CONCEPT 4

In a neutralization reaction, an acid reacts with a base.

Activity

What Reaction Type Is Neutralization?

Complete your summary of reaction types when you finish this concept. What are some ways that have helped you remember what happens to the atoms in the different types of reactions? After learning about neutralization reactions, describe another way you might classify this type of reaction.

Figure 2.38 Acids in citrus fruits such as this fingered citron makes them taste sour.

Many substances that you encounter every day are acids or bases. For example, the sour taste of citrus fruits such as grapefruit and lemons is due to the presence of acidic compounds (**Figure 2.38**). The bitter taste of coffee and the slippery feel of soap are due to the presence of basic compounds. Compounds may be classified as acids or bases depending on how they interact with water.

Acids

An **acid** is a substance that releases hydrogen ions, $H^+(aq)$, in an aqueous solution. For example, when hydrogen chloride gas is mixed with water, $H^+(aq)$ and $Cl^-(aq)$ form. Therefore, HCl(aq) is called an acidic solution.

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

acid compound that forms H^+ ions when dissolved in water

Acids include two broad categories. *Binary acids* are composed of two elements: hydrogen and a non-metal, such as HCl(aq). *Oxyacids* are composed of hydrogen, oxygen, and another element—for example, an acid with a polyatomic ion, such as $H_2CO_3(aq)$. The chemical formula of an acid can often be recognized by the presence of one or more hydrogen ions with a negative ion. **Table 2.1** lists some common acids.

Table 2.1 Common Acids and Their Uses

Chemical Formula	Classical Name	IUPAC Name	Uses
HCl(aq)	hydrochloric acid	aqueous hydrogen chloride	producing plastics and processing metals
HF(aq)	hydrofluoric acid	aqueous hydrogen fluoride	manufacturing and etching glass
$H_2SO_4(aq)$	sulfuric acid	aqueous hydrogen sulfate	in car batteries
$HNO_3(aq)$	nitric acid	aqueous hydrogen nitrate	making explosives and fertilizers
$H_2CO_3(aq)$	carbonic acid	aqueous hydrogen carbonate	in carbonated drinks
$CH_3COOH(aq)$	acetic acid	aqueous hydrogen acetate, or ethanoic acid	in vinegar

Bases

A **base** is a substance that releases hydroxide ions, $OH^-(aq)$, in an aqueous solution. For example, when sodium hydroxide crystals dissolve in water, the ions $Na^+(aq)$ and $OH^-(aq)$ form.

$$NaOH(s) \longrightarrow Na^+(aq) + OH^-(aq)$$

Therefore, $NaOH(aq)$ is called a basic solution.

base a compound that forms OH^- ions when dissolved in water

Table 2.2 lists the names, chemical formulas, and uses for some common bases. Many bases are ionic compounds composed of metal ions and hydroxide ions. The chemical formula for a base includes enough hydroxide ions in the formula to make the total charge of the compound zero.

Table 2.2 Common Bases and Their Uses

Chemical Formula	Common Name	IUPAC Name	Uses
NaOH(aq)	lye, caustic soda	sodium hydroxide	in drain cleaners, used in making soaps and paper
$Mg(OH)_2(aq)$	Milk of Magnesia®	magnesium hydroxide	antacids and laxatives
$Ca(OH)_2(aq)$	lime water	calcium hydroxide	soil and water treatment

Extending the Connections

Naming Acids and Bases

Like other compounds, acids and bases are named according to certain guidelines. Find out how the naming of acids and bases compares with naming other compounds.

Identifying Acids and Bases

Most common acids and bases form colourless solutions in water. One way to identify them is to use an **acid-base indicator**. This is a chemical that changes colour in response to whether it is exposed to an acid or a base. A common acid-base indicator is litmus. Litmus solution is often dried on thin paper strips (Figure 2.39).

acid-base indicator a chemical that changes colour in response to the concentration of hydrogen ions in a solution

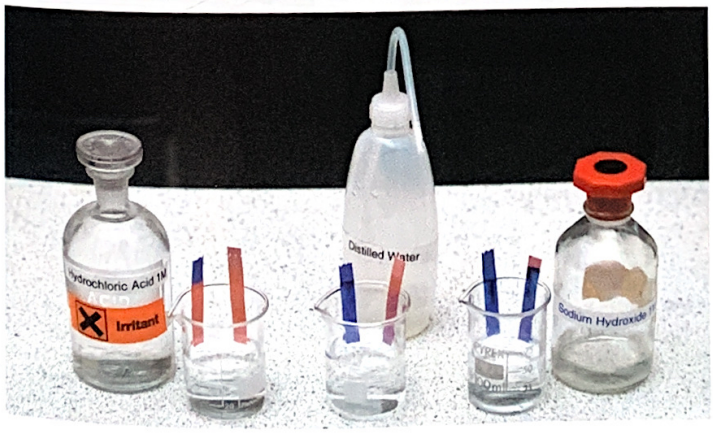

Figure 2.39 Blue litmus paper turns red in an acidic solution, and red litmus paper turns blue in a basic solution. **Evaluating: Why did neither change colour in the water?**

Activity

The Litmus Test

Your teacher will supply you with samples of materials to test. Make a prediction for each. Which samples do you think are basic, acidic, or neither? Place a small amount of each sample in a well of a spot plate. Make sure to keep track of what sample was added to which well. Dip a small piece of blue and red litmus paper into each well. Record your observations. How did your results compare with your predictions?

The pH Scale

pH scale a numbered scale between 0 and 14 that indicates the acidity or basicity of a solution

To more accurately determine how acidic or basic a solution is, chemists use the pH scale and instruments to measure pH. The **pH scale** typically ranges from 0 to 14. It provides a way to measure the acidity and basicity of solutions. Figure 2.40 shows the pH scale and pH values of some common substances.

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Acidic Solutions: pH < 7

Acids have pH values below 7. The lower the pH value, the more acidic the solution. This means there are many more hydrogen ions in the solution than hydroxide ions. For example, a lemon at pH = 2 is more acidic than milk at pH = 6 and has a greater number of H^+ ions. Each time the pH value changes by one unit, the number of H^+ ions changes by 10 times. The lemon at pH = 2 has 10^4 or 10 000 times more hydrogen ions than milk at pH = 6.

Basic Solutions: pH > 7

Bases have pH values above 7. This means there are many more hydroxide ions in the solution than hydrogen ions. The higher the pH, the more basic the solution is. For example, oven cleaner at pH = 13 is more basic than eggs at pH = 8.

Neutral Solutions: pH = 7

A solution that is neither acidic nor basic is neutral and falls in the middle of the pH scale at pH = 7. This means there are equal numbers of hydrogen ions and hydroxide ions in the solution. Pure water has a pH of 7, as do solutions of some compounds such as sodium chloride.

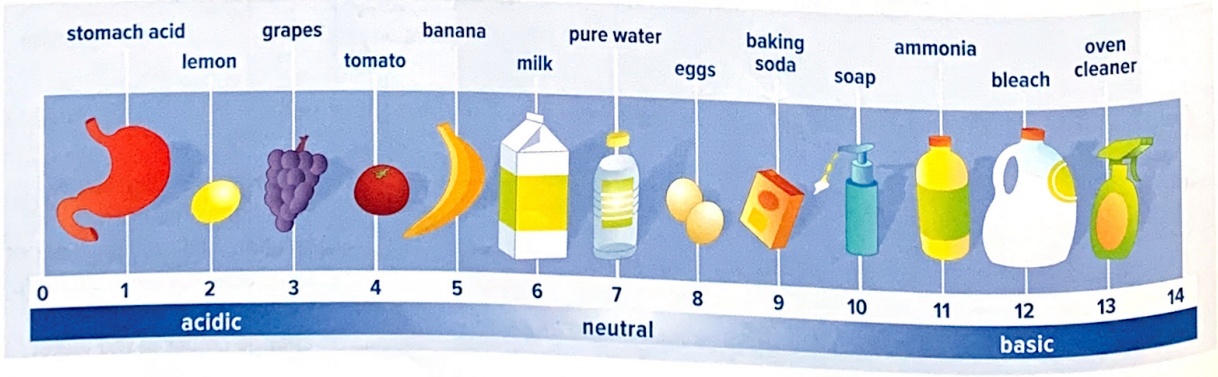

Figure 2.40 The pH scale ranges from 0 to 14.

Extending the Connections

Measuring pH

In the laboratory, there are several ways to determine how acidic or basic a solution is. Some indicators can provide a range of possible pH values for the solution, while universal indicators turn different colours at particular pH values. The most accurate method is to use a pH meter, which directly measures the pH. Choose one of these approaches to investigate further. What questions do you have? How can you answer them?

Acid-Base Neutralization

A **neutralization reaction** is a chemical reaction between an acid and a base that produces water and a salt (a type of ionic compound). A general equation for the reaction between an acid and a base can be represented as

$$\underset{\text{Acid}}{HA} + \underset{\text{Base}}{BOH} \rightarrow \underset{\text{Salt}}{BA} + \underset{\text{Water}}{HOH}$$

Notice that this reaction is actually a type of double replacement reaction. The ions of the reactants switch places to form two new compounds. The water forms as the hydrogen ions of the acid and the hydroxide ions of the base combine. The other ions form the salt.

When an acid and a base are added together, it results in the removal of hydrogen ions and hydroxide ions from the solution, since their combination produces water. This causes the pH of the solution to approach 7. Figure 2.41 shows a neutralization reaction. Notice how all the solutions are colourless. The progress of a neutralization reaction can be followed by measuring the pH of the solution as the acid and base are combined.

neutralization reaction a chemical reaction in which an acid reacts with a base to form a salt and water

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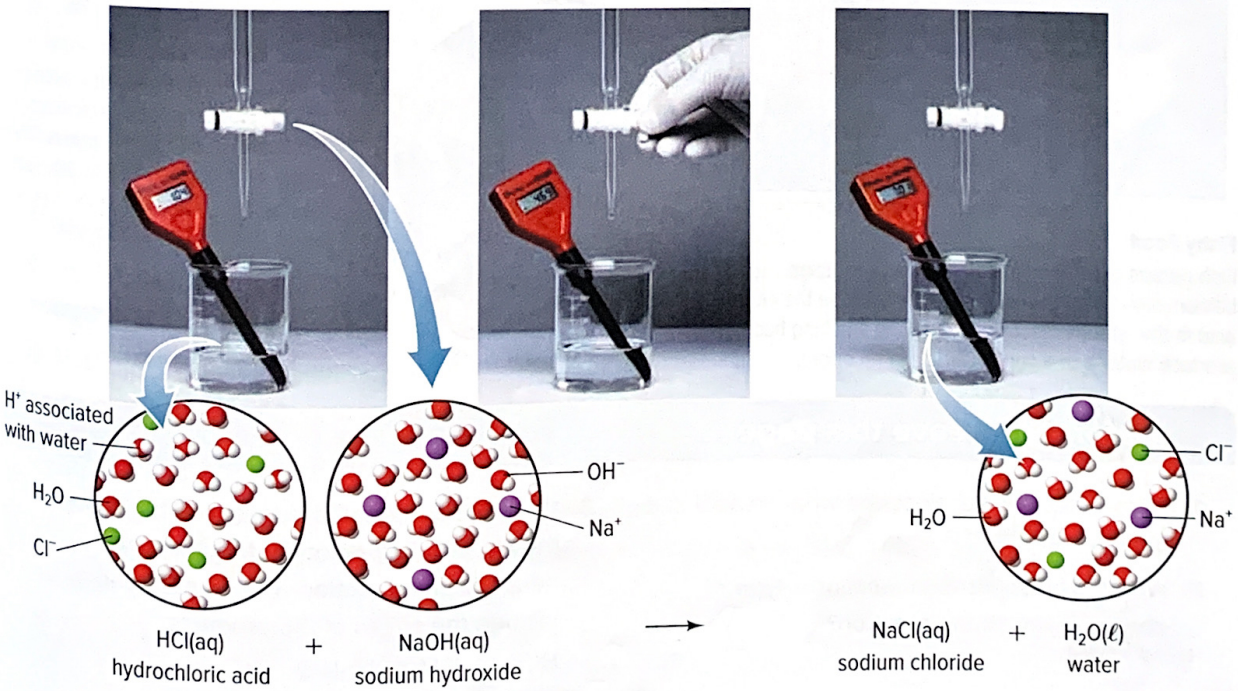


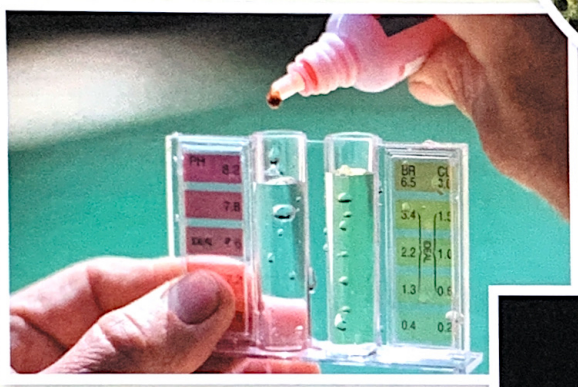
Figure 2.41 For all neutralization reactions, there is a net transfer of energy from the system to the surroundings. **Applying: Are neutralization reactions exothermic or endothermic?**

Neutralization Reactions in Our World

Neutralization is not just a chemical reaction that scientists carry out in the laboratory. It is one of the most common chemical reactions in everyday life. **Figure 2.42** shows a few examples of how we rely on reactions between acids and bases.

Figure 2.42
From medicinal products to our environment, neutralization reactions have many applications.

Antacids
The gastric pits in stomach lining secrete hydrochloric acid. Excess acid can cause a burning sensation in the stomach, chest, and throat. Antacids ease these symptoms, because they include basic hydroxide or carbonate compounds.



pH Adjustments
Monitoring pH is part of the regular maintenance of swimming pools and aquariums. Setting the correct pH relies on neutralization reactions so the water is safe to use.

Acid Precipitation
Acid precipitation can harm crops and aquatic ecosystems. Adding crushed limestone (called liming) is used to raise the pH of an affected area. Crushed limestone is mostly calcium carbonate.

Fishy Food
Fish odours are due to molecules that are bases. Lemon juice "neutralizes" the odour because the citric acid in the lemons reacts with the fishy-smelling base to produce water and a salt, which have no odour.

Chemical Spills
In 2005, a train derailment spilled 40 000 L of caustic soda (sodium hydroxide) into the Cheakamus River near Squamish, killing 500 000 fish. What is the condition of this river today, and who is responsible?

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Before you leave this page . . .

1. In your own words, describe what an acid and a base are.
2. Why is a neutralization reaction a type of double replacement reaction?
3. Write the predicted products and balance the chemical equation for the following neutralization reaction. You do not need to include the states of the products.

$HCl(aq) + Mg(OH)_2(aq) \longrightarrow$

Identifying Reaction Types

Now that you have learned about the six types of reactions, use the following Sample and Practice Problems to help you identify the type of reaction that a chemical equation represents.

Sample Problem 1:

Predicting the Products of a Synthesis Reaction

Identify the type of reaction. Then predict the products and give the balanced chemical equation.

$$Al + F_2 \rightarrow$$

Solution

1. This reaction has two reactants and both are elements. Therefore, this is a synthesis reaction.
2. Since one reactant is a metal and the other reactant is a non-metal, the product will be a binary ionic compound composed of ions of both elements. Aluminum forms a Al^{3+} ion and fluorine forms a F^- ion. Therefore, they will produce the compound, AlF_3
3. Write the skeleton equation with the reactants and predicted product.

   $Al + F_2 \rightarrow AlF_3$
4. Write the balanced chemical equation.

   $2Al + 3F_2 \rightarrow 2AlF_3$

Sample Problem 2:

Predicting the Products of a Decomposition Reaction

Identify the type of reaction. Then predict the products and give the balanced chemical equation.

$$Mg_3N_2 \rightarrow$$

Solution

1. This reaction has only one reactant. Therefore, this is a decomposition reaction.
2. The products will be the separate elements, Mg and N_2.
3. Write the skeleton equation with the reactant and predicted products.

   $Mg_3N_2 \rightarrow Mg + N_2$
4. Write the balanced chemical equation.

   $Mg_3N_2 \rightarrow 3Mg + N_2$

Sample Problem 3:

Predicting the Products of a Replacement Reaction

Identify the type of reaction. Then predict the products and give the balanced chemical equation.

$$Al + Pb(NO_3)_2 \rightarrow$$

Solution

1. This reaction has two reactants; one is an element and the other is a compound. Therefore, this is a single replacement reaction.
2. Aluminum is a metal and it will replace lead(II) ions in the compound to form the compound $Al(NO_3)_3$. The element lead will be the other product.
3. Write the skeleton equation with the reactants and predicted products.

   $Al + Pb(NO_3)_2 \rightarrow Pb + Al(NO_3)_3$
4. Write the balanced chemical equation.

   $2Al + 3Pb(NO_3)_2 \rightarrow 3Pb + 2Al(NO_3)_3$

Sample Problem 4:

Predicting the Products of a Hydrocarbon Combustion Reaction

Identify the type of reaction. Then predict the products and give the balanced chemical equation.

$$C_3H_8 + O_2 \rightarrow$$

1. This reaction has two reactants; one is oxygen and the other is a hydrocarbon, which is called propane. Therefore, this represents the combustion of a hydrocarbon.
2. The products of the combustion of a hydrocarbon are carbon dioxide and water.
3. Write the skeleton equation with the reactants and predicted products.

   $C_3H_8 + O_2 \rightarrow CO_2 + H_2O$
4. Write the balanced chemical equation. A common strategy for balancing these types of equations involves balancing the carbons first, then the hydrogens, and then the oxygens.

   $C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_2O$

Practice Problems

Identify the type of reaction. Then predict the products and give the balanced chemical equation.

1. $Al + CuCl_2 \rightarrow$
2. $NaCl + AgNO_3 \rightarrow$
3. $C_6H_{14} + O_2 \rightarrow$
4. $Ca(OH)_2 + HCl \rightarrow$
5. $KI \rightarrow$
6. $Zn + N_2 \rightarrow$
7. $Cd + Au(NO_3)_3 \rightarrow$
8. $Fe_2O_3 \rightarrow$
9. $K + Cl_2 \rightarrow$
10. $Cl_2 + CsBr \rightarrow$