Acids and Bases

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CHAPTER 1

Acids and Bases

Lesson Objectives

- Describe acids and how to detect them.
- Describe bases and how to detect them.
- Explain what determines the strength of acids and bases.
- Outline neutralization reactions and the formation of salts.

Lesson Vocabulary

- acid
- acidity
- base
- neutralization reaction
- pH
- salt

Introduction

No doubt you are familiar with some common acids. Besides orange juice, vinegar and lemon juice are both acids. Look at the boy in **Figure** 1.1. You can tell by the expression on his face that lemon juice tastes sour. In fact, all acids taste sour. They share certain other properties as well. You will learn more about their properties in this lesson. For a musical rendition of lesson content, go to this URL: http://www.youtube.com/watch?v=zTLiJE-j1-I .

FIGURE 1.1

Like other acids, lemon juice tastes sour.

Acids

An **acid** is an ionic compound that produces positive hydrogen ions (H^+) when dissolved in water. An example is hydrogen chloride (HCl). When it dissolves in water, its hydrogen ions and negative chloride ions (Cl^-) separate, forming hydrochloric acid. This can be represented by the equation:

$$HCl \xrightarrow{H_2O} H^+ + Cl^-$$

Properties of Acids

You already know that a sour taste is one property of acids. (**Never** taste an unknown substance to see whether it is an acid!) Acids have certain other properties as well. For example, acids can conduct electricity because they consist of charged particles in solution. Acids also react with metals to produce hydrogen gas. For example, when hydrochloric acid (HCl) reacts with the metal magnesium (Mg), it produces magnesium chloride ($MgCl_2$) and hydrogen (H_2). This is a single replacement reaction, represented by the chemical equation:

$$Mg + 2HCl \rightarrow H_2 + MgCl_2$$

You can see an online demonstration of a similar reaction at this URL: http://www.youtube.com/watch?v=oQz5YEsx7Fo .

Detecting Acids

Certain compounds, called indicators, change color when acids come into contact with them. They can be used to detect acids. An example of an indicator is a compound called litmus. It is placed on small strips of paper that may be red or blue. If you place a few drops of acid on a strip of blue litmus paper, the paper will turn red. You can see this in **Figure** 1.2. Litmus isn't the only indicator for detecting acids. Red cabbage juice also works well, as you can see in this entertaining video: http://www.youtube.com/watch?v=vrOUdoS2BtQ .

FIGURE 1.2

Blue litmus paper turns red when placed in an acidic solution.

Uses of Acids

Acids have many important uses, especially in industry. For example, sulfuric acid is used to manufacture a variety of different products, including paper, paint, and detergent. Some other uses of acids are illustrated in **Figure** 1.3.

Both nitric acid and phosphoric acid are used to make fertilizer.

Hydrochloric acid is used to clean swimming pools, bricks, and concrete.

Sulfuric acid is an important component of car batteries.

FIGURE 1.3

Acids are used widely for many purposes.

Bases

A **base** is an ionic compound that produces negative hydroxide ions (OH^-) when dissolved in water. For example, when the compound sodium hydroxide (NaOH) dissolves in water, it produces hydroxide ions and positive sodium ions (Na^+). This can be represented by the equation:

$$NaOH \xrightarrow{H_2O} OH^- + Na^+$$

Properties of Bases

All bases share certain properties, including a bitter taste. (**Never** taste an unknown substance to see whether it is a base!) Did you ever taste unsweetened cocoa powder? It tastes bitter because it is a base. Bases also feel slippery. Think about how slippery soap feels. Soap is also a base. Like acids, bases conduct electricity because they consist of charged particles in solution.

Detecting Bases

Bases change the color of certain compounds, and this property can be used to detect them. A common indicator of bases is red litmus paper. Bases turn red litmus paper blue. You can see an example in **Figure** 1.4. Red cabbage juice can detect bases as well as acids, as you'll see by reviewing this video: http://www.youtube.com/watch?v=vrOUdoS2BtQ (3:14).

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FIGURE 1.4

Red litmus paper turns blue when placed in a basic solution.

Uses of Bases

Bases are used for a variety of purposes. For example, soaps contain bases such as potassium hydroxide. Other uses of bases are pictured in **Figure** 1.5.

Many cleaning products contain bases such as sodium hydroxide.

Concrete contains the base calcium hydroxide.

Deodorant may contain the base aluminum hydroxide.

FIGURE 1.5

Bases are used in many products.

Strength of Acids and Bases

The acid in vinegar is weak enough to safely eat on a salad. The acid in a car battery is strong enough to eat through skin. The base in antacid tablets is weak enough to take for an upset stomach. The base in drain cleaner is strong enough to cause serious burns. What causes these differences in strength of acids and bases?

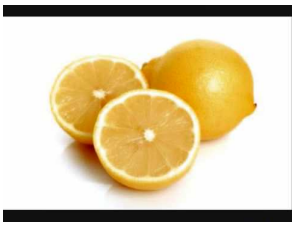
Concentration of Ions

The strength of an acid depends on the concentration of hydrogen ions it produces when dissolved in water. A stronger acid produces a greater concentration of ions than a weaker acid. For example, when hydrogen chloride is added to water, all of it breaks down into H^+ and Cl^- ions. Therefore, it is a strong acid. On the other hand, only about 1 percent of acetic acid breaks down into ions, so it is a weak acid.

The strength of a base depends on the concentration of hydroxide ions it produces when dissolved in water. For example, sodium hydroxide completely breaks down into ions in water, so it is a strong base. However, only a fraction of ammonia breaks down into ions, so it is a weak base.

The pH Scale

The strength of acids and bases is measured on a scale called the pH scale (see **Figure** 1.6). The symbol **pH** represents **acidity**, or the concentration of hydrogen ions (H^+) in a solution. Pure water, which is neutral, has a pH of 7. With a higher concentration of hydrogen ions, a solution is more acidic but has a lower pH. Therefore, acids have a pH less than 7, and the strongest acids have a pH close to zero. Bases have a pH greater than 7, and the strongest bases have a pH close to 14. You can watch a video about the pH scale at this URL: http://www.youtube.com/watch?v=M8tTELZD5Ek (2:23).



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Why pH Matters

Acidity is an important factor for living things. For example, many plants grow best in soil that has a pH between 6 and 7. Fish also need a pH close to 7. Some air pollutants form acids when dissolved in water droplets in the air. This results in acid fog and acid rain, which may have a pH of 4 or even lower (see **Figure** 1.6). **Figure** 1.7 shows the effects of acid fog and acid rain on a forest. Acid rain also lowers the pH of surface waters such as streams and lakes. As a result, the water became too acidic for fish and many other water organisms to survive.

Even normal (not acid) rain is slightly acidic. That's because carbon dioxide in the air dissolves in raindrops, producing a weak acid called carbonic acid. When acidic rainwater soaks into the ground, it can slowly dissolve rocks, particularly those containing calcium carbonate. This is how water forms caves, like the one that opened this chapter.

Reactions of Acids and Bases

As you read above, an acid produces positive hydrogen ions and a base produces negative hydroxide ions. If an acid and base react together, the hydrogen and hydroxide ions combine to form water. This is represented by the equation:

$$H^+ + OH^- \rightarrow H_2O$$

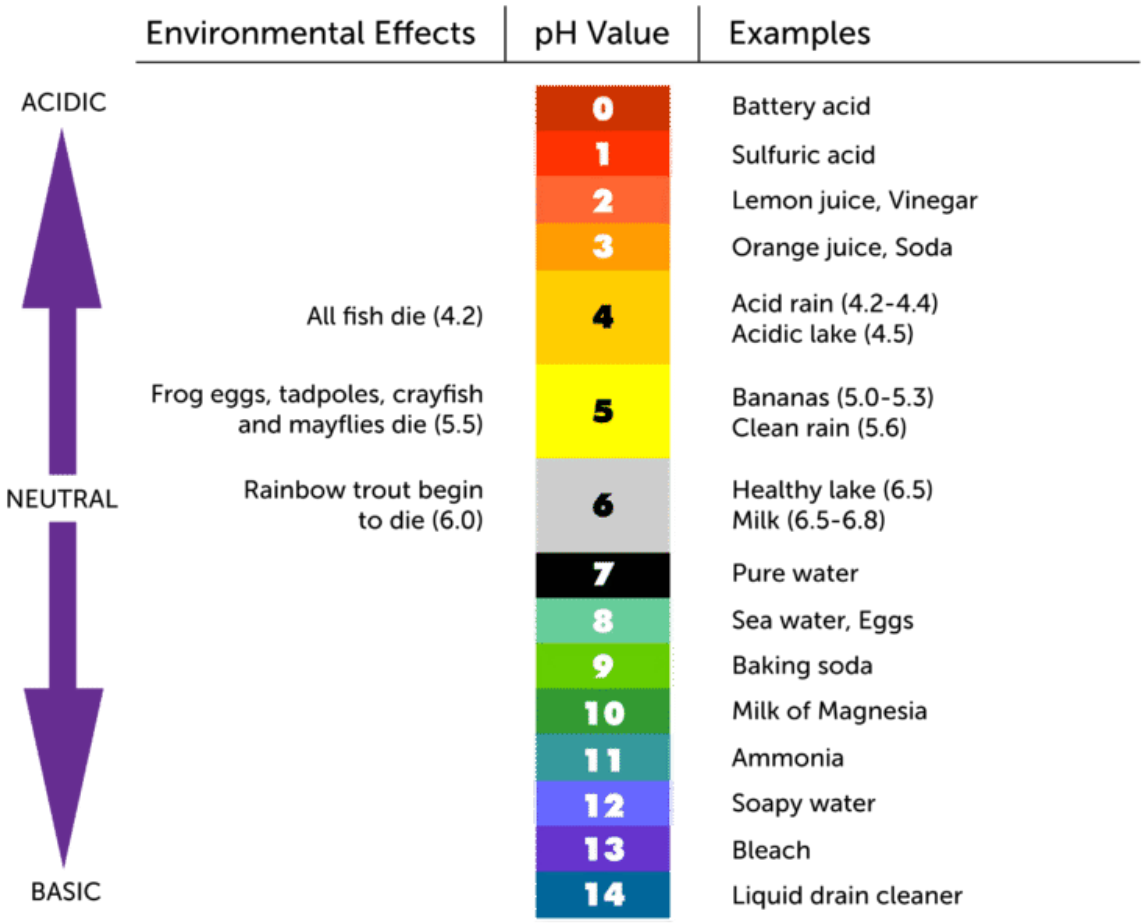

FIGURE 1.6

This pH scale shows the acidity of several common acids and bases. Which substance on this scale is the weakest acid? Which substance is the strongest base?

An acid also produces negative ions, and a base also produces positive ions. For example, the acid hydrogen chloride (HCl), when dissolved in water, produces negative chloride ions (Cl^-) as well as hydrogen ions. The base sodium hydroxide (NaOH) produces positive sodium ions (Na^+) in addition to hydroxide ions. These other ions also combine when the acid and base react. They form sodium chloride (NaCl). This is represented by the equation:

$$Na^+ + Cl^- \rightarrow NaCl$$

Sodium chloride is called table salt, but salt is a more general term. A **salt** is any ionic compound that forms when an acid and base react. It consists of a positive ion from the base and a negative ion from the acid. Like pure water, a salt is neutral in pH. That's why reactions of acids and bases are called **neutralization reactions**. Another example of a neutralization reaction is described in **Figure** 1.8. You can learn more about salts and how they form at this

FIGURE 1.7

Acid fog and acid rain killed the trees in this forest.

URL: http://www.youtube.com/watch?v=zjIVJh4JLNo (13:21).

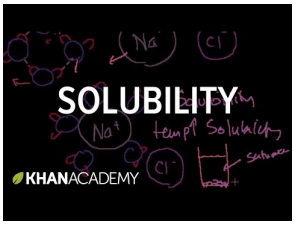

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FIGURE 1.8

What neutral products are produced when antacid tablets react with hydrochloric acid in the stomach?

Lesson Summary

- An acid is an ionic compound that produces positive hydrogen ions when dissolved in water. Acids taste sour and turn blue litmus paper red.
- A base is an ionic compound that produces negative hydroxide ions when dissolved in water. Bases taste bitter and turn red litmus paper blue.
- The strength of acids and bases is determined by the concentration of ions they produce when dissolved in water. The concentration of hydrogen ions in a solution is called acidity. It is measured by pH. A neutral substance has a pH of 7. An acid has a pH lower than 7, and a base has a pH greater than 7.
- The reaction of an acid and a base is called a neutralization reaction. It produces a salt and water, both of which are neutral.

Lesson Review Questions

Recall

1. What is an acid? Give one use of acids.
2. What is a base? Name a common product that contains a base.
3. Outline how litmus paper can be used to detect acids and bases.
4. Define acidity. How is it measured?

Apply Concepts

5. An unknown substance has a pH of 7.2. Is it an acid or a base? Explain your answer.
6. If hydrochloric acid (HCl) reacts with the base lithium hydroxide (LiOH), what are the products of the reaction? Write a chemical equation for the reaction.

Think Critically

7. Battery acid is a stronger acid than lemon juice. Explain why.

Points to Consider

Neutralization reactions, like the other chemical reactions you have read about so far, involve electrons. Electrons are outside the nucleus of an atom. Certain other reactions involve the nucleus of an atom instead. These reactions are called nuclear reactions. You will read about them in the next chapter, "Nuclear Chemistry."

- How do you think nuclear reactions might differ from chemical reactions?
- Elements involved in nuclear reactions are radioactive. How do you think radioactive elements differ from other elements?

References

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