

INTEGRATE Life Science

Many natural substances are acid–base indicators. In fact, the indicator litmus comes from a lichen—a combination of a fungus and an algae or a cyanobacterium. Flowers that are indicators include hydrangeas, which produce blue blossoms when the pH of the soil is acidic and pink blossoms when the soil is basic. This is just the opposite of litmus.

Other natural indicators possess a range of color. For example, the color of red cabbage varies from deep red at pH 1 to lavender at pH 7 and yellowish green at pH 10. Grape juice is also an indicator, as you can find out by doing the Try at Home MiniLAB.

Mini LAB

Testing a Grape Juice Indicator

Procedure

1. Add one-half cup of **water** to each of **two small glasses.**
2. Add 1 tablespoon of **purple grape juice** to each glass.
3. To one glass, add 1 teaspoon of **baking soda.** Stir.
4. To the other glass add 1 teaspoon of **white vinegar.**
5. Note the color after each addition in steps 2, 3, and 4.

Analysis

1. Did the color change when you added baking soda? Why?
2. Did the color change when you added vinegar? Did your grape juice contain any citric or ascorbic acid? How would this affect your experiment?

Try at Home

Applying Science

How can you handle an upsetting situation?

Most of us have, at some time, experienced an upset stomach. Often, the cause is the excess acid within our stomachs. For digestive purposes, our stomachs contain dilute hydrochloric acid with a pH between 1.6 and 3.0. A doctor might recommend an antacid treatment for an upset stomach. What type of compound is "anti acid"?

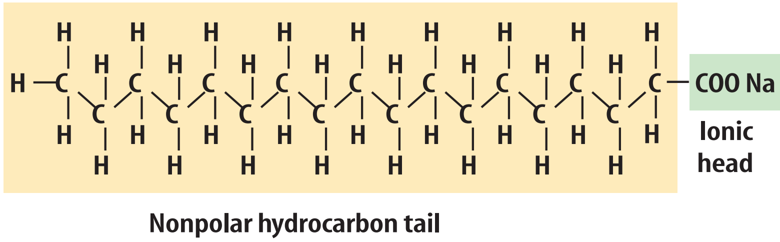
Identifying the Problem

You have learned that neutralization reactions change acids and bases into salts. Antacids typically contain small amounts of $Ca(OH)_2$, $Al(OH)_3$, or $NaHCO_3$, which are bases. Whereas having an excess of acid lowers the pH of your stomach contents, these compounds raise the pH of your stomach contents. How does this change of pH make you feel better?

Solving the Problem

1. What compounds are produced from a reaction of HCl and $Mg(OH)_2$?
2. Why is it important to have some acid in your stomach?
3. How could you compare how well antacid products neutralize acid? Describe the procedure you would use.

Figure 17 Soaps that contain sodium like this one made from stearic acid are solids, those that contain potassium are liquids. **Write** *the chemical formula for this soap.*



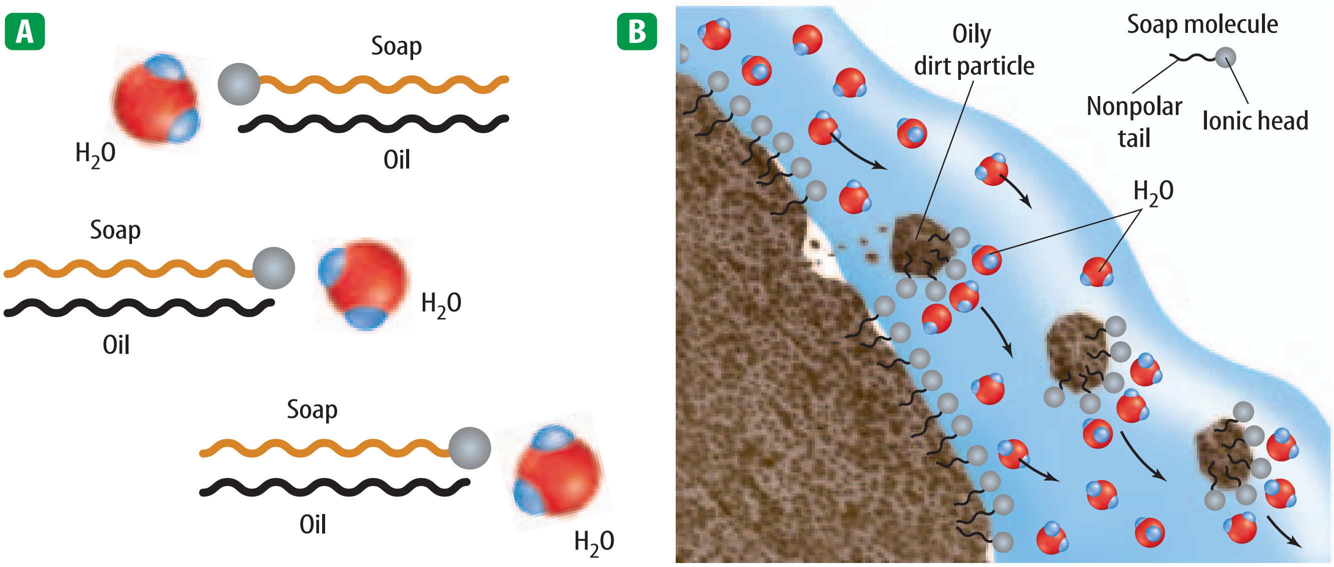
Soaps and Detergents

The next time you are in a supermarket, go to the aisle with soaps and detergents. You'll see all kinds of products—solid soaps, liquid soaps, and detergents for washing clothes and dishes. What are all these products? Do they differ from one another? Yes, they do differ slightly in how they are made and in the ingredients included for color and aroma. Still, all these products are classified into two types—soaps and detergents.

Soaps The reason soaps clean so well is explained by polar and nonpolar molecules. **Soaps** are organic salts. They have a nonpolar organic chain of carbon atoms on one end and either a sodium or potassium salt of a carboxylic acid (kar bahk SIHL ihk), −COOH, group at the other end. Look at **Figure 17.** The nonpolar, hydrocarbon end interacts with oils and dirt so that they can be removed readily, and the ionic end, COONa or COOK, helps them dissolve in water.

To make an effective soap, the acid must contain 12 to 18 carbon atoms. If it contains fewer than 12 atoms, it will not be able to mix well with and clean oily dirt. If it has too many carbon atoms, its sodium or potassium salt will not be soluble in water. **Figure 18** shows how soap interacts with dirt particles to clean your hands.

Figure 18 This is how soaps clean. **A** The long hydrocarbon tail of a soap molecule mixes well with oily dirt while the ionic head attracts water molecules. **B** Dirt now linked with the soap rinses away as water flows over it.



Commercial Soaps A simple soap like the one shown in **Figure 17** can be made by reacting a long-chain fatty acid with sodium or potassium hydroxide. The fatty acids used to make commercial soaps come from natural sources, such as canola, palm, and coconut oils. One problem with all soaps, however, is that the sodium and potassium ions can be replaced by ions of calcium, magnesium, and iron found in some water known as hard water. When this happens, the salts formed are insoluble. They precipitate out of solution in the form of soap scum. Detergents were developed to avoid this problem.

Reading Check *How are simple soaps made?*

Detergents Detergents are synthetic products that are made from petroleum molecules, instead of from natural fatty acids like their soap counterparts. Similar to soaps, detergents have long hydrocarbon chains, but instead of a carboxylic acid group (–COOH) at the end, they may contain instead a sulfonic acid group. These acids form more soluble salts with the ions in hard water and thereby lessen the problem of soap scum. Detergents can also be used in cold water. Most detergents contain additional ingredients called builders and surfactants to enhance sudsing and further improve cleaning in hard water.

Despite solving the problem of cleaning in hard water, detergents are not the complete solution to our needs. Some detergents contained phosphates, the use of which has been restricted or banned in many states, and these are no longer produced because they cause water pollution. Certain sulfonic acid detergents also present problems in the form of excess foaming in water treatment plants and streams, as shown in **Figure 19.** These detergents do not break down easily by bacteria and remain in the environment for long periods of time.

INTEGRATE History

Ecology Before the environmental impact of phosphates was understood, phosphates were added to detergents. Eventually water/detergent mixtures would be washed into streams where the phosphates acted like strong fertilizers, causing algae and water plants to grow uncontrollably. Research this problem and, in your Science Journal, write a pamphlet or speech that an environmental activist might have used to convince law makers of the need for change.

Figure 19 Foam from nonbiodegradable detergents can build up in waterways.

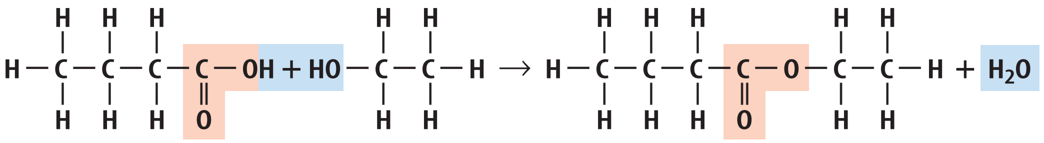


Figure 20 This structural equation shows the formation of the ester ethyl butyrate, an ester that tastes and smells like pineapple. **Predict** *which alcohol you would use to prepare butyl butyrate.*

Versatile Esters

In a way esters can be thought of as the organic counterparts of salts. Like salts, esters are made from acids, and water is formed in the reaction used to prepare them. The difference is that salts are made from bases and esters come from alcohols that are not bases but have a hydroxyl group.

Esters have many different applications. Esters of the alcohol glycerine are used commercially to make soaps. Other esters are used widely in flavors and perfumes, and still others can be transformed into fibers to make clothing.

Reading Check *What are three types of products that are made from esters?*

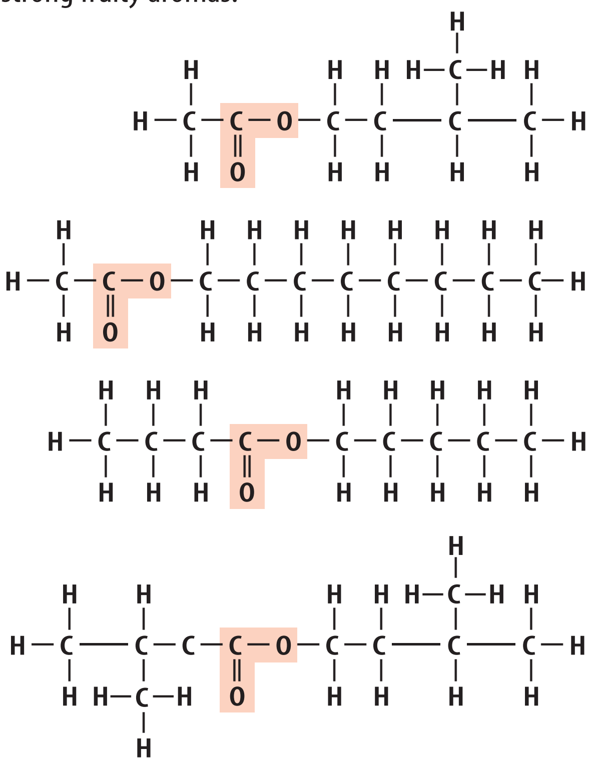
Esters for Flavor Many fruit-flavored soft drinks and desserts taste like the real fruit. If you look at the label though, you might be surprised to find that no fruit was used—only artificial flavor. Most likely this artificial flavor contains some esters.

The reaction to prepare esters involves removing a molecule of water from an acid and an alcohol. Often concentrated sulfuric acid is added to aid this reaction. **Figure 20** shows the reaction of butyric (byew TIHR ihk) acid and ethyl alcohol to produce water and the ester, ethyl butyrate, which is a component in pineapple flavor.

Although natural and artificial flavors often contain a blend of many esters, the odor of some individual esters immediately makes you think of particular fruits, as shown in **Figure 21.** For example, octyl acetate smells much like oranges, and both pentyl and butyl acetates smell like bananas.

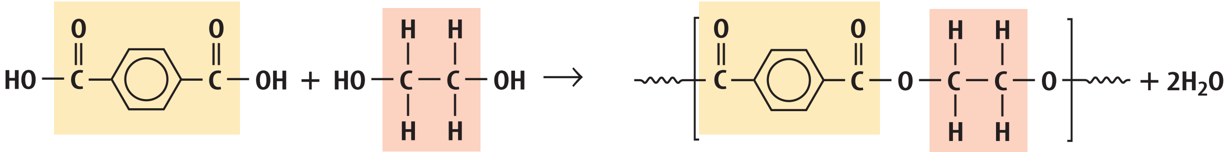
Making realistic synthetic flavors is an art, in which chemists vary the composition to achieve the desired taste. Strawberry flavor, for example, may contain several esters.

Figure 21 These esters have strong fruity aromas.



Amanita Pictures

Figure 22 Polyesters and nylons are polymers most often used for clothing fibers.



Polyesters Synthetic fibers known as polyesters are polymers; that is, they are chains containing many or *poly* esters. They are made from an organic acid that has two —COOH groups and an alcohol that has two —OH groups, as shown in **Figure 22.** The two compounds form long nonpolar chains that are closely packed together. This adds strength to the polymer fiber. Many varieties of polyesters can be made, depending on what alcohols and acids are used. They can be woven or knitted into fabrics that are durable, water repellent, colorfast, and do not wrinkle easily. Because of their low moisture content however, they tend to build up a static electric charge that causes them to cling. Polyesters often are combined with natural fibers, as shown in **Figure 22.**

Blends of polyester and cotton fibers make comfortable activewear.

section 3 review

Summary

Salts

- Salts are solid compounds formed from the negative ions of an acid and the positive ions from a base.
- Salt is a dietary essential.

Neutralization and Titration

- Acids and bases in solution can combine to bring pH closer to neutral. Products such as stomach antacids use this principle.
- Titration is a method used to determine the concentration of an acidic or basic solution.

Soaps, Detergents, and Esters

- Soaps and detergents are polar, which allows one end to attract dirt and grease molecules and the other end to attract water to wash the dirt away.
- Esters are organic compounds that are made from acids and alcohols.

Self Check

1. **Describe** a neutralization reaction. What are the products of such reactions?
2. **Identify** the purpose of an indicator in a titration experiment.
3. **Explain** how the composition of detergents differs from that of soaps.
4. **Identify** the molecule that is produced in the reaction between an alcohol and an acid to form an ester.
5. **Think Critically** Give the names and formulas of the salts formed in these neutralizations: sulfuric acid and calcium hydroxide, nitric acid and potassium hydroxide, and carbonic acid and aluminum hydroxide.

Applying Math

6. **Calculate Ratios** In the following reaction:
$2HCl(aq) + Ca(OH)_2(aq) \longrightarrow CaCl_2(aq) + 2H_2O(l)$
acid reacts with base in what ratio? How many molecules of HCl are needed to produce four molecules of H_2O?

Science Online gpscience.com/self_check_quiz

LAB **Design Your Own**

Be a Soda Scientist

Goals

- **Observe** evidence of a neutralization reaction using an indicator.
- **Compare** the acidity levels in soft drinks.
- **Design** an experiment that uses the independent variable of acid content of soft drinks and the dependent variable of amount of base added to determine the relative acidity of the drinks.

Possible Materials

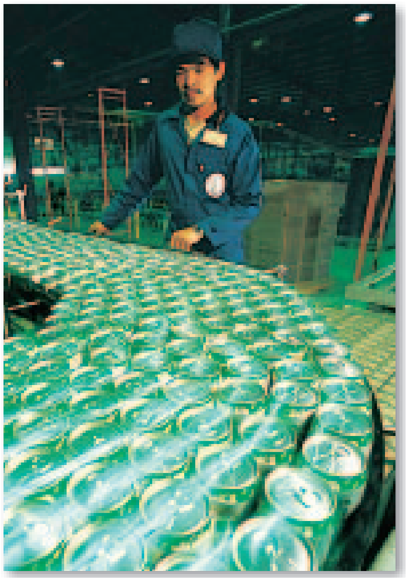
different colorless soft drinks (3)
test tubes (3)
25-mL graduated cylinder
droppers (2)
1% phenolphthalein
dilute NaOH solution (0.1*M*)

Safety Precautions

WARNING: *Sodium hydroxide is caustic. Wear eye protection and avoid any skin contact with the solution. Flush thoroughly under a stream of water if any of the NaOH touches your skin. Keep your hands away from your face.*

Real-World Question

The next time you drink a can of soda, take a look at the ingredients label. Carbonated soft drinks contain carbonic acid and sometimes phosphoric acid. You have learned that bases can neutralize acids. Using a proper indicator and a base solution, how could you compare the acidity levels in soft drinks?



Form a Hypothesis

Based on your knowledge of acids and bases, develop a hypothesis about how neutralization reactions can be used to rank the acidity of soft drinks.

(t)Bill Lyons/Liaison Agency/Getty Images, (b)Richard Megna/Fundamental Photographs

Test Your Hypothesis

Make a Plan

1. As a group, agree upon and write the hypothesis statement.
2. In a logical manner, list the specific steps that you will use to test your hypothesis.
3. **List** all of the materials that you will need to test your hypothesis.
4. **Design** a data table in your Science Journal that will allow you to record the amount of NaOH that was required to neutralize each soda sample.
5. **Decide** the amount of soda to be tested in each trial as a control. Decide also how many times to repeat each trial.
6. **Predict** whether you can test only colorless solutions with this procedure and explain why.

Follow Your Plan

1. Make sure your teacher approves your plan before you start.
2. **Observe** the color change that the indicator phenolphthalein undergoes in a solution that changes from an acidic pH to a basic pH.
3. While doing the experiment, write your observations and complete the data table in your Science Journal.

Analyze Your Data

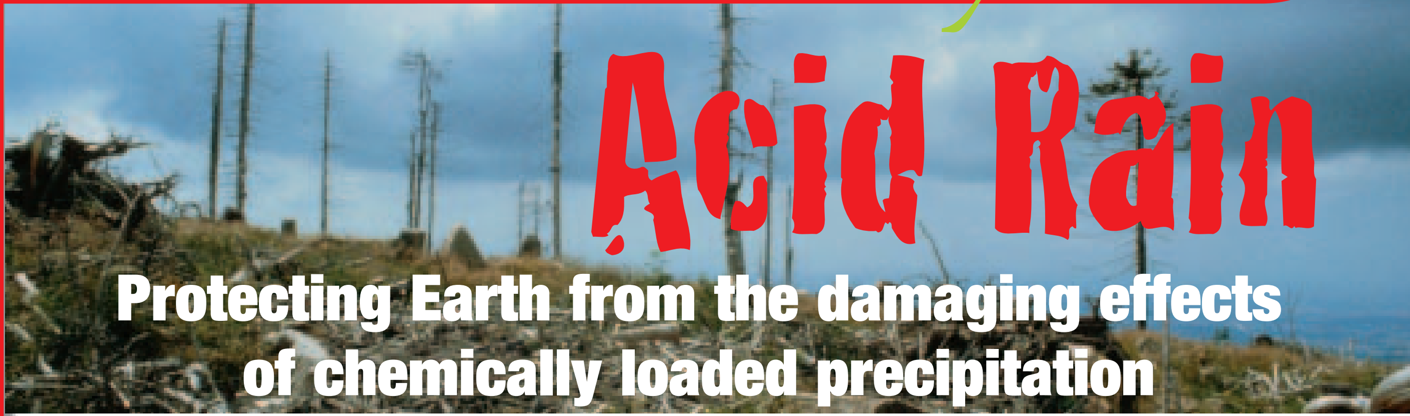
1. **Classify** the sodas you tested based on their acidities. Rank them in the order of most acidic to least acidic.
2. **Predict** if your acidity values can be compared with those of other groups if they used different amounts of soda.

Conclude and Apply

1. **Evaluate** the results. Do they support your hypothesis? Explain why or why not.
2. **Predict** At warmer temperatures less gas dissolves in a liquid. How would this affect the results of an experiment comparing two sodas stored at different temperatures?

Communicating Your Data

Compare your soda rankings with those of other class groups. **Discuss** possible reasons for any differences observed.



Acid Rain

Protecting Earth from the damaging effects of chemically loaded precipitation

Acid rain is rain, snow, or sleet that is more acidic than unpolluted precipitation. It's caused by the burning of fossil fuels, such as coal, oil, and natural gas. In the United States, most gasoline and electricity come from fossil fuels. People burn fossil fuels each time they drive a car, heat a building, or turn on a light.

Normally, raindrops pick up particles and natural chemicals in the air. When rain falls, it mixes with the carbon dioxide in the atmosphere, giving clean rain a slightly acidic pH of 5.6. Then, natural chemicals found in the air and soil balance out the acidity, giving most lakes and streams a pH between 6.0 and 8.0. But when pollutants are introduced, these natural bases are not strong enough to neutralize these solutions. Wind can carry this acidic moisture for hundreds of miles before it falls to Earth as acid rain.

Eating Away at History

Like all acids, acid rain can corrode, or eat away at, substances. Many historical monuments, such as the Mayan temples in Mexico and the Parthenon in Greece, have been slowly but steadily damaged by acid rain. This kind of damage can be fixed, though it costs billions of dollars to ensure that ancient monuments and buildings are not destroyed.

Some Solutions

In some countries, high acid levels in lakes and streams have been lowered by adding lime to the water. Lime, a natural base, balances out the damaging chemicals. In the United States, all new cars must have catalytic converters, which help reduce the amount of exhaust pollution that vehicles give off.

You also can make a difference. Turning off the lights when you are not using them means a power plant does not have to produce as much electricity. By carpooling, using public transportation, and walking, there is less pollution from cars. The results of all these individual actions can make a huge difference in preserving our environment.

Ride a bike! It saves fuel, is nonpolluting, and helps preserve the environment.

List Go to a local park or forest. List any effects of acid rain that you see. Make a list of the things you do that use energy or cause pollution. Think about what your family can do to reduce pollution and save energy. Share your list with an adult.

Science Online

For more information, visit gpscience.com/time

Reviewing Main Ideas

Section 1 Acids and Bases

1. An acid is a substance that produces hydrogen ions, H^+, in solution. A base produces hydroxide ions, OH^-, in solution.
2. Some foods can be classified as acidic or basic. Properties of acids and bases are due, in part, to the presence of the H^+ and OH^- ions.

3. Common acids include hydrochloric acid, sulfuric acid, nitric acid, and phosphoric acid. Common bases include sodium hydroxide, calcium hydroxide, and ammonia.
4. Acidic solutions form when certain polar compounds ionize as they dissolve in water. Except for ammonia, basic solutions form when certain ionic compounds dissociate upon dissolving in water.

Section 2 Strength of Acids and Bases

1. The strength of an acid or base is determined by how completely it forms ions when it is in solution.
2. Strength and concentration are not the same thing. Concentration involves the relative amounts of solvent and solute in a solution, whereas strength is related to the extent to which a substance dissociates.
3. pH measures the concentration of hydronium ions in water solution using a scale ranging from 0 to 14.
4. For acidic solutions of equal concentration, the stronger the acid is, the lower its pH is. For basic solutions of equal concentration, the stronger the base is, the higher its pH is.

Section 3 Salts

1. In a neutralization reaction, the H_3O^+ ions from an acid react with the OH^- ions from a base to produce water molecules. The products of a neutralization reaction are a salt and water.
2. Salts form when negative ions from an acid combine with positive ions from a base.
3. Soaps and detergents are organic salts. Unlike soaps, detergents do not react with compounds in hard water to form soap scum as shown here.

4. Esters are organic compounds formed by the reaction of an organic acid and an alcohol.

FOLDABLES™ Use the Foldable that you made at the beginning of this chapter to help you review acids, bases, and salts.

Using Vocabulary

acid p. 696	salt p. 707
base p. 698	soap p. 712
buffer p. 705	strong acid p. 702
hydronium ion p. 696	strong base p. 703
indicator p. 696	titration p. 710
neutralization p. 707	weak acid p. 702
pH p. 704	weak base p. 703

Explain the differences between each set of vocabulary words given below. Then explain how the words are related.

1. acid—base
2. acid—salt
3. salt—soap
4. base—soap
5. neutralization—salt
6. strong acid—pH
7. hydronium ion—acid
8. indicator—titration
9. pH—buffer
10. weak base—strong base

Checking Concepts

Choose the word or phrase that best answers the question.

11. What best describes solutions of equal concentrations of HCl and CH_3COOH?
    A) do not have the same pH
    B) will react the same with metals
    C) will make the same salts
    D) have the same amount of ionization

12. What is hydrochloric acid also known as?
    A) battery acid C) stomach acid
    B) citric acid D) vinegar

13. Which of the following acids ionizes only partially in water?
    A) HCl C) HNO_3
    B) H_2SO_4 D) CH_3COOH

14. Which of the following is another name for sodium hydroxide (NaOH)?
    A) ammonia C) lye
    B) caustic lime D) milk of magnesia

15. Carrots have a pH of 5.0, so how would you describe them?
    A) acidic C) neutral
    B) basic D) an indicator

16. What is the pH of pure water at 25°C?
    A) 0 C) 7
    B) 5.2 D) 14

17. A change of what property permits certain materials to act as indicators?
    A) acidity C) concentration
    B) color D) taste

18. Which of the following might you use to titrate an oxalic acid solution?
    A) HBr C) NaOH
    B) $Ca(NO_3)_2$ D) NH_4Cl

Interpreting Graphics

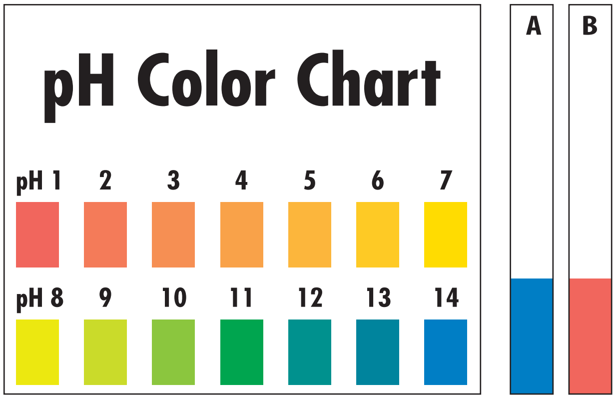
Use the table below to answer question 19.

19. Which of the substances listed in the table would be most effective for neutralizing battery acid?

pH Readings

Substance	pH
Battery acid	1.5
Lemon juice	2.5
Apple	3
Milk	6.7
Seawater	8.5
Ammonia	12

Use the illustration below to answer question 20.



20. Compare the pH test strips for Sample A and Sample B and determine which sample is the acid.

Thinking Critically

21. **Describe** what happens to hydrogen chloride, HCl, when dissolved in water to form hydrochloric acid.

22. **Explain** how the hydroxide ion in NaOH differs from the —OH group in an alcohol.

23. **Explain** why ammonia is considered a base, even though it contains no hydroxide ions. Is it a strong or weak base?

24. **Explain** why a concentrated acid is not necessarily a strong acid.

25. **Explain** why the substances CH_4 and SiO_2 do not conduct electricity.

26. **Compare and Contrast** How would the pH of a dilute solution of HCl compare with the pH of a concentrated solution of the same acid?

27. **Recognize Cause and Effect** Ramón often saw his mother cleaning white deposits from inside her teakettle using vinegar. When she added vinegar, bubbles formed. When she finished, all the white deposits were gone. What do you think these white deposits might be? Do you think dish detergent would have worked as well?

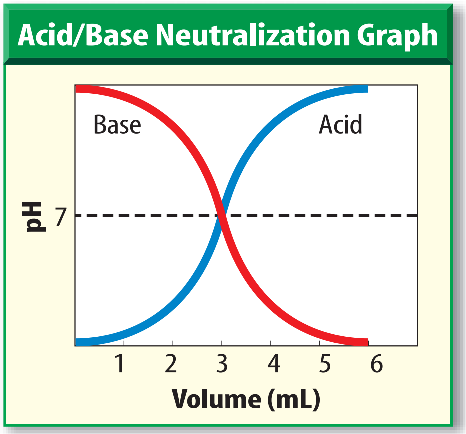
28. **Draw Conclusions** You have equal amounts of three colorless liquids: A, B, and C. You add several drops of phenolphthalein to each liquid. A and B remain colorless, but C turns pink. Next, you add some C to A and the pink color disappears. Then, you add the rest of C to B and the mixture remains pink. What can you infer about each of these liquids? Which original liquid could have had a pH of 7?

Applying Math

29. **Calculate pH** If an acid is added to a solution of pH 10 and the solution changes 4 pH units, what is the new pH?

30. **Use Proportions** To make an indicator solution, a student mixes 3 mL of a concentrated solution to 100 mL water. How much concentrate is needed to make 3 liters of the indicator?

Use the graph below to answer question 31.



31. **Interpret Graphs** The graph illustrates an acid-base neutralization reaction. Which line (red or blue) represents a base being neutralized by an acid?

32. **Interpret Graphs** Using the graph above, how much acid must be added to the base to neutralize it?

Part 1 Multiple Choice

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

Use the table below to answer questions 1 and 2.

Acid Solution Data		
Solution	**pH**	**Dissociation**
W	7	none
X	2	complete
Y	6	partial
Z	4	??

1. Which word best describes the dissociation of acid solution Z?
A. complete
B. partial
C. none
D. exactly 50%

2. Which solution contains a strong acid?
A. solution W
B. solution X
C. solution Y
D. solution Z

3. Hard water often contains various amounts of metallic substances. Which of the following ions does NOT contribute to hard water?
A. calcium
B. iron
C. magnesium
D. sodium

4. An unknown substance in solution is slippery to the touch, dissolves easily in water, and turns litmus paper blue. The substance is most likely a(n)
A. acid.
B. base.
C. salt.
D. ester.

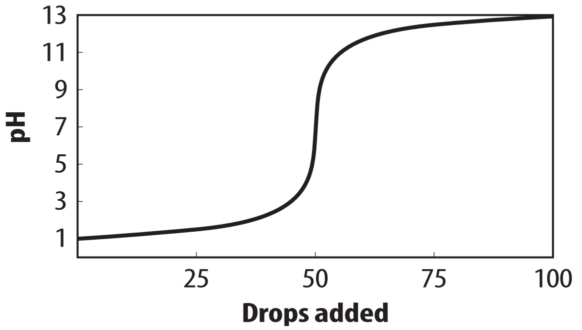
Test-Taking Tip

Answer All Questions Never skip a question. If you are unsure of an answer, mark your best guess on another sheet of paper and mark the question in your test booklet to remind you to come back to it at the end of the test.

5. Which chemical formula below describes a hydronium ion?
A. H_3O^+
B. OH^-
C. COOH
D. H_2O

The titration curve (below) indicates the changes that happened to the solution as drops of a strong base are added. Use the graph below to answer questions 6–9.

Acids, Bases, and Salts



6. Before any drops were added, what was the pH of the solution?
A. 1
B. 3
C. 9
D. 13

7. At what drop count are the acid and base exactly neutralized?
A. 0
B. 25
C. 50
D. 75

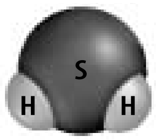
8. At the instant of neutralization, what is in the beaker besides water?
A. acid only
B. base only
C. salt only
D. equal amounts of each

9. If the chemical equation for this reaction is $2HCl + Ca(OH)_2 \rightarrow CaCl_2 + 2H_2O$, how many water molecules are formed as x molecules of $CaCl_2$ form?
A. 2
B. twice as many, $2x$
C. half as many, $x/2$
D. an equal number, x

Part 2 Short Response/Grid In

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

Use the model below of hydrogen sulfide to answer questions 10–13.



10. What is the chemical formula for this substance?

11. How many hydronium ions can it form in water?

12. Write the chemical equation for this dissociation reaction.

13. Hydrogen sulfide is a weak acid. Describe how much this substance will dissociate in water.

14. A conductivity apparatus is inserted into a beaker of water, but the light bulb does not glow. Describe what will happen if NaCl crystals are added with stirring.

15. When the pH of a solution drops from 3.0 to 1.0, the hydronium ion concentration increases by a factor of one hundred fold from 0.0010. What is the concentration at pH = 1.0?

16. Compare and contrast the terms *strength* and *concentration* as they apply to acids and bases in solution.

17. An environmental scientist tested rain puddles with pH test strips and a pH meter. The test strips indicated pH = 2.0 and the meter indicated pH = 2.9. By percent, calculate by how much these results differ.

18. Name the salt that is produced by each of the following acid-base pairs. HCl + NaOH; HNO_3 + KOH; H_2SO_4 + $Ca(OH)_2$

Part 3 Open Ended

Record your answers on a sheet of paper.

One of the solutions has a pH of 10, the other pH of 12. In one beaker the bulb glows more brightly than does the other. Use the figures below to answer questions 19 and 20.

19. Are the two solutions acids or bases? Explain how you know.

20. Explain why the bulbs glow with different intensities. Use the words *strong* and *weak* in your answer.

21. Describe how dishwashing liquid cleans dirty plates.

22. Na_2SO_4 is a soluble salt. Write the chemical equation describing its dissociation in water.

23. Identify the acid and base that are neutralized to form the salt Na_2SO_4 in a titration reaction.

24. Assume you have a HCl solution of unknown concentration. If 25.0 mL of this solution requires 50.0 mL of a known concentration of a NaOH solution to neutralize, how much more concentrated is the HCl solution than the NaOH solution?

25. Explain why a weak acid in solution has a higher pH than a strong acid of the same concentration.

Matt Meadows