Section 8.4

1 FOCUS

Objectives

8.4.1 **Define** pH, and **relate** pH to hydronium ion concentration in a solution.

8.4.2 **Distinguish** between strong acids and weak acids, and between strong bases and weak bases.

8.4.3 **Define** buffer, and **describe** how a buffer can be prepared.

8.4.4 **Explain** how electrolytes can be classified.

Reading Focus

Build Vocabulary L2

Word Meanings Ask students to brainstorm examples of product advertising that contain the terms *pH, electrolyte,* or *buffer. (Students may have heard of beauty products described as "pH-balanced," some sports beverages contain electrolytes, and many antacids contain buffers.)* Have students look up the definition of each term and speculate what is meant by the advertisers' claims. *(Answers may include that some deodorants differ in acidity, sports drinks contain ions in solution, and some antacids can be used to resist large changes in pH.)*

Reading Strategy L2

a. Ionizes almost completely when dissolved in water
b. Is a strong electrolyte
c. Dissociates almost completely when dissolved in water

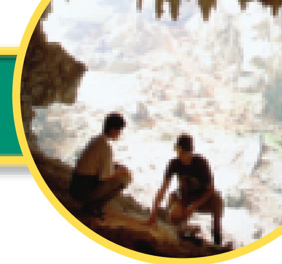
2 INSTRUCT

Build Reading Literacy L1

Identify Main Idea/Details Refer to page **98D** in **Chapter 4**, which provides the guidelines for identifying main idea and details.

Have students read the section and make a list of the main headings on each page. Under each heading, have them identify the main idea of the passage. Have students refer to their lists when answering the questions in the Section 8.4 Assessment.
Verbal

8.4 Strength of Acids and Bases



Reading Focus

Key Concepts

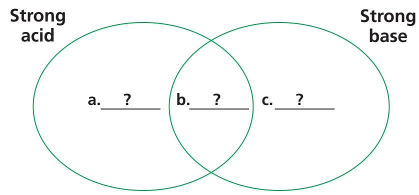
- How is pH used to describe the concentration of acids and bases?
- How do strong acids and bases differ from weak acids and bases?
- Why are strong acids and bases good electrolytes?

Vocabulary

- pH
- buffer
- electrolyte

Reading Strategy

Comparing and Contrasting Copy the Venn diagram below. As you read, complete the diagram by comparing and contrasting strong acids and bases.



On a hot summer day, you might go swimming in a pool with some of your friends. As the water evaporates from your skin, you feel cooler and refreshed.

Have you ever thought about how the water in a swimming pool is made safe for swimming? You may have noticed the odor of chlorine at a backyard swimming pool or at larger municipal pools. Certain compounds of chlorine are dissolved in the water. These compounds prevent the growth of bacteria that could make you sick.

Figure 21 Sodium bicarbonate, or baking soda, is often added to swimming pools to regulate the acidity of the water.

The concentration of hydronium ions in solution must be carefully controlled in a swimming pool. If there are too many or too few hydronium ions, then the right compounds of chlorine will not be present. Figure 21 shows a pool maintenance worker adding sodium bicarbonate, $NaHCO_3$, to the water. Sodium bicarbonate can be used to lower the concentration of hydronium ions in solution.

How can you describe the acidity or basicity of a solution? One way is to determine the concentration of hydronium or hydroxide ions present in solution. Another way is to describe how readily those hydronium ions or hydroxide ions formed.

Section Resources

Print
- ***Reading and Study Workbook With Math Support,*** Section 8.4
- ***Transparencies,*** Section 8.4

Technology
- ***Interactive Textbook,*** Section 8.4
- ***Presentation Pro CD-ROM,*** Section 8.4
- ***Go Online,*** NSTA SciLinks, pH

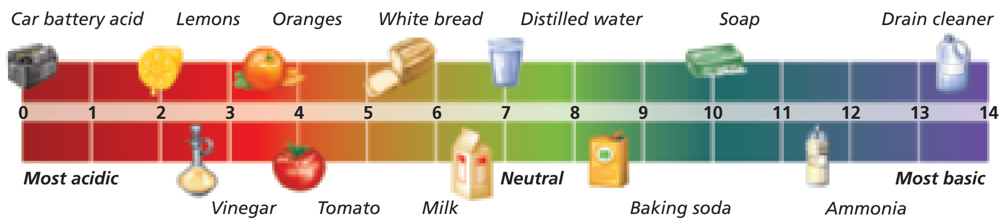


Figure 22 The pH scale can help you classify solutions as acids or bases.
Comparing and Contrasting ***The desired pH range of chlorinated water in swimming pools is 7.2 to 7.8. How does the concentration of hydronium ions in this solution compare to that of lemon juice?***

The pH Scale

Chemists use a number scale from 0 to 14 to describe the concentration of hydronium ions in a solution. It is known as the pH scale. The **pH** of a solution is a measure of its hydronium ion concentration. A pH of 7 indicates a neutral solution. Acids have a pH less than 7. Bases have a pH greater than 7.

Notice in Figure 22 that water falls in the middle of the pH scale. Water ionizes slightly according to the following reaction.

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

The arrow pointing to the left is longer than the arrow pointing to the right to show that water contains more molecules than ions. Water is neutral because it contains small but equal concentrations of hydronium ions and hydroxide ions. At 25°C, the concentration of both H_3O^+ and OH^- in water is 1.0×10^{-7} M. Pure water has a pH of 7.

If you add an acid to water, the concentration of H_3O^+ increases and the concentration of OH^- decreases. Suppose you have a hydrochloric acid solution in which the concentration of H_3O^+ is 0.10 M (or 1.0×10^{-1} M). The solution has a pH of 1. **The lower the pH value, the greater the H_3O^+ ion concentrtion in solution is.**

If you add a base to water, the concentration of OH^- increases and the concentration of H_3O^+ decreases. Consider a sodium hydroxide solution in which the concentration of OH^- is 0.10 M. The concentration of H_3O^+ in this solution is 1.0×10^{-13} M, which corresponds to a pH of 13. **The higher the pH value, the lower the H_3O^+ ion concentration is.**

Reading Checkpoint *What is the pH of pure water?*

Strong Acids and Bases

Recall that some reactions go to completion while others reach equilibrium. When certain acids and bases dissolve in water, the formation of ions from the solute almost goes to completion. Such acids and bases are classified as *strong*.

Go Online NSTA SCILINKS

For: Links on pH
Visit: www.SciLinks.org
Web Code: ccn-1084

The pH Scale

Use Visuals L1

Figure 22 Have students examine Figure 22 of the pH scale. Ask, **In which direction would you find substances that are more acidic?** *(To the left)* **Would a solution with a pH of 11 be an acid or a base?** *(A base)* **What is the pH of ammonia?** *(11.5)* **Compare the pH and acidity of oranges and tomatoes.** *(Oranges have a lower pH than tomatoes and are therefore more acidic.)* **Visual**

Build Math Skills L1

Exponents Many students have a hard time interpreting positive and negative exponents. Be sure that they understand that a value with a large negative exponent is significantly smaller than a value with a small negative exponent. **Logical**

Direct students to the **Math Skills** in the **Skills and Reference Handbook** at the end of the student text for additional help.

Strong Acids and Bases

Integrate Biology L2

Explain that the stomach contains a dilute solution of hydrochloric acid, HCl. Even though the solution is dilute, HCl is a strong acid, which means it ionizes completely in solution. Have students find out how this strong acid aids in digestion. Have them make a poster illustrating the stomach's role in digestion and explain how food is digested by stomach acid. *(Stomach acid works with enzymes to help break down proteins. Contraction of stomach muscles helps to mix the food, acid, and enzymes, turning food into a semiliquid.)* **Visual, Verbal**

Go Online NSTA SCILINKS

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

Answer to . . .

Figure 22 *Concentration of hydronium ions in lemon juice is greater.*

Reading Checkpoint *7*

Customize for English Language Learners

Think-Pair-Share
Have students work in pairs to think of other scales besides pH, and the quantities that they measure. Examples include temperature scales, hardness scales, and the Richter scale. Strengthen discussion skills by having students share their examples with the class. Encourage students to refer to Figure 22 and make comparisons between pH and other scales.

Section 8.4 (continued)

Weak Acids and Bases

Quick Lab

Making a Battery L2

Objective
After completing this activity, students will be able to
- make a battery using a lemon as a source for electrolytes.

Skills Focus **Observing, Predicting**

Prep Time 5 minutes

Advance Prep Use tin strips to cut copper and zinc into 2–5 cm strips. Strip the ends if using insulated wires. File down the rough edges of the metal strips. Wear heavy leather gloves when preparing the strips.

Class Time 10 minutes

Safety Have students observe safety symbols and wear lab aprons.

Teaching Tips
- Have students throw used lemons away.
- Clean used copper and zinc strips and save them for reuse.
- Current is the rate at which charge flows through a wire and is expressed in amps, while voltage is expressed in volts. Potential difference is a measure of the work required to carry positive charge from one point to another and is expressed in volts.

Expected Outcome The battery will probably produce less than 1 volt and a very small current, about 0.0001 amp. The actual voltage and current depend on how juicy the lemon is, how far apart the electrodes are placed, and how deep they go into the fruit.

Analyze and Conclude
1. There is no voltage when using two copper strips. Values between 0.5 V and 1 V are typical when using the copper and zinc strips.
2. A basic solution is also electrolytic and may provide a similar result.
Visual, Kinesthetic

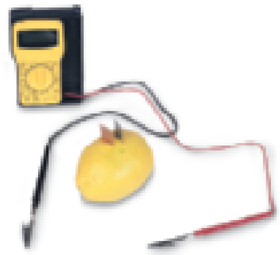
For Enrichment L3

Have students perform this lab with metals to determine which pairs of metals produce the greatest voltages. Then, refer them to a chemistry text to read about electronegativity. (Pairs of metals that are far apart in the electromotive series produce the greatest voltages.)
Kinesthetic

Quick Lab

Making a Battery

Materials
1 large fresh lemon, plastic knife, zinc strip, 2 copper strips, multimeter



Procedure
1. Roll the lemon between your hands until it softens.
2. Use the knife to carefully cut two parallel slits in the lemon about 1 cm apart. Push the copper strips into the slits to a depth of 2 to 3 cm. Don't allow the strips to touch.
3. Attach the copper strips to the terminals of the multimeter. Observe the reading and record it.
4. Replace one of the copper strips with the zinc strip and repeat step 3.

Analyze and Conclude
1. **Observing** What was the reading on the multimeter when you used two copper strips? A copper and a zinc strip?
2. **Predicting** Lemon juice is acidic. Would a basic solution provide a similar result?

Strong Acids When hydrogen chloride dissolves in water, almost all of its molecules ionize. After the reaction, there are about the same number of hydronium ions in solution as there were molecules of HCl to begin with. The products do not reform reactant molecules. HCl is an example of a strong acid. **When strong acids dissolve in water, they ionize almost completely.** Other strong acids include sulfuric acid, H_2SO_4, and nitric acid, HNO_3.

Strong Bases When dissolved in water, sodium hydroxide almost completely dissociates into sodium and hydroxide ions. Sodium hydroxide is an example of a strong base. **Strong bases dissociate almost completely in water.** Other strong bases include calcium hydroxide, $Ca(OH)_2$, and potassium hydroxide, KOH.

Weak Acids and Bases

The citric acid in orange juice and the acetic acid in vinegar are *weak* acids. Toothpaste and shampoo contain *weak* bases. **Weak acids and bases ionize or dissociate only slightly in water.**

Weak Acids A solution of acetic acid, CH_3COOH, and water can be described by the following equation.

$$CH_3COOH + H_2O \rightleftharpoons CH_3COO^- + H_3O^+$$

The equilibrium favors the reactants over the products, so few ions form in solution. A weak acid forms fewer hydronium ions than a strong acid of the same concentration. This also means that a weak acid has a higher pH than a strong acid of the same concentration.

It is important to understand the difference between concentration and strength. Concentration is the amount of solute dissolved in a given amount of solution. Strength refers to the solute's tendency to form ions in water. You cannot assume that a strong acid has a low pH, because its concentration also affects pH. For instance, a dilute solution of HCl (a strong acid) can have a pH of 6. But a concentrated solution of acetic acid (a weak acid) can have a pH of 3.

Weak Bases Ammonia, NH_3, is a colorless gas with a distinctive smell. When it dissolves in water, very little of it ionizes. Equilibrium favors the reactants, so few NH_4^+ and OH^- ions are produced.

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

Buffers Weak acids and bases can be used to make buffers. A **buffer** is a solution that is resistant to large changes in pH. Buffers can be prepared by mixing a weak acid and its salt or a weak base and its salt. Because a buffer can react with both an acid and a base, its pH remains relatively constant.

Facts and Figures

Buffered Aspirin Many drugs contain buffers to offset the effects they might have upon ingestion. For example, acetylsalicylic acid is the ingredient in aspirin medication that relieves pain. Many of the kinds of aspirin available for consumer use are buffered to minimize the acidity of aspirin.

Electrolytes

Figure 23 Drinking sports drinks after exercising can restore the balance of ions in your body.

Sports drinks, like the one shown in Figure 23, taste salty because they contain salts of elements such as sodium, potassium, and calcium. Salts are examples of electrolytes. An **electrolyte** is a substance that ionizes or dissociates into ions when it dissolves in water. The resulting solution can conduct electric current. The electrolytes in sports drinks help restore the balance of ions in your body.

Electrolytes can be classified as strong or weak. **Strong acids and bases are strong electrolytes because they dissociate or ionize almost completely in water.** For example, sodium hydroxide is a strong electrolyte that produces many ions in water. Salts are also strong electrolytes. When potassium chloride dissolves in water, it dissociates into potassium and chloride ions. In contrast, acetic acid is a weak electrolyte because it only partially ionizes.

Batteries and other portable devices that produce electricity also contain electrolytes. Car batteries use lead plates in combination with the electrolyte sulfuric acid to produce electricity. Space shuttles use devices called fuel cells that provide electricity to power all the crafts' devices. Fuel cells use the strong base potassium hydroxide as an electrolyte. Instead of metal electrodes, the fuel cells use oxygen and hydrogen brought from Earth. At the same time that the fuel cells provide electrical energy to power a space shuttle, they also produce water that the crew can use.

Section 8.4 Assessment

Reviewing Concepts

1. How is pH related to the concentration of hydronium ions in solution?
2. What determines the degree to which an acid or base is weak or strong?
3. Are strong acids and bases good electrolytes? Explain why or why not.
4. Why is pure water neutral?
5. What is a buffer?

Critical Thinking

6. **Comparing and Contrasting** Explain how the concentration of an acid differs from the strength of an acid.
7. **Relating Cause and Effect** Suppose you add another liter of water to 1 liter of a 1-molar solution of hydrochloric acid. What happens to the number of hydronium ions in solution? What happens to the concentration?

Writing in Science

Explanatory Paragraph Explain the concept of a pH scale, and compare the pH values of acids, bases, and pure water. (*Hint:* Use examples from Figure 22 to help you describe the range of the pH scale.)

Electrolytes

Address Misconceptions L2

Many students think that pure water is a good conductor of electricity. Though pure water has some ions due to self-ionization, the number of ions in pure water is not great enough to carry an electric current. Explain that practically all water obtained from traditional sources contains electrolytes. Thus, it is very difficult to find water that will not conduct electricity. Even deionized water samples may have some dissolved ions depending on the effectiveness of the deionizer or the method of storage.
Verbal

3 ASSESS

Evaluate Understanding L2

Encourage students to make a note card for each of the Key Concepts questions listed on p. 246. Then, ask them to make a note card that answers each question using one of the boldfaced key points in this section. Have them make three more sets of note cards using the vocabulary terms and their definitions. Encourage students to review the information on their cards.

Reteach L1

As a class, make a chart that lists what strong acids, strong bases, and strong electrolytes have in common. Do the same for weak acids, weak bases, and weak electrolytes.

Writing in Science

Acceptable answers include explaining that a pH scale allows you to describe how acidic or basic a solution is. Solutions with a pH lower than 7, such as vinegar, are acidic. Solutions with a pH higher than 7, such as household ammonia, are basic. Solutions with a pH of 7 (the same as pure water) are neutral.

Interactive Textbook If your class subscribes to the Interactive Textbook, use it to review key concepts in Section 8.4.

Section 8.4 Assessment

1. Solutions with a low pH have a high concentration of hydronium ions in solution and are acidic. Solutions with a high pH have a low concentration of hydronium ions in solution and are basic.
2. The degree to which an acid or base dissociates or ionizes when dissolved in water determines whether it is weak or strong.
3. Strong acids and bases are strong electrolytes because they dissociate or ionize almost completely when dissolved in water.
4. Pure water is neutral because it contains equal concentrations of hydronium and hydroxide ions.
5. A buffer is a solution that is resistant to large changes in pH.
6. The concentration of an acid is the amount of solute dissolved in a given amount of solution. The strength of an acid refers to the solute's tendency to form ions in water.
7. The number of hydronium ions stays the same. The concentration decreases because there are fewer ions per liter.