Section 8.3

1 FOCUS

Objectives

8.3.1 **Define** acid and **describe** some of the general properties of an acid.

8.3.2 **Define** base and **describe** some of the general properties of a base.

8.3.3 **Identify** a neutralization reaction, and **describe** the reactants and products of neutralization.

8.3.4 **Explain** how acids and bases can be defined as proton donors and proton acceptors.

Reading Focus

Build Vocabulary L2

Concept Map Have students construct a concept map of the vocabulary terms used in this section. Instruct students to place the vocabulary terms in ovals and connect the ovals with lines on which linking words are placed. Students should place the main concept (Properties of Acids and Bases) at the top or the center. As they move away from the main concept, the content should become more specific.

Reading Strategy L2

b. A compound that produces hydronium ions when dissolved in water **d.** A compound that produces hydroxide ions when dissolved in water **f.** Any ionic compound that forms when an acid reacts with a base

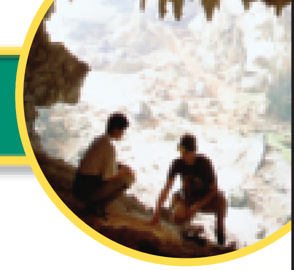
2 INSTRUCT

Identifying Acids

Address Misconceptions L2

Many students think that all acids are harmful or that all harmful chemicals are acids. Challenge these misconceptions by asking, **What juices might contain acids?** *(Orange juice, lemon juice, and tomato juice are all acidic.)* **Do you know of any acid that exists normally in your body?** *(Stomach acid contains hydrochloric acid, which aids in digestion.)*
Verbal

8.3 Properties of Acids and Bases



Reading Focus

Key Concepts
- What are some general properties of acids and bases?
- What are the products of neutralization?
- What are proton donors and proton acceptors?

Vocabulary
- acid
- indicator
- base
- neutralization
- salt

Reading Strategy

Using Prior Knowledge Before you read, copy the table below and write your definition for each vocabulary term. After you read, write the scientific definition of each term and compare it with your original definition.

Term	Your Definition	Scientific Definition
Acid	a. ?	b. ?
Base	c. ?	d. ?
Salt	e. ?	f. ?

Figure 14 Soap making involves the use of a base such as sodium hydroxide or potassium hydroxide.

One of the chemicals used to make the soaps shown in Figure 14 is sodium hydroxide. In traditional soap making, sodium hydroxide is added to a mixture of melted animal or vegetable fats. As the mixture is brought to a boil, the sodium hydroxide reacts with the fats. The products of the reaction are glycerol (a colorless, syrupy liquid) and soap. After the glycerol is separated from the soap, the soap is purified. Other chemicals are then mixed with the soap to give it a particular scent and color.

Sodium hydroxide belongs to a class of compounds, known as bases, that share some physical and chemical properties. Bases are related to another class of compounds called acids. As you will discover, there are several differences among acidic solutions, basic solutions, and solutions that have properties of neither an acid nor a base.

Identifying Acids

An **acid** is a compound that produces hydronium ions (H_3O^+) when dissolved in water. Recall that when hydrogen chloride gas dissolves in water, it ionizes and forms hydronium ions and chloride ions.

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

The solution that results is called hydrochloric acid. Figure 15 lists some common acids and their uses.

Section Resources

Print
- ***Laboratory Manual***, Investigation 8A
- ***Reading and Study Workbook With Math Support***, Section 8.3
- ***Transparencies***, Section 8.3

Technology
- ***Probeware Lab Manual***, Lab 3
- ***Interactive Textbook***, Section 8.3
- ***Presentation Pro CD-ROM***, Section 8.3
- ***Go Online***, NSTA SciLinks, Bases

Common Acids		
Name	**Formula**	**Use**
Acetic acid	CH_3COOH	Vinegar
Carbonic acid	H_2CO_3	Carbonated beverages
Hydrochloric acid	HCl	Digestive juices in stomach
Nitric acid	HNO_3	Fertilizer production
Phosphoric acid	H_3PO_4	Fertilizer production
Sulfuric acid	H_2SO_4	Car batteries

Figure 15 The table lists names, formulas, and uses for several common acids. **Inferring** ***What products are formed when nitric acid ionizes in water?***

Acids have certain chemical and physical properties that are similar. **Some general properties of acids include sour taste, reactivity with metals, and ability to produce color changes in indicators.**

Sour Taste Foods that taste sour often contain acids. For example, lemons, grapefruits, limes, and oranges all contain citric acid. The vinegar used in salad dressings contains acetic acid, CH_3COOH. Dairy products that have spoiled contain butyric (byoo THIR ik) acid. While many of the foods you eat contain acids, you should never test an acid by tasting it.

Reactivity With Metals When you use aluminum foil to cover a bowl of leftover spaghetti sauce or other foods containing tomatoes, the foil often turns dark. The foil may also develop small holes, and the food may acquire a metallic taste. Tomatoes contain citric acid, which reacts with metals such as aluminum.

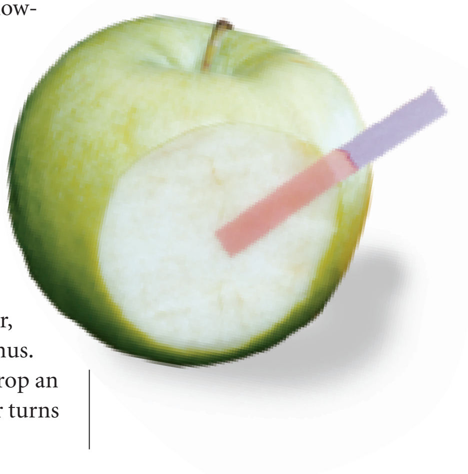
The reaction between an acid and a metal is an example of a single-replacement reaction. For example, when zinc is added to a test tube containing hydrochloric acid, bubbles form in the tube. The following equation describes the reaction.

$$Zn + 2HCl \longrightarrow H_2 + ZnCl_2$$

As the zinc replaces hydrogen in hydrochloric acid, hydrogen gas and zinc(II) chloride are produced.

Color Changes in Indicators An **indicator** is any substance that changes color in the presence of an acid or base. One of the most common indicators used is litmus, a kind of dye derived from plants called lichens (LY kens). Litmus paper, shown in Figure 16, is made by coating strips of paper with litmus. Blue litmus paper turns red in the presence of an acid. If you drop an unknown solution onto blue litmus paper and the litmus paper turns red, you can classify the solution as an acid.

Figure 16 Litmus paper is an indicator that changes color in the presence of acids and bases. When blue litmus paper touches an acid, it turns red. Apples contain several acids, including malic acid, ascorbic acid (vitamin C), and citric acid.



Build Reading Literacy L1

Compare and Contrast Refer to page **226D** in this chapter, which provides the guidelines for comparing and contrasting.

Have students read the section. As they read, they should create lists of how acids and bases are similar and different. **Verbal**

Customize for Inclusion Students

Behaviorally Disordered
Have students collect soil samples from various locations near the school and their homes. Have them note the types of plants that are found in the locations where they collected their samples. Provide students with water test kits so they can determine the pH of each sample. Have students determine if there is a correlation between the types of plants that grow in an area and the pH of the soil.

Answer to . . .

Figure 15 *NO_3^- and H_3O^+*

Identifying Bases

Build Science Skills

L2

Observing Encourage students to bring in various products from home and test each product with litmus paper. Many of the following products contain acids: fruit juices, vinegar, carbonated beverages, milk, and fertilizers. Many of the following products contain bases: cleaning products, detergents, soaps, deodorants, and antacids. Avoid having students bring in corrosive products such as car batteries or drain cleaners. As a class, make a chart that classifies each product as acidic, neutral, or basic. **Visual**

Build Science Skills

L2

Comparing and Contrasting Have students examine the table in Figure 17. Ask, **What do the bases listed in the table have in common?** *(They all contain OH^-, hydroxide ions.)* **How do the bases differ?** *(They have different cations and different numbers of hydroxide ions.)* **Logical**

Go Online NSTA SCILINKS

Download a worksheet on bases for students to complete, and find additional teacher support from NSTA SciLinks.

Go Online NSTA SCILINKS

For: Links on bases
Visit: www.SciLinks.org
Web Code: ccn-1083

Identifying Bases

Sodium hydroxide, NaOH, is an example of a base. A **base** is a compound that produces hydroxide ions (OH^-) when dissolved in water. When sodium hydroxide dissolves in water, it dissociates into sodium ions and hydroxide ions.

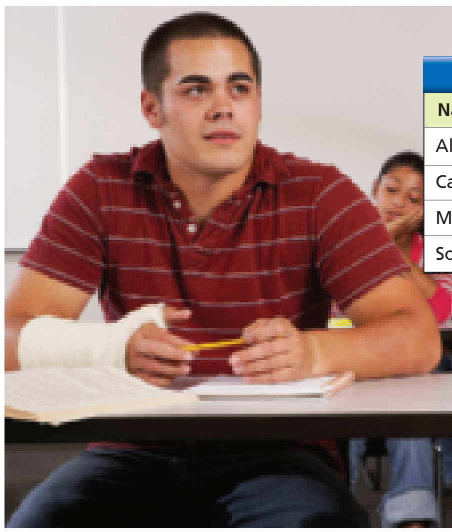
$$NaOH \longrightarrow Na^+ + OH^-$$

Figure 17 lists some common bases and their uses. Like acids, bases have certain physical and chemical properties that you can use to identify them. **Some general properties of bases include bitter taste, slippery feel, and ability to produce color changes in indicators.** Unlike acids, bases usually do not react with metals. However, low reactivity with metals is not considered a general property of bases. For example, sodium hydroxide reacts very vigorously with metals such as aluminum and zinc.

Bitter Taste Have you ever tasted unsweetened chocolate (sometimes called baking chocolate)? Without sugar, chocolate tastes bitter. Cacao beans contain a base called theobromine that gives unsweetened chocolate its bitter taste.

Many cough syrups and other liquid medicines contain similar bases. Fruit flavorings are often added to mask the taste of these basic solutions.

Slippery Feel Bases feel slippery. Wet soap and many cleaning products that contain bases are slippery to the touch. When wet, some rocks feel slippery because the water dissolves compounds trapped in the rocks, producing a basic solution.



Common Bases

Name	Formula	Uses
Aluminum hydroxide	$Al(OH)_3$	Deodorant, antacid
Calcium hydroxide	$Ca(OH)_2$	Concrete, plaster
Magnesium hydroxide	$Mg(OH)_2$	Antacid, laxative
Sodium hydroxide	NaOH	Drain cleaner, soap production

Figure 17 A base is a compound that produces hydroxide ions when dissolved in water. The plaster in this boy's cast contains a base. Bases are also commonly found in products used for cleaning.

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Quick Lab

Using an Indicator

Materials

one quarter cup of frozen blueberries, foam cup, spoon, 4 small plastic cups, 2 dropper pipets, lemon juice, white vinegar, window cleaner, baking soda

Procedure

1. Place the blueberries in the foam cup and mash them with the spoon. Try to get as much juice out of the berries as possible. You will use the juice as an indicator.
2. Use the spoon to remove most of the crushed berries and discard them as directed by your teacher. Leave as much juice behind as possible.
3. Use a dropper pipet to place a few drops of lemon juice (which is acidic) in one of the plastic cups. Use a second pipet to add one drop of your indicator to the lemon juice. Swirl the cup. Record your observations.
4. Rinse out the pipets with water. Repeat Step 3, using vinegar and then window cleaner in place of lemon juice. Record your observations.
5. Place several drops of the indicator in the last plastic cup. Add a small pinch of baking soda to the cup. Swirl the cup. Record your observations.

Analyze and Conclude

1. **Classifying** Use your observations to determine how the color of blueberry juice changes in acids and bases.
2. **Drawing Conclusions** How does the blueberry indicator help you determine whether a material is an acid or a base?
3. **Inferring** Why does the color of the blueberry indicator change less when added to acids than when added to bases?

Color Changes in Indicators Bases turn red litmus paper blue. The litmus paper will change back to red if you drop an acidic solution on it.

Phenolphthalein (fee nol THAY leen) is another example of an acid-base indicator. In a solution containing a base, phenolphthalein is red. In a solution containing an acid, phenolphthalein is colorless.

Some flowers, like the hydrangeas shown in Figure 18, contain natural indicators. The color of the flowers depends on whether the plant is growing in acidic or basic soil. When hydrangeas grow in acidic soil, the flowers are bluish-purple. When hydrangeas grow in basic soil, the flowers are pink. By manipulating the acidity of the soil, gardeners can determine the color of the flowers.

Figure 18 Soil acidity can affect the color of flowers such as hydrangeas.

Reading Checkpoint ***What color does litmus paper turn in a base?***

Facts and Figures

Litmus Paper Litmus paper contains a combination of several organic compounds that come from a species of lichen. Originally litmus was used as a dye. Today, some of these compounds are also used in perfume making and antibiotics.

Quick Lab

Using an Indicator L2

Objective
After completing this activity, students will be able to
- extract an indicator from blueberries and use it to classify substances as acids or bases.

Skills Focus **Observing, Classifying, Drawing Conclusions, Inferring**

Prep Time 15 minutes

Advanced Prep Provide ammonia-based window cleaner because alcohol-based window cleaner may not be basic.

Class Time 15 minutes

Safety Have students observe safety symbols and wear safety goggles and lab aprons.

Teaching Tips
- Have students dispose of crushed berries in the trash.
- Dispose of all waste solutions in the sink with excess water.

Expected Outcome The indicator will stay purple with lemon juice and vinegar. It will turn green with window cleaner and baking soda.

Analyze and Conclude
1. Lemon juice and vinegar contain acids and do not change the color of the indicator. Window cleaner and baking soda contain bases and change the color of the indicator to green.
2. It is purple in an acid and green in a base.
3. Blueberries contain acid. The indicator does not change color in an acid because it is already indicating an acid.
Visual, Logical

For Enrichment L3

Have students use their blueberry indicator on other substances, such as a carbonated beverage, deionized water, and a laundry detergent solution. Ask them if they can conclude that a substance, such as water, is acidic if it does not turn the indicator green. Have them test their inferences using litmus paper.
Visual, Logical

Answer to . . .

Reading Checkpoint *Blue*

Neutralization and Salts

Teacher Demo

Neutralization Reaction L2

Purpose Students observe a neutralization reaction.

Materials 2 lemons, beaker, 0.1-M solution of NaOH, phenolphthalein solution (indicator), syringe, knife

Procedure Tell students that the phenolphthalein solution is an indicator that is pink in the presence of bases. Pour a small amount of the 0.1-M NaOH solution in the beaker. Add a couple of drops of indicator. Have students note the pink color. Explain that you are going to try to turn one of the lemons pink by injecting it with the base and indicator. Use the syringe to inject the NaOH solution into one of the lemons. Wait a few moments and then cut open both lemons.

Safety Use caution when handling the base solution. Sodium hydroxide is corrosive. In case of spills, clean thoroughly with water. Have students wear safety goggles, plastic gloves, and lab aprons should they handle the demo materials. Do not allow students to handle the syringe.

Expected Outcome Both lemons will have their normal color. Explain that a neutralization reaction occurred. The base reacted with the acid in the lemons to produce a salt. You cannot use phenolphthalein to turn a lemon pink unless you add enough base to react with all of the acid in the lemon with some base left over. The amount of base required to neutralize a lemon depends on the amount of juice in the lemon and the amount of acid the juice contains. Pour a small amount of the base (with indicator) solution onto the cut face of one of the lemons to allow students to observe the pink color of the basic solution disappear as the base is neutralized.
Visual

Neutralization and Salts

When people eat fish, they sometimes squeeze lemon juice over the fish. Fish contains bases that can leave a bitter taste. Lemon juice contains acids, such as citric acid. By squeezing lemon juice over the fish, the citric acid reacts with the bases in the fish, and the fish tastes less bitter.

The reaction between an acid and a base is called **neutralization.** During neutralization, the negative ions in an acid combine with the positive ions in a base to produce an ionic compound called a **salt.** At the same time, the hydronium ions from the acid combine with the hydroxide ions from the base to produce water. **The neutralization reaction between an acid and a base produces a salt and water.**

For example, when hydrochloric acid reacts with sodium hydroxide, the following neutralization reaction occurs.

$$\underset{\text{acid}}{(H_3O^+ + Cl^-)} + \underset{\text{base}}{(Na^+ + OH^-)} \longrightarrow \underset{\text{water}}{2HOH} + \underset{\text{salt}}{(Na^+ + Cl^-)}$$

The products of the reaction are a salt made up of sodium and chloride ions, and water. If you let the water in the resulting solution evaporate, the sodium and chloride ions would begin to crystallize out of solution, forming table salt.

Table salt is the most common example of a salt compound. Other common salts are listed in Figure 19. For instance, baking soda, $NaHCO_3$, is produced during the neutralization reaction between sodium hydroxide and carbonic acid, H_2CO_3. The other product is water. The ocean contains many dissolved salts, including chlorides and sulfates of potassium, calcium, magnesium, and sodium. Many of these salts go into solution as seawater washes against rocks.

Figure 19 The common salts listed in the table can all be made by reacting an acid with a base. One of these salts, sodium carbonate, was used to make the glass for the vases shown below. **Inferring** ***Name an acid and a base that could react to form potassium chloride, KCl.***

Common Salts

Name	Formula	Uses
Sodium chloride	NaCl	Food flavoring, preservative
Sodium carbonate	Na_2CO_3	Used to make glass
Potassium chloride	KCl	Used as a salt substitute to reduce dietary intake of sodium
Potassium iodide	KI	Added to table salt to prevent iodine deficiency
Magnesium chloride	$MgCl_2$	De-icer for roads
Calcium carbonate	$CaCO_3$	Chalk, marble floors, and tables
Ammonium nitrate	NH_4NO_3	Fertilizer, cold packs

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Facts and Figures

Differing Definitions The definitions for acids and bases given on the previous pages are similar to those described by Swedish physicist Svante Arrhenius in 1884. Note that acids do not necessarily contain hydronium ions and bases do not necessarily contain hydroxide ions. An alternative way of defining acids and bases was developed independently in 1923 by J. N. Brønsted and T. M. Lowry and is described on p. 245. A Brønsted-Lowry base is a proton acceptor, while a Brønsted-Lowry acid is a proton donor. The distinction is important when describing nonaqueous solutions.

Proton Donors and Acceptors

Recall that hydronium ions (H_3O^+) are produced when acids dissolve in water. When an acid and a base react in water, a proton from the hydronium ion from the acid combines with the hydroxide ion (OH^-) from the base to form water (H_2O). Acids lose, or "donate," protons. Bases "accept" protons, forming water, a neutral molecule. **Acids can be defined as proton donors, and bases can be defined as proton acceptors.** This definition allows you to classify a wider range of substances as acids or bases.

Based on the definitions of acids and bases that you read earlier in this section, water is neither an acid nor a base. However, using the proton-donor or proton-acceptor definition, water can act as either an acid or a base depending on the compound with which it reacts.

Figure 20 shows the ionization of hydrogen chloride and ammonia as they form solutions. In the first reaction, water acts as a base. It accepts a proton from hydrogen chloride and becomes a hydronium ion. In the second reaction, water acts as an acid. It donates a proton to the ammonia, which acts as a base. The resulting solution contains hydroxide ions and ammonium ions, NH_4^+.

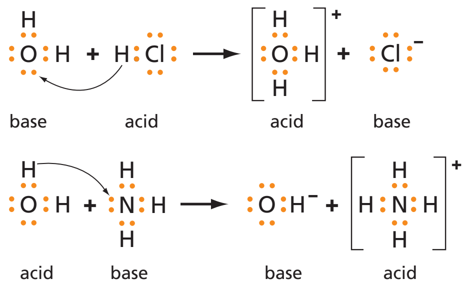

Figure 20 In the first reaction, water acts as a base, accepting a proton from hydrogen chloride. In the second reaction, water acts as an acid, donating a proton to the ammonia. **Applying Concepts** ***What acts as the proton donor in the first reaction?***

Section 8.3 Assessment

Reviewing Concepts

1. List three general properties of acids.
2. List three general properties of bases.
3. What are the two products of a neutralization reaction?
4. What are the proton-donor and proton-acceptor definitions of acids and bases?
5. What ion is present in all common acid solutions?

Critical Thinking

6. **Using Analogies** Commercials for antacids often claim these products neutralize stomach acid. Antacids are bases. Think of an analogy for the way in which antacids neutralize acids.
7. **Applying Concepts** In the following equation, which reactant is a proton donor? Which is a proton acceptor?
   $HNO_3 + H_2O \longrightarrow H_3O^+ + NO_3^-$

Connecting Concepts

Classifying Reactions Compare neutralization with the types of chemical reactions described in Section 7.2. To which type of reaction is neutralization most similar? Explain your choice.

Proton Donors and Acceptors

Use Visuals L1

Figure 20 Have students examine and read the caption for Figure 20. **How many reactions are represented in the figure?** *(2)* **How are atoms represented in this figure?** *(Atoms are represented by their chemical symbol and small, orange dots.)* **What do the small, orange dots represent?** *(Valence electrons)* **What do the positive and negative signs represent?** *(The charge of each ion)* **How can you tell which substance is the proton donor?** *(When that substance loses an H, a proton)* **What happens to a proton donor in this figure after it donates a proton?** *(It becomes a negative ion.)*
Visual

3 ASSESS

Evaluate Understanding L2

Have students write the equation for a neutralization reaction and label each reactant or product as an acid, base, salt, proton donor, or proton acceptor. Then, have them indicate the color each reactant and product would turn red and blue litmus paper.

Reteach L1

Use Figure 20 to summarize the key features of acids, bases, and neutralization reactions.

Connecting Concepts

Neutralization is an example of a double-replacement reaction. During neutralization, an acid and a base exchange positive ions, forming water and a salt.

Interactive Textbook If your class subscribes to the Interactive Textbook, use it to review key concepts in Section 8.3.

Section 8.3 Assessment

1. They taste sour, react with certain metals, and turn blue litmus paper red.
2. They taste bitter, feel slippery, and turn red litmus paper blue.
3. Water and a salt
4. Acids are proton donors, and bases are proton acceptors.
5. Hydronium (H_3O^+)
6. Acceptable answers include saying that it's like a positive number canceling out a negative number of the same value when added: $6+ (-6) = 0$
7. HNO_3 is the proton donor, and H_2O is the proton acceptor.

Answer to . . .

Figure 19 *Potassium hydroxide (KOH) and hydrogen chloride (HCl)*

Figure 20 *Hydrogen chloride*