4 Acids and Bases in Solution

Reading Preview

Key Concepts

- What kinds of ions do acids and bases form in water?
- What does pH tell you about a solution?
- What happens in a neutralization reaction?

Key Terms

- hydrogen ion (H^+)
- hydroxide ion (OH^-)
- pH scale
- neutralization
- salt

Target Reading Skill

Previewing Visuals When you preview, you look ahead at the material to be read. Preview Figure 21. Then write two questions that you have about the diagram in a graphic organizer like the one below. As you read, answer your questions.

Neutralization

Q. What is a neutral solution?
A.
Q.

Go Online
PHSchool.com

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

Lab zone Discover Activity

What Can Cabbage Juice Tell You?

1. Using a dropper, put 5 drops of red cabbage juice into each of three separate plastic cups.
2. Add 10 drops of lemon juice (an acid) to one cup. Add 10 drops of ammonia cleaner (a base) to another. Keep the third cup for comparison. Record the colors you see.
3. Now add ammonia, 1 drop at a time, to the cup containing lemon juice. Keep adding ammonia until the color no longer changes. Record all color changes you see.
4. Add lemon juice a drop at a time to the ammonia until the color no longer changes. Record the changes you see.

Think It Over

Forming Operational Definitions Based on your observations, what could you add to your definitions of acids and bases?

A chemist pours hydrochloric acid into a beaker. Then she adds sodium hydroxide to the acid. The mixture looks the same, but the beaker becomes warm. If she tested the solution with litmus paper, what color would the paper turn? Would you be surprised if it did not change color at all? If exactly the right amounts and concentrations of the acid and the base were mixed, the beaker would hold nothing but salt water!

Acids and Bases in Solution

How can two corrosive chemicals, an acid and a base, produce something harmless to the touch? To answer this question, you must know what happens to acids and bases in solution.

Acids What do acids have in common? Notice that each formula in the list of acids in Figure 17 begins with hydrogen. The acids you will learn about in this section produce one or more hydrogen ions and a negative ion in solution with water. A **hydrogen ion** (H^+) is an atom of hydrogen that has lost its electron. The negative ion may be a nonmetal or a polyatomic ion. Hydrogen ions are the key to the reaction of acids.

Important Acids and Bases			
Acid	**Formula**	**Base**	**Formula**
Hydrochloric acid	HCl	Sodium hydroxide	$NaOH$
Nitric acid	HNO_3	Potassium hydroxide	KOH
Sulfuric acid	H_2SO_4	Calcium hydroxide	$Ca(OH)_2$
Carbonic acid	H_2CO_3	Aluminum hydroxide	$Al(OH)_3$
Acetic acid	$HC_2H_3O_2$	Ammonia	NH_3
Phosphoric acid	H_3PO_4	Calcium oxide	CaO

FIGURE 17
The table lists some commonly encountered acids and bases.
Making Generalizations *What do all of the acid formulas in the table have in common?*

Acids in water solution separate into hydrogen ions (H^+) and negative ions. In the case of hydrochloric acid, for example, hydrogen ions and chloride ions form:

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

Now you can add to the definition of acids you learned in Section 3. **An acid is any substance that produces hydrogen ions (H^+) in water.** These hydrogen ions cause the properties of acids. For instance, when you add certain metals to an acid, hydrogen ions interact with the metal atoms. One product of the reaction is hydrogen gas (H_2). Hydrogen ions also react with blue litmus paper, turning it red. That's why every acid gives the same litmus test result.

Bases The formulas of bases give you clues to what ions they have in common. You can see in the table in Figure 17 that many bases are made of positive ions combined with hydroxide ions. The **hydroxide ion** (OH^-) is a negative ion, made of oxygen and hydrogen. When bases dissolve in water, the positive ions and hydroxide ions separate. Look, for example, at what happens to sodium hydroxide:

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

Not every base contains hydroxide ions. For example, the gas ammonia (NH_3) does not. But in solution, ammonia is a base that reacts with water to form hydroxide ions.

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

Notice that in both reactions, there are negative hydroxide ions. **A base is any substance that produces hydroxide ions (OH^-) in water.** Hydroxide ions are responsible for the bitter taste and slippery feel of bases, and turn red litmus paper blue.

FIGURE 18
Comparing Bases
Many bases are made of positive ions combined with hydroxide ions.

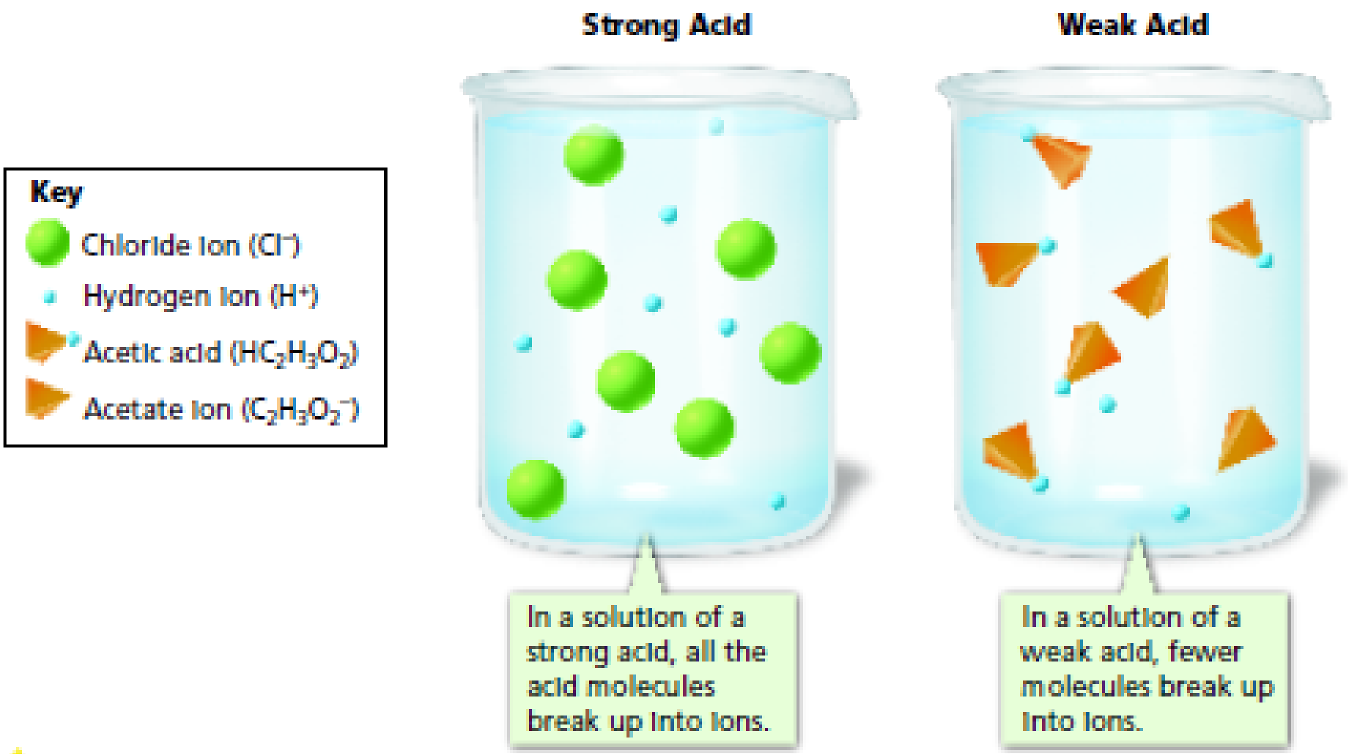


Figure 19
Acids in Solution
Strong acids and weak acids act differently in water. Hydrocloric acid (left) is a strong acid. Acetic acid (right) is a weak acid.

Lab zone Try This Activity

pHone Home

1. Select materials such as fruit juices, soda water, coffee, tea, and antacids. If the sample is solid, dissolve some in a cup of water. Use a liquid as is.
2. Predict which materials are most acidic or most basic.
3. Using a plastic dropper, transfer a drop of one sample onto a fresh strip of pH test paper.
4. Compare the color of the strip to the pH test scale on the package.
5. Repeat for all your samples, rinsing the dropper between tests.

Interpreting Data List the samples from lowest to highest pH. Did any results surprise you?

Strength of Acids and Bases

Acids and bases may be strong or weak. Strength refers to how well an acid or a base produces ions in water. As shown in Figure 19, the molecules of a strong acid react to form ions in solution. With a weak acid, very few molecules form ions. At the same concentration, a strong acid produces more hydrogen ions (H^+) than a weak acid does. Examples of strong acids include hydrochloric acid, sulfuric acid, and nitric acid. Most other acids, such as acetic acid, are weak acids.

Strong bases react in a water solution in a similar way to strong acids. A strong base produces more hydroxide (OH^-) ions than does an equal concentration of a weak base. Ammonia is a weak base. Lye, or sodium hydroxide, is a strong base.

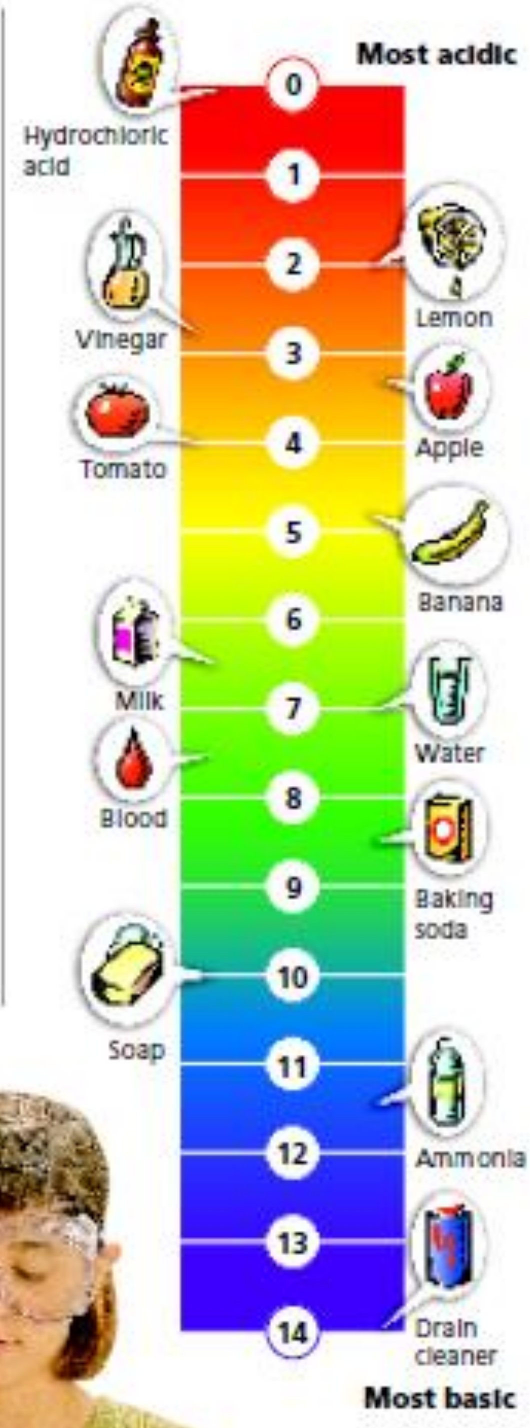
Measuring pH Knowing the concentration of hydrogen ions is the key to knowing how acidic or basic a solution is. To describe the concentration of ions, chemists use a numeric scale called pH. The **pH scale** is a range of values from 0 to 14. It expresses the concentration of hydrogen ions in a solution.

Figure 20 shows where some familiar substances fit on the pH scale. Notice that the most acidic substances are at the low end of the scale. The most basic substances are at the high end of the scale. You need to remember two important points about pH. **A low pH tells you that the concentration of hydrogen ions is high. In contrast, a high pH tells you that the concentration of hydrogen ions is low.** If you keep these ideas in mind, you can make sense of how the scale works.

You can find the pH of a solution by using indicators. The student in Figure 20 is using indicator paper that turns a different color for each pH value. Matching the color of the paper with the colors on the test scale tells how acidic or basic the solution is. A pH lower than 7 is acidic. A pH higher than 7 is basic. If the pH is 7, the solution is neutral. That means it's neither an acid nor a base. Pure water has a pH of 7.

Using Acids and Bases Safely Strength determines, in part, how safe acids and bases are to use. People often say that a solution is weak when they mean it is dilute. This could be a dangerous mistake! Even a dilute solution of hydrochloric acid can eat a hole in your clothing. An equal concentration of acetic acid, however, will not. In order to handle acids and bases safely, you need to know both their pH and their concentration.

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



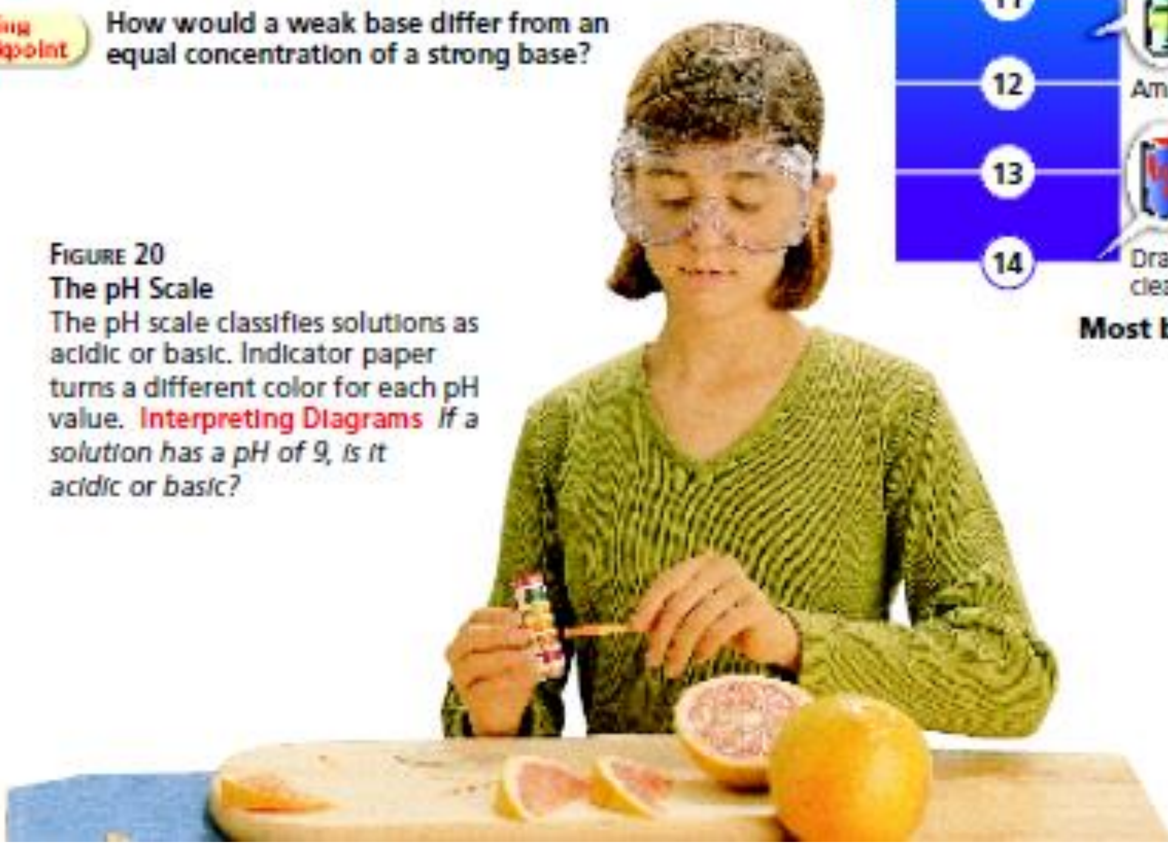


FIGURE 20
The pH Scale
The pH scale classifies solutions as acidic or basic. Indicator paper turns a different color for each pH value. **Interpreting Diagrams** *If a solution has a pH of 9, is it acidic or basic?*

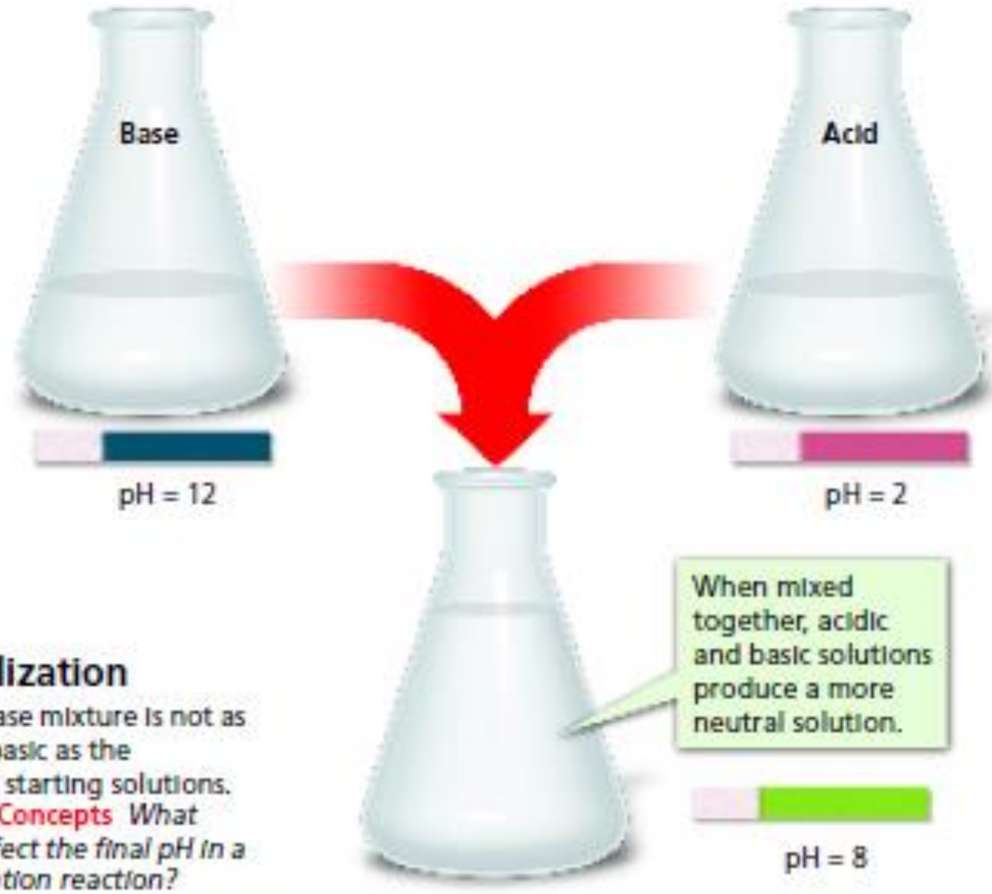


FIGURE 21
Neutralization
An acid-base mixture is not as acidic or basic as the individual starting solutions.
Applying Concepts *What factors affect the final pH in a neutralization reaction?*

Acid-Base Reactions

The story at the start of this section describes a chemist who mixed hydrochloric acid with sodium hydroxide. She got a solution of table salt (sodium chloride) and water.

$$HCl + NaOH \longrightarrow H_2O + Na^+ + Cl^-$$

If you tested the pH of the mixture, it would be close to 7, or neutral. In fact, a reaction between an acid and a base is called **neutralization** (noo truh lih ZAY shun).

Reactants After neutralization, an acid-base mixture is not as acidic or basic as the individual starting solutions were. Sometimes an acid-base reaction even results in a neutral solution. The final pH depends on such factors as the volumes, concentrations, and identities of the reactants. For example, some acids and bases react to form products that are not neutral. Also, common sense tells you that if only a small amount of strong base is reacted with a much larger amount of strong acid, the solution will remain acidic.

Products "Salt" may be the familiar name of the stuff you sprinkle on food. But to a chemist, the word refers to a specific group of compounds. A **salt** is any ionic compound that can be made from the neutralization of an acid with a base. A salt is made from the positive ion of a base and the negative ion of an acid.

Look at the equation for the reaction of nitric acid with potassium hydroxide:

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

One product of the reaction is water. The other product is potassium nitrate (KNO_3), a salt. **In a neutralization reaction, an acid reacts with a base to produce a salt and water.** Potassium nitrate is written in the equation as separate K^+ and NO_3^- ions because it is soluble in water. Some salts, such as potassium nitrate, are soluble. Others form precipitates because they are insoluble. Look at the table in Figure 22 to see a list of some common salts and their formulas.

Reading Checkpoint What is a salt?

Common Salts

Salt	Uses
Sodium chloride $NaCl$	Food flavoring; food preservative
Potassium iodide KI	Additive in "iodized" salt that prevents iodine deficiency
Calcium chloride $CaCl_2$	De-icer for roads and walkways
Potassium chloride KCl	Salt substitute in foods
Calcium carbonate $CaCO_3$	Found in limestone and seashells
Ammonium nitrate NH_4NO_3	Fertilizer; active ingredient in cold packs

FIGURE 22
Each salt listed in this table can be formed by the reaction between an acid and a base.

Section 4 Assessment

Target Reading Skill Previewing Visuals Refer to your questions and answers about Figure 21 to help you answer Question 3 below.

Reviewing Key Concepts

1. a. Identifying Which ion is found in the acids described in this section?
   b. Describing What kinds of ions do acids and bases form in water?
   c. Predicting What ions will the acid HNO_3 form when dissolved in water?
2. a. Reviewing What does a substance's pH tell you?
   b. Comparing and Contrasting If a solution has a pH of 6, would the solution contain more or fewer hydrogen ions (H^+) than an equal volume of solution with a pH of 3?
   c. Making Generalizations Would a dilute solution of HCl also be weak? Explain.
3. a. Reviewing What are the reactants of a neutralization reaction?
   b. Explaining What happens in a neutralization reaction?
   c. Problem Solving What acid reacts with KOH to produce the salt KCl?

Lab zone **At-Home Activity**

pH Lineup With a family member, search your house and refrigerator for the items found on the pH scale shown in Figure 20. Line up what you are able to find in order of increasing pH. Then ask your family member to guess why you ordered the substances in this way. Use the lineup to explain what pH means and how it is measured.