5 Acids and bases are important to our health, industries, and environment.

In order to properly maintain a swimming pool, you need to understand acids and bases.

Skills You Will Use

In this chapter, you will:

- use appropriate terminology related to chemical reactions
- plan and conduct an investigation to classify some common substances as acidic, basic, or neutral

Concepts You Will Learn

In this chapter, you will:

- analyze, on the basis of research, various safety and environmental issues associated with chemical reactions and their reactants and/or products
- analyze how an understanding of the properties of chemical substances and their reactions can be applied to solve environmental challenges
- describe the process of acid-base neutralization
- describe how the pH scale is used to classify solutions as acidic, basic, or neutral
- identify acids, using the periodic table and a list of the most common polyatomic ions, and write their formulas

Why It Is Important

With the exception of pure water, almost every liquid you encounter in daily life is an acid or a base. Acids play important roles in our bodies, and many foods are acidic. Both acids and bases are used in industrial processes. Since acids and bases can also cause harm to living things and the environment, it is important to know how to use them safely.

Before Reading

Thinking Literacy

Monitoring Comprehension

Good readers constantly monitor their understanding of what they are reading. They note areas of difficulty and know ways to fix up meaning so that they can continue to read without getting frustrated. Preview this chapter, and then predict topics you think you will understand and topics where you may have to use fix-up strategies. List some ways you already know to fix up meaning.

Key Terms

• acid • acid-base indicator • base • neutral
• neutralization • pH • pH scale

5.1 Acids and Bases

Here is a summary of what you will learn in this section:

- The pH scale is used to classify aqueous solutions as acidic, basic, or neutral.
- Acids and bases react with pH indicators.
- Acids have a pH less than 7.
- Bases have a pH greater than 7.
- A neutral solution has a pH of 7.

Figure 5.1 During exercise and in its day-to-day functioning, your body gets much of the energy it needs from the breakdown of glucose. The process by which glucose is broken down produces carbon dioxide gas, which dissolves in your blood and forms an acid.

Acids, Bases, and Your Body

Acids and bases are compounds with particular properties. Members of these two classes of compounds play many different roles in the functioning of your body.

Some acids are harmful to your body. For example, the cells in your body are fuelled by the breakdown of molecules of glucose (Figure 5.1). The products of this process usually include carbon dioxide gas ($CO_2(g)$). This carbon dioxide gas dissolves in the water in your blood and forms carbonic acid ($H_2CO_3(aq)$). A build-up of this acid in the blood would be harmful, so your body converts the carbonic acid to a hydrogen ion (H^+) and a hydrogen carbonate ion (HCO_3^-). These ions are then transported in the blood without harming the body.

Other acids are essential to your body functions. One such essential acid is deoxyribonucleic acid (DNA). DNA is a complex molecule that is responsible for passing on inherited characteristics, such as hair colour, from one generation to the next.

Similarly, some bases produced by your body are harmful and some are helpful. An example of a harmful base is ammonia (NH_3). Your body produces ammonia as a waste product of the breakdown of some types of food. Ammonia is toxic to humans, so your body converts it to urea ($(NH_2)_2CO$). Urea is not toxic and is removed from your body in your urine.

Digestion is a process that breaks down your food into components that your body can use for energy. The digestive process begins with the saliva in your mouth (Figure 5.2). The saliva of a healthy person is usually basic. Your stomach contains hydrochloric acid (HCl), which helps your stomach to break down your food into smaller particles. However, hydrochloric acid can also damage the cells of your body. The lining of your stomach is protected from acid by a thick layer of mucus, but the rest of your digestive system lacks a protective layer. An organ called the pancreas produces a base called sodium hydrogen carbonate ($NaHCO_3$). This base counteracts the hydrochloric acid, which protects the rest of your digestive system. The digestion of fats depends on the production of another base, called bile. Bile is produced by the liver.

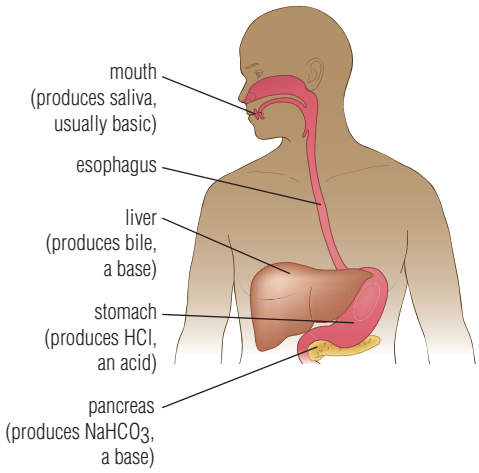


Figure 5.2 A simplified drawing of some of the organs involved in human digestion

B13 *Quick Lab*

What Do You Know about Acids and Bases?

Acids and bases are found in many of the foods we eat and the products we use. For example, grapes contain an acid and some soaps are made using a base (Figure 5.3 and Figure 5.4). In this activity, you will identify foods and products that are acids or bases or that contain an acid or a base.

Purpose

To brainstorm a list of foods and household products that are acids and bases or that contain an acid or a base

Procedure

1. Working with a partner or in a group, brainstorm foods and products that you think are acids or bases or that contain an acid or a base.
2. Record your list in a T-chart with two columns.
3. Share your T-chart with your classmates. Add any new ideas from their T-charts to yours.

Figure 5.3 Grapes contain tartaric acid.

Questions

4. What criteria did you use to predict if a food or product was an acid or a base?
5. Compare and contrast the criteria you used with those used by your classmates.

Figure 5.4 The base potassium hydroxide (KOH) is used in producing soft and liquid soaps.

During Reading Thinking Literacy

Listen to Your Inner Voice

Good readers are conscious of an inner voice that tells them when they understand and when they do not understand what they are reading. Choose a paragraph and, while you are reading, be conscious of that inner voice that tells you what you understand and where you may need to fix up meaning.

Identifying Acids and Bases

Thousands of years ago in Asia and Europe, early chemists tried to classify the substances they found in nature. One property they used was taste. This property accurately distinguished acids from bases: acids taste sour, while bases taste bitter. Tasting unknown substances is not safe, and you should never taste an unknown substance to identify it or its properties.

pH and the pH Scale

Today, you can determine if a substance is an acid or a base by measuring its pH. You have probably heard the term "pH" before. It is used in advertising (e.g., pH-balanced shampoo), in the care instructions for pools (pH of the pool water), and even in gardening (soil pH). The pH measurement is related to the number of hydrogen ions (H^+) that are in a solution. The abbreviation "pH" stands for power (or potential) of hydrogen. The **pH scale** is a number scale that indicates how acidic or basic a solution is (Figure 5.5).

The pH of a substance can be determined only when it is in aqueous solution (i.e., dissolved in water). Looking at the pH scale in Figure 5.5, you see that pure water has a pH of 7. Any substance with a pH of 7 when it is in aqueous solution is **neutral**. A neutral substance, such as pure water, is neither an acid nor a base.

An **acid** is a substance that has a pH less than 7 when it is in aqueous solution. The more acidic a substance is, the lower the pH. For example, lemon juice is an aqueous solution of a number of chemicals, including citric acid and ascorbic acid (vitamin C). Lemon juice has a pH of 2, and so it is moderately acidic.

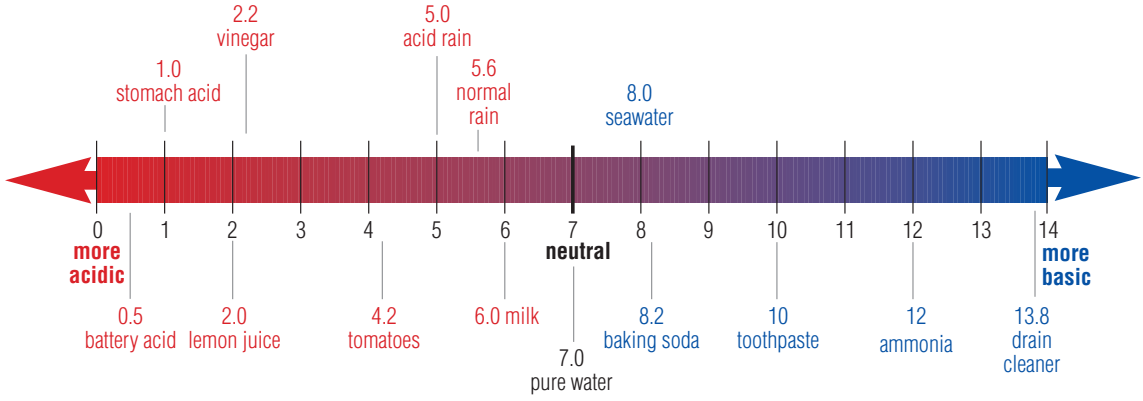


Figure 5.5 The pH scale is used to identify how acidic or basic an aqueous solution is.

A **base** is a substance that has a pH greater than 7 when it is in aqueous solution. The more basic a substance is, the higher the pH. Sodium hydrogen carbonate is commonly called baking soda and is used to make a number of foods. When sodium hydrogen carbonate is dissolved in water, the resulting solution is basic.

One unit of change on the pH scale represents a 10 times change in how acidic or basic a solution is. For example, the hydrochloric acid in your stomach has a pH of 1. This is 10 times more acidic than lemon juice (pH 2). The closer the pH of a solution is to 0, the more acidic it is. The closer the pH of a solution is to 14, the more basic it is.

ACID
RED
BASE
BLUE

Figure 5.6 This diagram shows a trick to help remember what happens to the colour of litmus paper when placed in acids and bases.

Acid-Base Indicators

There are a number of ways of determining the pH of a solution. One way is to use an acid-base indicator. An **acid-base indicator** is any substance that changes colour in the presence of an acid or a base.

The most widely known acid-base indicator is litmus. Litmus is a plant extract and can be blue or red (pink). Litmus paper is made from blue or red litmus dried onto strips of filter paper. Red litmus paper turns blue when it is dipped into a basic solution. Blue litmus paper turns red when it is dipped in an acidic solution. Neither litmus paper changes colour in a neutral solution. Figure 5.6 shows a memory aid for remembering these colour changes.

It would be impossible to determine the pH of all solutions using just one indicator, such as litmus. A **universal indicator** is a mixture of chemicals that changes colour through a wide range of pH values.

Paper strips called pH paper are embedded with a universal indicator. When pH paper is dipped in a solution, one or more of these indicators will change colour. You can then determine the pH of the solution by comparing the colour of the dipped strip with a standard colour chart. An even more precise way of determining pH is to use a pH meter (Figure 5.7).

Figure 5.7 A pH meter can precisely measure the pH of an acidic or basic solution.

Learning Checkpoint

1. Is a solution with a pH of 11 acidic or basic?
2. Is a solution with a pH of 5 acidic or basic?
3. What is the pH of pure water?
4. Could you determine a specific pH value for a solution using blue litmus paper? Explain.
5. What is the advantage of using a universal indicator?

Properties of Acids and Bases

The properties of acids and bases make them useful in many different ways. For example, sulphuric acid is used in automobile batteries because it is a good conductor of electricity. Table 5.1 compares the properties of acids and bases.

Table 5.1 Comparison of the Properties of Acids and Bases

Acids	Bases
Similarities	
dissolve in water	dissolve in water
conduct electricity in aqueous solution	conduct electricity in aqueous solution
can irritate or burn skin	can irritate or burn skin
Differences	
taste sour	taste bitter
do not feel slippery	feel slippery
pH less than 7	pH greater than 7
turn blue litmus paper red	turn red litmus paper blue
release hydrogen ions (H^+) in aqueous solution	release hydroxide ions (OH^-) in aqueous solution
corrode metals	do not corrode metals
react with metals to produce a compound and hydrogen gas	do not react with metals to produce a compound and hydrogen gas

Figure 5.8 Brook trout cannot survive in water with a pH lower than 4.1.

Acids and bases can sometimes be harmful. For instance, if water in the environment becomes too acidic or too basic, it can harm the living organisms in it (Figure 5.8). Solutions that are very acidic or very basic can be quite dangerous. The sulphuric acid in an automobile battery has a pH of 0.5, so it is very acidic. If battery acid were to touch your skin, it would quickly cause severe burns.

Identifying and Naming Acids

You can identify an acid from its name or from its chemical formula. Usually, the name of an acid ends with the word "acid." If you are given the chemical formula of a substance, you know that it is an acid if:

- the chemical formula starts with H (the symbol for a hydrogen atom) OR
- the chemical formula ends with COOH (the formula for a carboxyl polyatomic ion)

For example, HF(aq) is an acid because it starts with an H. One way that hydrofluoric acid (HF) is used is in etching glass (Figure 5.9). $CH_3COOH(aq)$ is an acid because it ends with COOH. The name of this acid is acetic acid. You have probably used a diluted solution of acetic acid in your food. Diluted $CH_3COOH(aq)$ is vinegar.

Suggested Activity •
B14 Quick Lab on page 202

Naming Acids

There are two rules for naming acids that you will use in this science course. You may learn additional rules for other types of acids in a future chemistry course.

When the chemical formula of an acid starts with H and has only one other non-metallic element, it is named according to the steps shown in Table 5.2.

Figure 5.9 This beautiful etched glass window was made using hydrofluoric acid (HF).

Table 5.2 Naming Acids That Contain Hydrogen and a Non-Metallic Element

Step	Examples	
	HCl(aq)	**HF(aq)**
1. Start with the prefix "hydro."	hydro	hydro
2. To the first part of the name of the non-metallic element, add the suffix "ic" and the word "acid."	hydrochloric acid	hydrofluoric acid

Some acids contain a polyatomic ion. When the polyatomic ion in an acid contains an oxygen atom (O) and its name ends in "ate", the acid can be named by the steps shown in Table 5.3. For example, $H_2SO_4(aq)$ is an acid that contains the polyatomic ion sulphate (SO_4^{2-}). Sulphuric acid has many uses, such as in dyeing clothing (Figure 5.10). The sulphate ion contains an oxygen atom, and its name ends in "ate." However, the acid $HNO_3(aq)$ is called nitric acid, not "nitrogenic acid."

Figure 5.10 Sulphuric acid is used to produce the colourful dyes in these clothes.

Table 5.3 Naming Acids That Contain a Polyatomic Ion with an Oxygen Atom and a Name Ending in "ate"

Step	Examples	
	$H_2SO_4(aq)$	**$H_3PO_4(aq)$**
1. Start with the name of the element in the polyatomic ion that is not oxygen.	sulphur	phosphorus
2. Add the suffix "ic" and the word "acid."	sulphuric acid	phosphoric acid

Many acids have common names. Table 5.4 shows you the formulas, chemical names, and common names of some acids and some ways in which these acids are used.

Table 5.4 Formulas, Chemical and Common Names, and Uses of Some Acids

Chemical Formula	Chemical Name	Common Name(s)	Uses
HCl(aq)	hydrochloric acid	muriatic acid, stomach acid	cleaning concrete, making other chemicals
H_2SO_4(aq)	sulphuric acid	battery acid	car batteries, making fertilizer, manufacturing
HCOOH(aq)	methanoic acid	formic acid	dyeing wool, tanning leather
CH_3COOH(aq)	ethanoic acid	acetic acid	diluted to make vinegar, making plastic, added to foods for flavour

Learning Checkpoint

1. State the common names of the following acids.
   (a) HCl(aq)
   (b) HNO_3(aq)
   (c) CH_3COOH(aq)
2. Name the polyatomic ion in each of the following acids.
   (a) sulphuric acid
   (b) nitric acid

Identifying and Naming Bases

A base can also be identified from its name or its chemical formula. A substance is a base if its name begins with the name of a metallic ion and ends with the word "hydroxide." A substance is also a base if:

- the chemical formula starts with a metallic ion or with the ammonium ion NH_4^+ AND
- the chemical formula ends with OH (called a hydroxyl group)

For example, NaOH(s) starts with the metallic ion sodium (Na^+) and ends with OH^-. Similarly, KOH(s) starts with the metallic ion potassium (K^+) and ends with OH^-. NH_4OH(aq) starts with the ammonium ion and ends with OH^-. All these compounds are bases.

Sodium hydroxide (NaOH) is a base you may know about. The base is commonly found in drain cleaners and oven cleaners (Figure 5.11). Sodium hydroxide is a white solid that easily dissolves in water. The resulting solution is very basic and corrosive.

Figure 5.11 This oven cleaner contains sodium hydroxide and is very basic. This warning label shows the symbol for corrosive chemicals. You should always wear gloves when working with corrosive substances.

Naming Bases

The name of a base can be determined from its chemical formula by following the steps shown in Table 5.5. Notice that all bases are followed by the word "hydroxide."

Table 5.5 Naming Bases

Step	Examples	
	KOH(aq)	**NH_4OH(aq)**
1. Write the name of the positively charged metallic ion that is at the beginning of the chemical formula. This step remains the same if the positively charged ion is a polyatomic ion.	potassium	ammonium
2. Add the word "hydroxide."	potassium hydroxide	ammonium hydroxide

Like acids, many bases also have common names. A substance that is a base may be called an alkali or said to be alkaline. Table 5.6 shows the formulas, chemical names, and common names of some bases and some ways in which they are used.

Table 5.6 Formulas, Chemical Names, Common Names, and Uses of Several Important Bases

Chemical Formula	Chemical Name	Common Name	Uses
NaOH(s)	sodium hydroxide	caustic soda	cleaning drains; making soap, plastic, and textiles; controlling pollution
NH_4OH(aq)	ammonium hydroxide	ammonia solution	cleaning windows; making dyes, plastic, and glass; controlling pollution
$Ca(OH)_2$(s)	calcium hydroxide	slaked or hydrated lime	making glass, cement, and steel; correcting acidic soil; removing hair; making baby formula
$Mg(OH)_2$(s)	magnesium hydroxide	milk of magnesia	treating indigestion, bleaching clothes, treating wastewater, making articles fire resistant

Learning Checkpoint

1. Name the following bases.

(a) KOH(s)

(b) $Ca(OH)_2$(s)

(c) $Mg(OH)_2$(s)

(d) NH_4OH(aq)

2. Which polyatomic group is found at the end of the chemical formula for most bases?

Take It **Further**

Deoxyribonucleic acid (DNA) is found in every cell of your body. The three-dimensional structure of this acid remained a mystery for many years. You can solve the mystery for yourself. Begin your research at ***ScienceSource***.

The pH of Household Liquids

Figure 5.12 When dipped in an acid, pH paper turns red to pinkish. When dipped in a base, it turns dark blue to green.

Purpose

To determine which types of household liquids are acidic and which are basic

Materials & Equipment

- samples of common household liquids
- small containers, such as petri dishes
- pH paper
- paper towels
- samples of liquids labelled "Dish soap," "Soft drink," and "Orange juice"

Procedure

1. In your notebook, make a table similar to Table 5.7. Add the name of each liquid you will be testing to your table.
2. Pour a small sample of one of the liquids into a small container. Dip a strip of pH paper (Figure 5.12) into the liquid.

Table 5.7 Approximate pH of Household Liquids

Name of Liquid	pH Value	Acidic, Basic, or Neutral

3. Compare the colour of the pH paper strip to the pH colour standards on the pH paper package. Record the approximate pH in your table. Classify each liquid as acidic, basic, or neutral.
4. Place the used pH paper strip on a paper towel.
5. Repeat steps 2 to 4 for the remaining liquids.
6. Obtain the three liquids identified only as "Dish soap," "Soft drink," and "Orange juice." Based on your results so far, predict whether each is acidic, basic, or neutral, and predict the approximate pH of each.
7. Measure the pH of each of the three liquids using the procedure in steps 2 to 4. Compare your measurements to the predictions you made in step 6.
8. Clean up your work area. Make sure to follow your teacher's directions for safe disposal of materials. Wash your hands thoroughly.

Question

9. Sort the liquids you tested according to their use. For example, some are cleaning products and some are foods. Which types of liquids were acids? Which were bases?

5.1 CHECK and REFLECT

Key Concept Review

1. What is an acid? Name several acids.
2. What is a base? Name several bases.
3. Use the chemical or physical properties identified below to classify each solution as acidic, basic, or neutral.
   (a) feels slippery and conducts electricity
   (b) Red litmus stays red, and blue litmus turns red.
   (c) tastes sour and feels wet but not slippery
   (d) has a pH of 3 and turns blue litmus red
   (e) conducts electricity and has a pH of 9
4. Would a solution that contains calcium hydroxide ($Ca(OH)_2$) dissolved in water be acidic, basic, or neither? Explain how you know.
5. How are acids similar to bases? How are acids different from bases? (Hint: Check Table 5.1 on page 198.)
6. What is an acid-base indicator?
7. From the following formulas, decide whether the solution is acidic, basic, or salt.
   (a) KOH(aq)
   (b) NaCl(aq)
   (c) HCl(aq)
   (d) C_6H_5COOH(aq)
8. State the name or the formula for each of the following substances. Then indicate if it is an acid or a base.
   (a) aqueous hydrogen nitrate
   (b) cesium hydroxide
   (c) aqueous hydrogen chloride
   (d) phosphoric acid
   (e) KOH(aq)
   (f) H_2SO_4(aq)
9. Write the chemical formulas for the following bases.
   (a) magnesium hydroxide
   (b) potassium hydroxide
   (c) aluminum hydroxide

Connect Your Understanding

10. Would you expect to find acids or bases inside an alkaline battery? Why?
11. One strip of red litmus paper was dipped into an acidic solution of lemon juice, and a second strip was dipped into a basic solution of baking soda. Which of the two strips shown in the photograph below was dipped in the lemon juice solution and which into the solution of baking soda?

Question 11

12. Household (white) vinegar contains 5 percent acetic acid. Suggest why 100 percent acetic acid is not used as a food.
13. Why is a universal indicator more useful than litmus paper for measuring pH in some applications?
14. Neatly draw a two-column chart. Label the columns "Uses for Acids" and "Uses for Bases." Then, use the information in this section to complete the chart.

Reflection

15. What would you like to know more about concerning acids and bases?

For more questions, go to ***ScienceSource***.

5.2 Neutralization Reactions

Here is a summary of what you will learn in this section:

- Neutralization is a type of chemical reaction that occurs between an acid and a base and produces water and a salt.
- A precipitate is an insoluble compound that forms in some chemical reactions.
- Neutralization reactions can be used to help us solve environmental challenges.

Figure 5.13 Growers of fruits, vegetables, and other crops monitor and adjust the pH of soil in order to provide the best growing conditions.

Figure 5.14 (a) When the soil pH is 6.0 to 6.2, hydrangea flowers are pink. (b) When the soil pH is 5.2 to 5.5, hydrangea flowers are blue.

pH and Plants

Ontario farmers produce a wide variety of fruits, vegetables, and other crops (Figure 5.13). Growing plants for a living can be risky. Many factors can affect the success of a crop, from weather conditions to the nutrient content of the soil. Soil pH is one of these factors. The pH of soil affects the growth of plants in a number of ways. For example, growers can change the colour of hydrangea flowers by changing the soil pH (Figure 5.14).

An important effect of altering soil pH is to change the availability of nutrients in the soil to plants. Plants can use only nutrients that are dissolved in the water in the soil. Different plant species require different levels of nutrients. In acidic soils, the nutrients phosphorus, potassium, calcium, and magnesium are less able to dissolve in the soil water. A plant that needs high levels of these nutrients may not grow as well in an acidic soil. Other nutrients, such as zinc, manganese, copper, and iron, dissolve more easily in acidic soil. A plant that needs high levels of these nutrients may grow better in an acidic soil. The pH of the soil therefore can determine if a plant gets too little or too much of a nutrient.

Adjusting Soil pH

Soil pH can also change the variety and numbers of micro-organisms that live in the soil. Some micro-organisms help plant growth, but others cause disease.

Even areas that are close to each other can have different soil conditions, including soil pH. Therefore, farmers and other large growers, such as flower producers, need to know the soil pH in many areas of their land. On commercial operations such as farms, soil pH is usually determined by specially trained technologists. On a smaller scale, home gardeners can test their soil using a test kit.

Once soil pH is known, growers can use this information in one of two ways. First, they could plant crops that are most suited to the soil pH. For example, legumes (beans and peas) grow best at a pH of 6.2 or higher, but corn can do well in soils with a pH as low as 6.0. Second, a grower can adjust the pH of soil to support particular plants (Figure 5.15). If the soil pH is too acidic, adding a basic substance can increase the pH. If the soil pH is too basic, then adding acidic substances can lower the pH.

Figure 5.15 Calcium carbonate, commonly called lime, is added to soil to raise the pH.

B15 *Quick Lab*

Testing Soil pH

Purpose

To compare the pH of soil samples from different sources

Materials & Equipment

- paper towels
- potting soil
- 2 or more samples of soil from outdoors
- teaspoon or scoopula
- soil pH test kit
- water

Procedure

1. Working on paper towels, remove any larger objects, such as stones or twigs, from the potting soil. Break up any clumps with a teaspoon or scoopula.
2. Add soil to fill the testing container supplied with the soil pH test kit, according to the instructions that came with the kit.
3. Add the testing powder to the soil in the testing container. Add the amount of water indicated by the manufacturer's instructions.
4. Mix the contents. Allow any particles to settle, then compare the colour with the colour chart supplied in the test kit.
5. Repeat steps 1 to 4 for the remaining soil samples.
6. Clean up your work area. Make sure to follow your teacher's directions for safe disposal of materials. Wash your hands thoroughly.

Questions

7. Potting soil is intended for use with a wide variety of plants. Based on your analysis, do you think most plants prefer acidic soil or basic soil?
8. Plants in the mint family grow best in basic soil (from pH 7.0 to 8.0). Which outdoor soil would be best for mint?
9. Roses grow well in a pH range from 5.5 to 7.0. Which outdoor soil would be best for roses?

During Reading

Thinking Literacy

Use Text Management Strategies

When good readers do not understand, they may slow down and reread parts of a text, read ahead to get more clues from words or graphics, or pause and reflect, trying to connect what they know to new knowledge. Choose part of a text that you found difficult, and try one of these strategies to make meaning of it.

Neutralization

Neutralization is a chemical reaction between an acid and a base that produces water (H_2O) and a salt (Figure 5.16). The salts formed may be soluble in water or can be insoluble. If a salt is insoluble, a precipitate will form. A **precipitate** is a suspension of small, solid particles formed during a chemical reaction.

A neutralization reaction can be summarized as follows:

acid + base → salt + water

For example, the chemical equation for the neutralization reaction illustrated in Figure 5.16 is:

$$HCl(aq) + NaOH(aq) \rightarrow NaCl(aq) + H_2O(l)$$

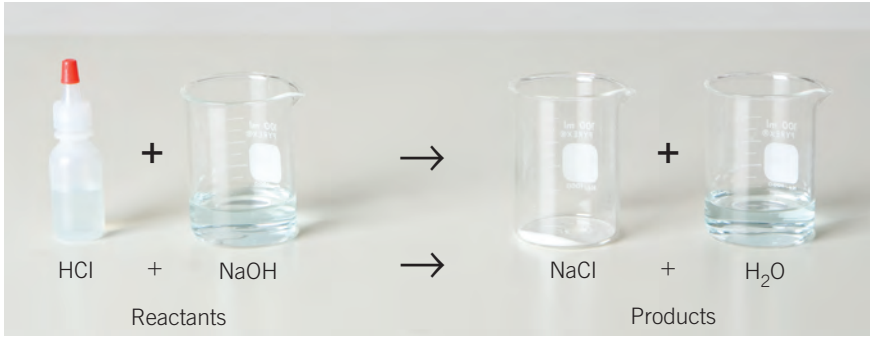


Figure 5.16 When hydrochloric acid and sodium hydroxide are mixed in solution, they undergo a neutralization reaction. The products are sodium chloride (table salt) and water. After the actual chemical reaction, the sodium chloride would be dissolved in the water.

Practice Problems

1. When HBr(aq) reacts with KOH(aq), a neutralization reaction occurs. The products are KBr(aq) and $H_2O(l)$. What is the balanced chemical equation for this reaction, including states?
2. When $H_2SO_4(aq)$ reacts with $Mg(OH)_2(aq)$, the products are $MgSO_4(aq)$ and liquid water. Write the balanced chemical equation for this neutralization reaction, including states.
3. When aqueous phosphoric acid reacts with aqueous sodium hydroxide, sodium phosphate (Na_3PO_4) and water are produced. What is the balanced chemical equation for this neutralization reaction, including states?

Example Problem 5.1

When aqueous sulphuric acid reacts with solid sodium hydroxide, dissolved sodium sulphate and liquid water are produced. What is the balanced chemical equation for this neutralization reaction, including states?

1. Write a word equation for the reaction.
   sulphuric acid + sodium hydroxide → sodium sulphate + water
2. Write the correct formulas, using the charges on the periodic table. Include the states of matter.
   sulphuric acid: $H_2SO_4(aq)$ sodium hydroxide: $NaOH(s)$
   sodium sulphate: $Na_2SO_4(aq)$ water: $H_2O(l)$
3. Write the skeleton equation.
   $H_2SO_4(aq) + NaOH(s) \rightarrow Na_2SO_4(aq) + H_2O(l)$
4. Write the balanced chemical equation, including states:
   $H_2SO_4(aq) + 2NaOH(s) \rightarrow Na_2SO_4(aq) + 2H_2O(l)$

Applications of Neutralization Reactions

Neutralization reactions have commercial uses, such as in pharmaceutical manufacturing, waste treatment, and agriculture. In making pharmaceuticals, the pH of a solution may be changed from acidic to basic (or vice versa) so that the desired product forms a precipitate. The precipitate can then be collected by filtering the products of the reaction. In agriculture, calcium carbonate may be added to acidic soil. The calcium carbonate enters into a neutralization reaction with some of the acid in the soil water, and the soil pH becomes more basic.

Neutralization reactions are also used in medicine. For example, acid reflux is a condition in which stomach acid (HCl) causes discomfort. The symptoms of acid reflux can be treated with antacids, which are composed of bases. They can produce a neutralization reaction with some of the hydrochloric acid in the stomach. Bee stings can also be treated using a neutralization reaction (Figure 5.17). When it stings, a bee releases methanoic acid, which attacks nerves in the skin. Bee stings can be treated with a cream that contains ammonia, which is a base. The ammonia enters into a neutralization reaction with the methanoic acid, which prevents further irritation of the nerve endings.

Figure 5.17 The methanoic acid in a bee sting, also known as formic acid (HCOOH), can be neutralized with an ammonia-based cream.

The food industry uses neutralization reactions to adjust the pH of products. Packaged and processed foods often have an acidic pH, since harmful bacteria are less likely to grow under these conditions. For example, vinegar (dilute acetic acid) or citric acid may be added to foods to lower the pH. You will find vinegar in the ingredient list of many prepared foods, such as ketchup (Figure 5.18).

Suggested Activity •

B18 Inquiry Activity on page 213

Figure 5.18 Vinegar is added to packaged foods, such as ketchup, for taste and to prevent harmful bacteria growing and causing them to spoil.

Figure 5.19 A neutralization reaction occurs when lemon juice is added to fish.

You may be using acids and bases without realizing it. For example, we often serve fish with a wedge of lemon (Figure 5.19). Fish is a weak base. Lemon juice (an acid) lowers the pH, which eliminates the fishy odour. Lemon juice is also often added to spinach salads. Spinach contains iron, which is an important nutrient for your body. Lemon juice contains vitamin C (ascorbic acid). Nutritionists believe that adding lemon juice will help your body to absorb iron.

Figure 5.20 The damage to the limestone on this building is the result of acid precipitation.

Using Neutralization Reactions to Solve Environmental Challenges

Every day, you use products that use acids and bases in some way. Your clothes may be dyed bright colours that are produced using acids and bases. Your home is made of materials such as lumber, steel, and copper, which are manufactured or processed using acids and bases. Although industries that use acids and bases are beneficial to us, they can also affect the environment negatively. Sometimes, neutralization reactions can help to reduce negative effects and even repair environmental damage.

Acid Precipitation

Acid precipitation is rain, snow, fog, or dew that has a pH less than 5.6. (Rain usually has a pH of around 5.6.) Two main causes of acid precipitation are sulphur dioxide (SO_2) and nitrogen oxides in the atmosphere. Nitrogen oxides come in many forms, such as N_2O, NO_2, and N_2O_4. The gases then undergo chemical reactions in the atmosphere that result in the formation of acids, which eventually fall as acid precipitation.

Sulphur dioxide is converted to sulphuric acid by the following two chemical reactions:

$$2SO_2(g) + O_2(g) \rightarrow 2SO_3(g)$$
$$SO_3(g) + H_2O(l) \rightarrow H_2SO_4(aq)$$

Nitrogen dioxide gas dissolves in water droplets in the atmosphere to form nitric acid.

A significant source of gases that cause acid precipitation is electricity production in coal-fired power plants. Iron and steel production, smelting of metals (such as zinc, nickel, and copper), fertilizer production, pulp and paper production, and automobile engines also emit gases that contribute to acid precipitation.

When acid precipitation falls on cities and towns, it can corrode the stone surfaces of buildings and statues and the concrete of roads and bridges. The acids in the precipitation enter into neutralization reactions with bases in the stone. For example, limestone contains calcium carbonate, which can be dissolved by acid precipitation (Figure 5.20). Acids react with metals, so acid precipitation can cause corrosion of iron reinforcing rods in structures.

Acid precipitation changes the pH of the soil in forests, which can cause trees and other plant species to die (Figure 5.21(a)). This reduces habitat for the species that depend on forests. Loss of forests means losses in the forestry industry and in recreational use. The water in lakes, streams, and other freshwater bodies can also become more acidic as a result of acid precipitation. The change in pH can cause fish and other water organisms to die (Figure 5.21(b)).

(a)

(b)

Figure 5.21 (a) This photograph shows the effect of acid precipitation on forests. (b) When lakes and streams become too acidic, fish and other organisms may die.

Learning Checkpoint

1. What gases are the main causes of acid precipitaion?
2. What are nitrogen oxides?
3. Write two chemical equations for reactions that cause acid precipitation.
4. What is the source of water in the reactions you wrote in question 3?
5. Name two industries or human activities that contribute to acid precipitation.

Neutralizing Acidic Lakes

In some provinces, such as Alberta and Saskatchewan, most lakes are naturally protected from the effects of acid precipitation because they are surrounded by limestone. This type of rock reacts with excess acid and neutralizes it, which restores the pH of the lake water. However, this is not true of lakes in Ontario. The surroundings of Ontario lakes do not contain much limestone, and a significant amount of acid precipitation enters the lakes in Ontario. This means that Ontario lakes are at greater risk of acidification.

One way to raise the pH of heavily acidified lakes is by adding a substance called lime. When lime mixes with water, the base calcium hydroxide ($Ca(OH)_2$) is formed. Calcium hydroxide can neutralize both the sulphuric acid and the nitric acid that are found in acid precipitation. The neutralization reaction involving nitric acid is:

$$2HNO_3(aq) + Ca(OH)_2(s) \rightarrow Ca(NO_3)_2(aq) + 2H_2O(l)$$

However, this process is very expensive and, therefore, only practical in protecting lake ecosystems in the short term.

Reducing Acid Precipitation

Once the relationship between sulphur dioxide and nitrogen oxides and acid precipitation was understood, work began to develop technology that could help reduce the emission of these gases. Two of those technologies are smokestack scrubbers and automobile emissions controls.

Scrubbers are devices that are found in tall industrial smokestacks of industries that release sulphur dioxide gas and nitrogen oxide gases, such as coal-fuelled power plants and ore smelting facilities (Figure 5.22). Scrubbers remove these gases using a specially formulated chemical mixture.

Figure 5.22 Scrubbers in these smokestacks trap pollutants that could otherwise cause acid precipitation.

Figure 5.23 A catalytic converter converts various emissions into less harmful chemicals, often using a combination of metals and chemical reactions.

The gases in a smokestack contact the chemical mixture in the scrubber and enter into chemical reactions. The products of the chemical reactions are a wet slurry or a solid. Scrubbers also have a filter that collects and traps small particles that would otherwise be released into the atmosphere. The substances collected can then be separated and removed for recycling.

Internal combustion engines found in automobiles emit a number of harmful gases, including nitrogen oxides. One approach to reducing harmful emissions is to use technologies that convert the harmful gases to other, harmless substances. The most common of these technologies is the catalytic converter, which is located in the exhaust system of a vehicle (Figure 5.23). A catalytic converter uses nitrogen oxides in a chemical reaction that decomposes them into nitrogen gas and oxygen gas. For example, when dinitrogen trioxide is the reactant, the following chemical reaction occurs:

$$2N_2O_3(g) \rightarrow 2N_2(g) + 3O_2(g)$$

More Work Needed

Researchers continue to closely study the acid content of lakes. One study looked at changes in the pH of 152 lakes in southeastern Canada. From 1988 to 2008, only 41 percent of the lakes studied were less acidic, 50 percent had not changed, and 9 percent were more acidic.

Central Ontario is the only region where there has been a significant decline of acidity in most lakes. Scientists believe this change is due mostly to the considerable reduction in sulphur dioxide emissions from smelters in the nearby Sudbury area. Computer models have predicted that up to one-quarter of the lakes in eastern Canada will remain chemically damaged for years to come.

Learning Checkpoint

1. Describe two effects that acid precipitation has on the environment.
2. How can the pH of an acidic lake be increased?
3. Why are lakes on limestone rock less affected by acid rain?
4. What are scrubbers, and what do they do?
5. Catalytic converters use chemical reactions to reduce the emission of a number of harmful gases. Write the chemical equation for the reaction with dinitrogen trioxide that occurs in a catalytic converter.

Heavy Metals

Heavy metals are metal elements that have a high atomic mass. Examples of heavy metals include arsenic (As), copper (Cu), mercury (Hg), and zinc (Zn). Heavy metal accumulation can cause kidney disease, diseases of the lungs, bone defects, and damage to nervous system development.

The soil in areas with a lot of heavy industry is often contaminated with heavy metals and other contaminants. However, roadways and automobiles can also be contaminated with high levels of heavy metals (Figure 5.24). Copper may be released from bearings, engine parts, and brakes, and nickel is found in diesel fuel and gasoline. Nickel and cadmium in rechargeable batteries can also cause heavy metal contamination, if they are not properly disposed of.

Figure 5.24 Soils may be contaminated with heavy metals anywhere that automobiles are used.

Contamination at Mine Sites

In Ontario, many abandoned mine sites are significantly contaminated with heavy metals. Old mines often were operated in ways that would no longer be allowed. There were no rules that required mine owners to clean up the sites after the mines were closed.

In times past, waste from mines was stored in tailings ponds or in slag heaps. The rock waste (tailings) in these sites contained metals that generate acids when they are exposed to air. For example, many mine tailings in Ontario contain iron sulphide (pyrite or fool's gold). In the presence of oxygen and water, the iron sulphide enters into a series of chemical reactions. The end products of these reactions are iron hydroxide, sodium sulphate, and sulphuric acid.

As this process continues, the soil and water in the area become more and more acidic. **Acid leaching** is a process in which acids dissolve metals found in soil. As the pH falls, the heavy metals begin to dissolve. At least 250 abandoned mine sites in Ontario continue to add to soil and water contamination through acid leaching of the wastes left behind (Figure 5.25). For example, the Kam Kotia mine site, located near Timmins, Ontario, caused acidification of soil and water and release of heavy metals into the surrounding areas.

Figure 5.25 Tailings ponds and slag heaps at many abandoned mine sites in Ontario are contaminating the surrounding soil and water with heavy metals, through acid leaching.

Restoring Soils

Soils contaminated by heavy metals can be restored to a healthy state by acid leaching. When soil is heavily contaminated, such as in an abandoned mine, it is first removed and taken to a treatment facility. The contaminated soil is treated with acid to decrease the pH. This dissolves the metals in the soil, which are then collected in an acidic solution. The metals are recovered by raising the pH of the solution with a base, which causes the metals to form a precipitate.

Neutralization reactions are used to prevent further acid leaching from mine sites. For example, at the closed Deloro Mine site near Peterborough, Ontario, which was leaching heavy metals and the poison

Take It Further

The rehabilitation of the abandoned sites of the Kam Kotia mine, near Timmins, and of the Deloro mine, near Peterborough, continues. Find out what progress has been made and whether these sites continue to negatively affect the environment. Begin your research at ***ScienceSource***.

Suggested STSE Activity
B19 Inquiry Activity on page 214

arsenic into the environment, an eight-hectare tailings pond was capped with half a metre of crushed limestone (calcium carbonate) to raise the pH and reduce the amount of acid leaching. Acid leaching at this old gold mine had contaminated the water in the area with heavy metals and the poison arsenic.

B16 STSE Science, Technology, Society, and the Environment

Transporting Acids

On March 30, 2007, two dozen cars of an Ontario Northland train jumped the tracks about 16 km north of Englehart, a community of about 1500 people north of North Bay, Ontario. Nine of the cars were carrying sulphuric acid. Over 100 tonnes (100 000 kg) of acid spilled into the Blanche River (Figure 5.26). This massive acid spill quickly killed fish and other organisms in or by the shores of the river. Health officials from Ontario's Ministry of the Environment were also concerned that the drinking water for the people and livestock in the area would be contaminated.

To monitor the damage caused by the acid spill, health officers immediately began to take water and soil samples at the spill site. To reduce the environmental impact, emergency response crews added kilogram amounts of lime (calcium hydroxide, $Ca(OH)_2$) to the river several kilometres upstream.

Figure 5.26 Sulphuric acid was released into the Blanche River when tank cars overturned, spilling their contents.

1. Why was calcium hydroxide added to the river? Use a word equation and a skeleton equation in your answer.
2. Should acids be transported large distances? Why or why not?

B17 Skill Builder Activity

Making an Inference

In Activity B18, you will be making inferences. An inference is a conclusion made by analyzing facts. When you draw conclusions about the observations you make in a scientific investigation, you are making inferences. An inference is a logical analysis of facts, so it can always be justified by those facts.

For example, an advertisement states that 20 out of 25 people prefer Brand A cola over Brand B. Can you infer that 80 percent of all people prefer Brand A cola? No, because you do not know how many people were interviewed or how these people were chosen. Were they chosen at random, or were they all regular buyers of Brand A cola? Without this information, there is not enough data to make an inference.

For each of the following situations, write an inference based on the given data. If there isn't enough data to justify an inference, write a sentence to explain why.

1. The juice stored in the back of the bottom shelf of the refrigerator is frozen. What can you infer about the temperature in the refrigerator?
2. Your cake comes out of the oven looking more like a pancake than a light, fluffy cake. What can you infer about the length of the baking time?
3. Eight in 10 dentists recommend Brand X toothpaste for reducing cavities. What can you infer about this toothpaste?

B18 *Inquiry Activity*

Skills References 1, 2, 3

SKILLS YOU WILL USE
- Identifying variables
- Drawing conclusions

Antacids and Neutralization Reactions

Question

How many drops of each antacid will you need to neutralize 5 drops of hydrochloric acid?

Materials & Equipment

- 3 samples of liquid antacids (A, B, C)
- dilute hydrochloric acid (HCl)
- pH paper
- spot plate
- dropper
- glass stirring rod

Procedure

1. Measure the pH of the HCl and of the three samples of liquid antacid using pH paper. Record your data.
2. Using the dropper, add 5 drops of HCl to a well in the spot plate.
3. Draw some of antacid A into a clean dropper. Add three drops of antacid A to the HCl in the spot plate well (Figure 5.27). Mix the solution with a clean glass stirring rod.
4. Measure the pH of the solution with pH paper. If the pH is close to 7, record the number of drops of antacid A. If not, add another drop of the antacid and measure again. Continue until the solution is neutral or nearly neutral. Record the total number of drops of the antacid that you added.
5. Rinse the dropper.
6. Repeat steps 2 to 5 using antacid A again.
7. Repeat Steps 2 to 6 for antacid B and antacid C.
8. Clean up your work area. Make sure to follow your teacher's directions for safe disposal of materials. Wash your hands thoroughly.

Analyzing and Interpreting

9. For each antacid, calculate and record the average number of drops needed to neutralize the HCl.
10. Using your results, list the antacids in order from most effective to least effective in neutralizing HCl.
11. Compare your results to others in your class. Why might the results of all the groups not be the same?

Skill Practice

12. Identify the independent and dependent variables in this investigation.
13. Why did you carry out two trials for each antacid?

Forming Conclusions

14. Based on your data, make an inference about which antacid would relieve acid indigestion most effectively. Give reasons for your answer.

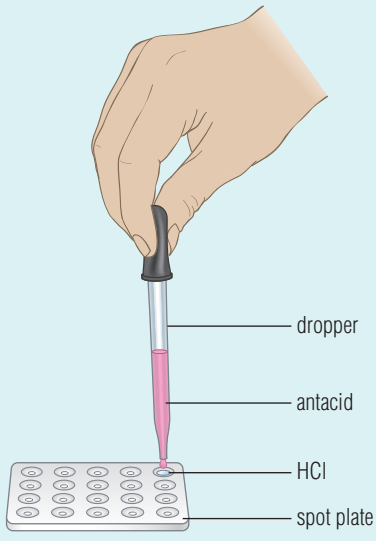


Figure 5.27 Add drops of the antacid until the pH is close to 7.

B19 **STSE** *Inquiry Activity*

Skills References 2, 6

SKILLS YOU WILL USE
- Identifying variables
- Justifying conclusions

Neutralizing Acidic Lake Water Samples

The job of an environmental chemist includes conducting research and designing systems and equipment for measuring the quality of air, water, and soil (Figure 5.28). Imagine you are an environmental chemist studying the quality of water in lakes. You have just returned from a field trip with samples of water from several different lakes in northwestern Ontario (Figure 5.29). This region has several old, abandoned mine sites that might be undergoing acid leaching of heavy metals. In this activity, you will determine the pH of lake water samples and then use a basic solution to neutralize them.

Figure 5.28 Environmental chemists may collect water samples as part of their work.

Question

How effective is a sodium hydrogen carbonate solution in neutralizing acidic lake samples?

Materials & Equipment

- lake water samples (labelled A, B, C, etc.)
- 10-mL graduated cylinders (1 per water sample)
- 50-mL beakers (1 per water sample)
- pH paper
- paper towels
- 0.1 M sodium hydrogen carbonate ($NaHCO_3(aq)$) solution
- stirring rod

Procedure

1. In your notebook, make a table similar to Table 5.8 (on the next page) to record your data.
2. Using a clean 10-mL graduated cylinder, measure 5 mL of lake water sample A. Pour the 5 mL of sample A into a clean 50-mL beaker.

Figure 5.29 A map of the area of study, in which there are a number of old, abandoned mine sites

3. Measure the pH of sample A with pH paper. Record your data in your table.
4. Rinse the 10-mL graduated cylinder, and shake to dry.
5. Use the clean 10-mL graduated cylinder to measure and add 1 mL of sodium hydrogen carbonate solution to the beaker. Stir the solution with the stirring rod.
6. Measure the pH of the solution in the beaker with pH paper.
7. If the pH of the solution in the beaker is still acidic, repeat steps 5 and 6 until the pH is approximately 7. Keep track of the volume of $NaHCO_3$ solution you have added.
8. In your table, record the total volume of sodium hydrogen carbonate solution you added to the sample to reach pH 7.
9. Rinse and dry the 10-mL graduated cylinder and the 50-mL beaker.
10. Repeat steps 2 to 7 with the remaining lake water samples.
11. Clean up your work area. Make sure to follow your teacher's directions for safe disposal of materials. Wash your hands thoroughly.

Analyzing and Interpreting

12. Compare your results for the lake water samples in your data table. How are they similar? How are they different?
13. Compare your data with those of other groups in your class. Suggest why your group's results may have been different from the results of other groups in your class.

Skill Practice

14. Why is it important to always start by measuring the same volume (5 mL) of each of the water samples?

Forming Conclusions

15. Would sodium hydrogen carbonate be suitable for neutralizing a lake? Support your decision with one or more reasons.
16. Suppose that one of the samples you tested was collected from the site of an abandoned mine in the area shown in Figure 5.29. Based on the initial pH measurements you observed, which of the lake water samples would be most likely to indicate that heavy metal contamination of the water might be occurring? Explain.

Table 5.8 Data Table for Lake Water Testing

Acidic Lake Water Sample	Approximate pH of Sample	Volume of $NaHCO_3$ Solution Needed to Neutralize	Approximate pH of Neutralized Sample
Sample A			
Sample B			
Sample C			

5.2 CHECK and REFLECT

Key Concept Review

1. Define "neutralization" in your own words.
2. What are the products of a neutralization reaction?
3. How does an antacid work?
4. What is acid precipitation?
5. Name two gases that contribute to acid precipitation.
6. Explain the term "acid leaching." Use an example in your answer.

Connect Your Understanding

7. Identify which of the following is a neutralization reaction. Explain how you know.
   (a) $2FeBr_3 + 3Cu_2SO_4 \rightarrow Fe_2(SO_4)_3 + 6CuBr$
   (b) $H_3PO_4 + 3NaOH \rightarrow Na_3PO_4 + 3H_2O$
8. Complete the following word equations:
   (a) sulphuric acid + calcium hydroxide → ? + calcium sulphate
   (b) hydrogen bromide + sodium hydroxide → water + ?
   (c) ? + sodium hydroxide → water + sodium chloride
9. Write skeleton equations for each word equation you completed in question 8.
10. Write balanced chemical equations for each skeleton equation you wrote in question 9.
11. Suppose that a classmate combines a colourless acid and a colourless base. The resulting solution is clear and colourless, with no evidence of a precipitate. Your classmate says that this means that no reaction has occurred. Do you agree with your classmate's conclusion? Explain.
12. You can temporarily receive relief from acid indigestion by using an antacid that contains a base. Why is it not a good idea to use an antacid routinely? Suggest two or more reasons.
13. Acids can react with most metals. Suggest why this would be a problem in a region of Ontario where the rain is acidic.
14. Explain why acid precipitation is a costly result of human activities. Start your answer by referring to the photograph below.

Question 14

15. Describe how acid precipitation affects lakes.
16. Explain what role limestone has in protecting lakes from acidification.
17. Describe the positive and negative effects of acid leaching with respect to metal pollution from disused mines.

Reflection

18. What do you know about neutralization reactions that you did not know before you started this section?

For more questions, go to *ScienceSource*.

Phosphoric Acid

Phosphoric acid (H_3PO_4) is an important acid that is used in many ways. One way is to acidify foods and beverages, such as soft drinks. It gives foods a tangy or sour taste.

Phosphoric acid may be used for removing rust from iron or steel. It may be applied as a liquid or as a component of a product called naval jelly. The phosphoric acid in both the liquid or jelly converts iron(III) oxide (rust) to iron(III) phosphate.

Etching solutions used in dentistry and orthodontics contain phosphoric acid. Etching cleans and/or roughens the surfaces of teeth where dental appliances or fillings are to be placed. The acid is applied for only a short time and is quickly removed to prevent damage to the enamel of the teeth. This process helps the appliance or filling to stick to the tooth more tightly.

Many fertilizers are made with phosphoric acid. Fertilizers are an important part of the agricultural industry. Care must be taken when choosing the type and amount of a phosphate fertilizer. If too much phosphate is added to soil, it can dissolve in the soil water and pollute waterways.

5 CHAPTER REVIEW

ACHIEVEMENT CHART CATEGORIES

- (k) Knowledge and understanding
- (t) Thinking and investigation
- (c) Communication
- (a) Application

Key Concept Review

1. List several properties of acids and bases. Organize the list using a graphic organizer such as a Venn diagram. (k)

2. What is litmus paper? Describe the two types of litmus paper. (k)

3. What is the pH scale? What pH values correspond to acidic, neutral, and basic solutions? (k)

4. Use the chemical or physical properties identified below to classify each solution as acidic, basic, or neutral. (k)

(a) reacts with magnesium to produce bubbles and conducts electricity

(b) Blue litmus stays blue, and red litmus stays red.

(c) does not conduct electricity, and red litmus stays red

(d) has a pH of 10, and blue litmus stays blue

(e) tastes bitter and does not react with magnesium

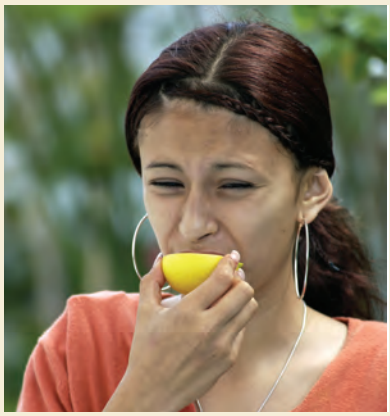
Connect Your Understanding

5. The pH of human blood is usually 7.35–7.45. Is blood normally acidic, neutral, or basic? Explain how you know. (a)

6. Suppose you have a colourless solution. You suspect it is an acid. How could you safely test the liquid to confirm your suspicions? (t)

7. How many times more acidic is a solution of pH 3 compared to a solution of pH 5? (a)

8. The person in the following photograph has just bitten into a sour lemon. Using what you know about the properties of acids and bases, is the lemon acidic or basic? (a)



Question 8

9. From the following formulas, decide whether the compound is an acid, a base, or neither. (a)

(a) $H_2SO_4(aq)$

(b) $CH_3COOH(aq)$

(c) $Mg(OH)_2(aq)$

10. Write the formula for each of the following substances, and indicate whether each is an acid, a base, or neither. (a)

(a) sulphuric acid

(b) calcium hydroxide

(c) hydrogen bromide solution

(d) magnesium hydroxide solution

11. Name each of the following, and indicate whether it is an acid or a base. (a)

(a) $HF(aq)$

(b) $HNO_3(aq)$

(c) $NaOH(aq)$

(d) $NH_4OH(aq)$

(e) $CH_3COOH(aq)$

(f) $H_3PO_4(aq)$

(g) $Ca(OH)_2(aq)$

12. Fish will survive only in water that is within a specific, narrow pH range. Suggest at least two ways that human activities could disrupt the normal pH of bodies of water and cause harm to fish. (a)

13. Suppose that some hydrochloric acid is placed in a beaker and a pH meter is set into the solution. It reads pH 1.5.

(a) Describe how the pH will change when a small amount of NaOH solution is added drop by drop to the acid. (t)

(b) Explain why the pH will change. (a)

14. (a) Chemical reactions in your body produce more acids than bases. How might your body get rid of these extra acids? (a)

(b) How could a lab technician test a urine sample to determine its pH? (a)

15. Your saliva is usually basic.

(a) Suggest how basic saliva helps to protect your health. (k)

(b) Many soft drinks contain sugars, which are converted to acids by bacteria in the mouth. Based on your answer to (a), predict how drinking a lot of acidic soft drinks could affect your dental health. (a)

16. Part of the job of an environmental chemist is to conduct research and design systems and equipment for measuring the quality of air, water, and soil. Suggest some positive aspects of this science and technology career. (a)

17. Use one of the acids or bases discussed in this chapter as a character in a story. Write your story in the first person. For example, your story might begin "I am hydrochloric acid, and this is my story." (c)

18. Choose an acid and a base from the lists in this chapter. Suppose your acid and your base are having a debate about whether acids or bases are more important and useful. Write the dialogue for this debate, using facts about acids and bases from this chapter. (c)

19. Figure 5.6 on page 197 illustrates a visual way to remember the differences between acids and bases. Design your own graphic to help you remember these differences. (c)

20. Ontario produces some of its electricity from coal-fuelled power plants. The government of Ontario plans to shut these power plants down to reduce acid precipitation.

(a) How do coal-fired power plants contribute to acid precipitation? (a)

(b) Describe a technology that can reduce the amount of acid precipitation caused by the operation of a coal-fired power plant. (a)

Reflection

21. Describe at least three things about acids and bases that you did not know before you completed this chapter. (c)

22. What topics that were discussed in this chapter would you like to learn more about? Why? (c)

After Reading

Reflect and Evaluate

Monitoring your understanding of text and having ways to fix up meaning are important reading strategies. List the *During Reading* strategies in this chapter, and evaluate them. Which one was most helpful to you? Rate the other ones from most helpful to not very helpful. Compare your ratings with a partner's, and explain your reasons for the ratings.

Unit Task Link

In the Unit Task, you will have an opportunity to combine HCl(aq) and a piece of Mg ribbon. Do you think that a neutralization reaction will occur between these reactants? Explain your answer.