Key Terms
acid
binary acid
oxoacid
base

6.1 Identifying Acids and Bases

In the previous chapters of this unit, you learned about compounds and different types of chemical reactions that they can undergo. In this chapter, two particular types of compounds—acids and bases—and the chemical reactions they undergo are discussed. As you will see, this includes a type of double displacement reaction that occurs between acids and bases.

Many of the substances that you encounter every day can be classified as acids or bases. Have you ever taken a bite of a grapefruit or other citrus fruit, like the lemon shown in **Figure 6.1**, and felt an immediate reaction? Perhaps your lips puckered and your cheeks pulled inward, or your eyes watered. This type of reaction is due to the presence of edible acids. The word *acid* comes from the Latin word *acidus*, which means "sour." In the case of citrus fruits, citric acid causes the sour taste that you are familiar with. Acids have been used for thousands of years. Vinegar is an acidic solution that is common to many household products. It was discovered centuries ago, during the fermentation of fruit juices to make wine.

One of the earliest known uses of bases is in making soaps. Nearly 5000 years ago, Babylonians made soap using chemicals in wood ash. Today, many modern household cleaning products are bases. Edible bases, which have a bitter taste, include baking soda and quinine in tonic water. Nevertheless, while some acids and bases are safe to eat, others are deadly and highly corrosive. Therefore, learning to identify acids and bases and how they react with each other is especially important.

Figure 6.1 The sour taste associated with lemons is due to a naturally occurring acid called citric acid.

Acids

acid a compound that produces hydrogen ions, $H^+(aq)$, when dissolved in water

An **acid** is often defined as a compound that produces hydrogen ions, $H^+(aq)$, when it dissolves in water. In future courses, you will expand on this definition as you learn additional ways to describe acids. Although some acids are safe to eat, such as citric acid and acetic acid (in vinegar), many other acids are not. Many acids are corrosive and will react with metals, so even though a sour taste is one property of acids, you should never taste an unknown chemical to try to identify it.

Forming Hydrogen Ions in Water

Aqueous solutions of acids conduct electric current because of the ions present in the solution. When an acid dissolves in water, it reacts with the water to form ions, in a process called *ionization*. For example, when hydrogen chloride gas is bubbled through and dissolved in water, as shown in **Figure 6.2**, it reacts with water to form ions, and then the hydrogen ions and chloride ions separate in solution.

$$HCl(aq) \rightarrow H^+(aq) + Cl^-(aq)$$

The chemistry of acids is a process that is carried out by numerous naturally occurring chemicals. **Figure 6.3**, on the opposite page, discusses just a few examples of the acids that can be found in nature and the effect that some of these acids can have.

Study Toolkit

Using Graphic Organizers
After reading this page, draw a graphic organizer like the one on page 218. This will help you to remember this information about acids.

Figure 6.2 Hydrochloric acid, HCl(aq), forms when hydrogen chloride gas, HCl(g), is added to water. The resulting solution contains hydrogen ions and chloride ions.

NATIONAL GEOGRAPHIC

VISUALIZING ACIDS IN NATURE

Figure 6.3

From giant limestone structures to delicate flower petals, acids are at work in nature. All of the animals, plants, and rock formations you see here either produce their own acids or are affected by acids in the environment. In addition, many of the foods you eat are acidic, including lemons, peaches, and tomatoes.

◀ **WHIP SCORPION** The whip scorpion is also known as the vinegaroon because it smells like vinegar. In self-defence, the whip scorpion sprays a mist of acetic acid from glands near the rear of its abdomen. Acetic acid is the active ingredient of vinegar. The whip scorpion, which has no venom, is sometimes kept as a pet.

▲ **LIMESTONE CAVES** Carbon dioxide in the air dissolves in rainwater, forming carbonic acid. Therefore, rainwater is naturally acidic. Acidic water reacts with limestone, very slowly dissolving it. Over a long time, this process can carve large caverns in regions that have thick layers of limestone. In the caverns, some of the dissolved limestone can be deposited as solid rock again, forming twisted spires and flowing draperies of stone.

▲ **HYDRANGEA FLOWERS** Acids in soil determine whether some types of hydrangeas produce blue or pink flowers. In acidic soil, the plants produce blue flowers. In soils that are less acidic, the plants produce pink flowers.

▲ **ANT AND NETTLE STINGS** When you are bitten by an ant or brush against the tiny hairs on a stinging nettle plant, you feel a stinging pain that comes in large part from formic acid. The acid dissolves the ends of the nerves in your skin, causing pain.

Naming Acids

When naming acids, there are specific steps to follow according to the type of acid that is being named.

Naming Binary Acids

binary acid an acid composed of hydrogen and a non-metal

Binary acids are composed of two elements—hydrogen and a non-metal. For example, as just discussed, when the gas hydrogen chloride is dissolved in water, a binary acid, HCl(aq), is formed. **Table 6.1** lists chemical formulas, names, and uses of some binary acids. In addition to the names based on guidelines from the International Union of Pure and Applied Chemistry (IUPAC), the classical names for the acids are also provided. Since this classical system is still widely used, it is important to recognize these more conventional names. To name a binary acid according to the classical method,

1. Write the root of the non-metal name.
2. Add the prefix *hydro-* to the root name.
3. Add the ending *-ic acid* to the root name.

Table 6.1 Examples of Binary Acids

Chemical Formula in Solution	Classical Acid Name	IUPAC Name	Uses
HF(aq)	hydrofluoric acid	aqueous hydrogen fluoride	• manufacturing aluminum and uranium • etching glass
HCl(aq)	hydrochloric acid	aqueous hydrogen chloride	• producing plastic • processing metals
HBr(aq)	hydrobromic acid	aqueous hydrogen bromide	• extracting metal ore
HI(aq)	hydroiodic acid	aqueous hydrogen iodide	• taking part in chemical reactions to make other compounds

An application of acids in art is the production of etched glass, shown in **Figure 6.4**. This etching is the result of the highly corrosive property of hydrofluoric acid, HF(aq). The acid is so corrosive that it "eats away at" the glass.

Figure 6.4 Hydrofluoric acid, HF(aq), is used to etch glass. Therefore, hydrofluoric acid cannot be stored in glass containers.

Naming Oxoacids

Oxoacids are composed of hydrogen, oxygen, and another element. For example, an acid can be formed with hydrogen and a polyatomic ion that contains oxygen. Examples of some common oxoacids are provided in **Table 6.2**. To name an oxoacid according to the classical method,

oxoacid an acid composed of hydrogen, oxygen, and another element

1. Write the name of the anion, without the *-ate* or *-ite* ending.
2. If the anion name ended in *-ate,* replace it with *-ic* at the end of the name
3. If the anion name ended in *-ite,* replace it with *-ous* at the end of the name
4. Add the word *acid*

Notice that the acid names for the compounds that are composed of sulfur use *sulfur-* as the root of the name rather than just *sulf-*. Acids that are composed of phosphorus are named in a similar way and use *phosphor-* as the root rather than *phosph-*. The extra syllable helps in the pronunciation of these names.

Table 6.2 Names of Acids That Contain Polyatomic Ions

Chemical Formula in Solution	Classical Acid Name	IUPAC Name	Uses
$H_2SO_4(aq)$	sulfuric acid	aqueous hydrogen sulfate	• in most car batteries • component of acid precipitation
$H_2SO_3(aq)$	sulfurous acid	aqueous hydrogen sulfite	• disinfecting and bleaching
$HNO_3(aq)$	nitric acid	aqueous hydrogen nitrate	• producing explosives and fertilizers
$H_3PO_4(aq)$	phosphoric acid	aqueous hydrogen phosphate	• making fertilizers, soaps, and detergents
$HClO_3(aq)$	chloric acid	aqueous hydrogen chlorate	• producing explosives and matches
$H_2CO_3(aq)$	carbonic acid	aqueous hydrogen carbonate	• occurs naturally in water • in carbonated drinks

Study Toolkit

Word Parts Look at the names of the acids in **Table 6.2**. Identify the word parts in each name. These indicate the ions that the acids are composed of. Knowing how to do this will help you to easily identify an acid.

Learning Check

1. What are three properties of acids?
2. What are two common uses of acids? Refer to **Tables 6.1** and **6.2**.
3. Write the name for each of the following acids.
   - **a.** HCl(aq)
   - **b.** HF(aq)
   - **c.** $H_2SO_4(aq)$
   - **d.** $H_3PO_4(aq)$
4. Name two products you use or foods you eat that contain acidic substances.

Writing Chemical Formulas for Acids

To write the chemical formula for an acid, first determine which anion to use in the formula. The periodic table is helpful for determining the symbol and charge for anions in binary acids, and **Table 4.7** on page 148 lists the chemical formulas and charges for polyatomic ions in other acids. Once you know what the anion is, combine it with enough hydrogen ions, H^+, so that the overall charge of the compound is zero.

GRASP

Go to **Science Skills Toolkit 11** to learn about an alternative problem solving method.

Sample Problem: Writing Chemical Formulas for Acids

Problem

What is the chemical formula for carbonic acid?

Solution

The problem asks you to determine the chemical formula for an acid.

Step 1: Determine if it is a binary acid or an acid containing a polyatomic ion.

- The name ends in *-ic acid* and does not begin with *hydro-*. This indicates that the acid is composed of a polyatomic ion that ends in *-ate*.

Step 2: Identify the chemical formula for the polyatomic ion, using **Table 4.7** on page 148.

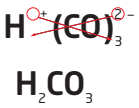
- The formula for the carbonate ion is CO_3^{2-}.

Step 3: Determine how many H^+ ions are required so that the net charge of the acid is zero.

- Because each hydrogen ion has a 1+ charge, two hydrogen ions are needed to cancel the charge on the carbonate ion. The cross-over method for determining the chemical formula is shown in the margin.

The chemical formula for carbonic acid is H_2CO_3.

Cross-Over Method



Check Your Solution

The name of the acid indicates that it contains a polyatomic ion, which is the carbonate ion. Since the carbonate ion has a charge of 2–, two hydrogen ions, H^+, make the overall charge of the compound zero.

Practice Problems

1. Write the chemical formula for hydrobromic acid. Then write the name and formula for the anion that forms.
2. Determine the chemical formulas for the following acids.
   - **a.** hydrochloric acid
   - **b.** nitric acid
   - **c.** hydrofluoric acid
   - **d.** sulfuric acid

Activity 6-2

Chemical Card Games

How well do you remember the names and chemical formulas of common acids? Play with other students to improve your knowledge. The objective is to match an ion formula to an acid name, or an ion name to an acid formula.

Materials

- set of chemical cards

Procedure

1. Play in groups of two to four students. One student should shuffle the chemical cards and deal four cards to each player. The rest of the deck is placed in the centre of the group.
2. Each player examines his or her cards and places any matching pairs, (for example, the formula NO_3^- and the name of the related acid) face-up on the table.
3. Player 1 draws a card from either the deck or a player's hand. If the player has a match, the matching pair is placed on the table. Play then passes to the next person. When all of the cards have been played, the player with the most matches wins.

Questions

1. Did you find that certain acid names or chemical formulas were easier to recognize than others? If so, explain why you think this occurred.
2. Determine a practical use for each acid that you identified.

Bases

Many **bases** are compounds that contain hydroxide ions, OH^-. Common household examples of bases include soap, baking soda, and remedies such as antacids, shown in **Figure 6.5**.

base a compound that forms hydroxide ions, $OH^-(aq)$, when dissolved in water

Although some bases are safe to consume or be in contact with, many bases are not. Some people mistakenly think that acids are dangerous and bases are not. This is false. Both acids and bases can cause severe chemical burns. So, even though a bitter taste and a slippery feel are properties of bases, you should *never* taste or touch an unknown chemical to try to identify it.

Figure 6.5 Many common household products contain bases.

Forming Hydroxide Ions in Water

Aqueous solutions of bases conduct electric current because of the ions in solution. When a base dissolves in water, the ions separate from one another and hydroxide ions are released into the water in a process called *dissociation*. For example, when sodium hydroxide dissolves in water, the ions separate in solution according to the chemical equation

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

Naming Bases

Go to **scienceontario** to find out more

Since many bases are ionic compounds composed of metal ions and hydroxide ions, their names and chemical formulas are written following the same rules you learned for ionic compounds. Some bases also have a common name often found on consumer products. **Table 6.3** lists the names, chemical formulas, and uses for several common bases.

Table 6.3 Some Common Bases

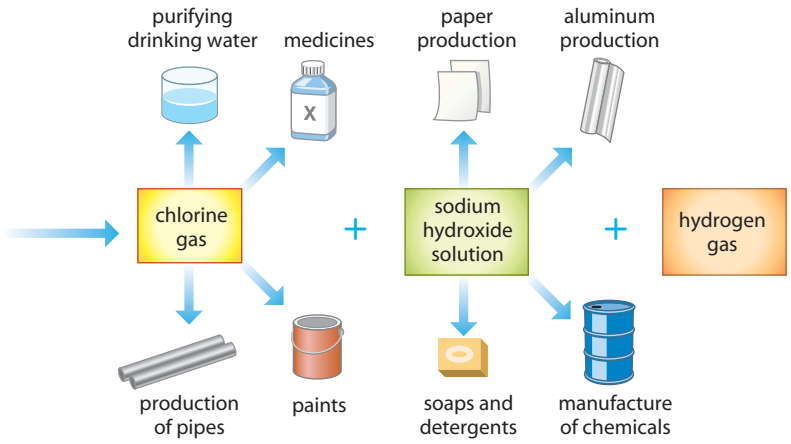
Chemical Formula	Chemical Name	Common Name	Uses
NaOH	sodium hydroxide	lye, caustic soda	• in drain and oven cleaners • used to make paper, glass, and soap
$Mg(OH)_2$	magnesium hydroxide	Milk of Magnesia®	• in laxatives and antacids
$Ca(OH)_2(aq)$	calcium hydroxide	lime water	• for soil and water treatment

Sodium Hydroxide in Industry

Sodium hydroxide is one of the most important chemicals in industry. The majority of sodium hydroxide is mass-produced by a method called the chlor-alkali process. The name of this process is based on the fact that sodium hydroxide is produced simultaneously with chlorine gas—another very important chemical in industry. The chlor-alkali process is composed of multiple reactions and involves the electrolysis of aqueous sodium chloride. The reactions can be summarized in the chemical equation in **Figure 6.6**.

Figure 6.6 Sodium hydroxide is mass-produced for industry by the chlor-alkali process. This procedure involves the electrolysis of aqueous sodium chloride and also produces chlorine gas, with hydrogen gas as a by-product.

$$2NaCl(aq) + 2H_2O(\ell) \rightarrow 2NaOH(aq) + Cl_2(g) + H_2(g)$$



Writing Chemical Formulas for Bases

The principles for writing the chemical formula for a base are the same as those used for writing the chemical formula for an acid. To write the chemical formula for a base, you must make sure to include enough hydroxide ions in the formula so that the total charge of the compound is zero. Remember that the charge of the hydroxide ion is 1–, and the charge of the metal ions can be determined from the periodic table.

Sample Problem: Writing Chemical Formulas for Bases

Problem

What is the chemical formula for aqueous potassium hydroxide?

Solution

The problem asks you to determine the chemical formula for a base.

Step 1: Identify the cation and anion for the base.

- The name indicates that the anion is a hydroxide ion (OH^-) and the metal cation is potassium.

Step 2: Determine the ion charge of the cation.

- According to the periodic table, potassium has an ion charge of 1+ (K^+).

Step 3: Determine the correct subscripts for the chemical formula.

- For the compound to have a net charge of zero, there must be one hydroxide ion in the formula for each potassium cation. The cross-over method for determining the chemical formula is shown in the margin.

Therefore, the formula for aqueous potassium hydroxide is KOH(aq).

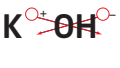
Check Your Solution

The name indicates that the compound is a base since it contains the word *hydroxide*. The name also indicates that the metal ion is potassium. Since the ion charge for potassium is 1+ and the charge for the hydroxide ion is 1–, addition of the charges in the formula KOH results in a net charge of zero.

GRASP

Go to **Science Skills Toolkit 11** to learn about an alternative problem solving method.

Cross-Over Method



KOH

Practice Problems

1. Write the chemical formula for an aqueous solution of sodium hydroxide. Then write the name and formula for the metal cation.
2. Determine the chemical formulas for the following bases (assume all are solids).
   - **a.** calcium hydroxide
   - **b.** aluminum hydroxide
   - **c.** beryllium hydroxide
   - **d.** lithium hydroxide
   - **e.** manganese(II) hydroxide
   - **f.** nickel(II) hydroxide

Sense of scale

Each year, over 65 million tonnes of sodium hydroxide are produced worldwide. Over 50 percent of that is consumed by China and the European Union. Canada consumes about 3 percent of the world's supply of sodium hydroxide.

Section 6.1 Review

Section Summary

- Acids are compounds that have a sour taste. When dissolved in water, they produce hydrogen ions, $H^+(aq)$.
- Binary acids are composed of hydrogen and a non-metal. The name of a binary acid is written using the prefix *hydro-*, the root of the non-metal name, and the ending *-ic acid*.
- Oxoacids that form between hydrogen and polyatomic ions are named by replacing *-ate* with *-ic acid* and *-ite* with *-ous acid*.
- Bases are compounds that have a bitter taste. Many bases are ionic compounds that separate into metal ions and hydroxide ions, $OH^-(aq)$, when dissolved in water.
- Since bases are ionic compounds, their names and chemical formulas are written following the same rules that are used for ionic compounds.

Review Questions

K/U **1.** Describe the ions that form when an acid is dissolved in water.

C **2.** Make a table that shows how the endings of acid names relate to the endings of the names of ions. Include an example of each.

A **3.** What type of chemical in the grapefruit on the right provides it with its sour taste? Explain.

K/U **4.** What are two properties of bases?

K/U **5.** Write the name for each of the following.

a. $Ca(OH)_2(aq)$ **c.** $HF(aq)$

b. $H_3PO_3(aq)$ **d.** $KOH(s)$

K/U **6.** Write the chemical formula for each of the following.

a. phosphoric acid **c.** magnesium hydroxide

b. hydrobromic acid **d.** aluminum hydroxide

T/I **7.** Complete the following chemical equations to illustrate the ions in solution, and identify the compound as an acid or base.

a. $HClO_3(aq) \rightarrow$

b. $KOH(aq) \rightarrow$

T/I **8.** You have been asked to organize the following aqueous solutions: HCl, NaOH, H_2SO_4, $Ca(OH)_2$, LiOH, and $HClO_3$. How would you group them? On what are you basing your decision?