

3.3 Types of Chemical Reactions

Chemists classify reactions to make it easier to predict the products of reactions and recognize new reactions. You have already learned one way to classify reactions — as endothermic or exothermic. There are other ways in which chemical reactions can be classified. In the following activity, model different chemical reactions and look for patterns that can help you classify them.

Modelling Chemical Reactions



You can develop a classification system for chemical reactions by paying close attention to patterns in the products and reactants involved.

Materials

blank paper
coloured pencils or markers

Procedure • Performing and Recording

- Working in groups, you will make drawings to represent atoms and model chemical reactions. First, copy the following word equation into your notebook:
 $\text{iron} + \text{sulfur} \rightarrow \text{iron(II) sulfide}$
- Under the word equation, write the skeleton equation for the reaction.
- Choose one colour to represent iron atoms, and another colour to represent sulfur atoms. Draw diagrams to represent an iron atom and a sulfur atom.
- Draw diagrams in your notebook to represent the reaction. Use shaded or coloured circles to represent atoms.
- Repeat steps 1–4 for your assigned reactions.
 - $\text{calcium} + \text{oxygen gas} \rightarrow \text{calcium oxide}$
 - $\text{calcium oxide} + \text{carbon dioxide} \rightarrow \text{calcium carbonate}$
 - $\text{copper(II) oxide} \rightarrow \text{copper} + \text{oxygen gas}$
 - $\text{water} \rightarrow \text{hydrogen gas} + \text{oxygen gas}$

Find Out



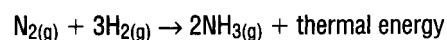
- $\text{potassium} + \text{water} \rightarrow \text{potassium hydroxide} + \text{hydrogen gas}$
 - $\text{zinc} + \text{tin(II) chloride} \rightarrow \text{zinc chloride} + \text{tin}$
 - $\text{copper} + \text{silver nitrate} \rightarrow \text{copper(II) nitrate} + \text{silver}$
 - $\text{potassium iodide} + \text{lead(II) nitrate} \rightarrow \text{potassium nitrate} + \text{lead(II) iodide}$
 - $\text{sodium chloride} + \text{silver nitrate} \rightarrow \text{sodium nitrate} + \text{silver chloride}$
 - $\text{barium chloride} + \text{potassium sulfate} \rightarrow \text{barium sulfate} + \text{potassium chloride}$
- Compare your diagrams with the diagrams of other groups.

What Did You Find Out? • Analyzing and Interpreting

- Think about the diagrams for the following groups of reactions:
 - (a) and (b)
 - (c) and (d)
 - (e), (f), and (g)
 - (h), (i), and (j)For each reaction, compare the products with the reactants. What do the reactions in each group have in common?
- Develop a classification system for the chemical reactions you observed in this activity.
- For each class of reaction, try to find one example in this unit that is not listed in Procedure question 6.



Figure 3.15 Fertilizers contain nitrogen compounds such as ammonia, which plants can use easily. The following exothermic formation reaction is used to produce ammonia.

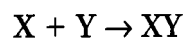


Farmers often supply nitrogen to their crops by applying fertilizers as shown in the photograph.

Chemists often use five broad categories to classify reactions. These categories are formation (or synthesis) reactions, decomposition reactions, single-replacement reactions, double-replacement reactions, and hydrocarbon combustion. Each name provides a clue about the reaction type.

Formation Reactions

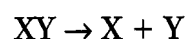
In a **formation** (or synthesis) **reaction**, *two or more reactants combine to produce a new product*. This general equation represents a formation reaction:



Often the reactants in formation reactions are elements. Figures 3.15 and 3.16 provide some examples of formation reactions.

Decomposition Reactions

In a **decomposition reaction**, *one compound breaks down into two or more simpler compounds or elements*. The general equation of a decomposition reaction is:



You can think of decomposition reactions as the opposite of formation reactions. Figures 3.17 and 3.18 show several examples of decomposition reactions.



Figure 3.16 Energy released by the formation reaction between liquid hydrogen and liquid oxygen helps to propel the space shuttle into orbit.

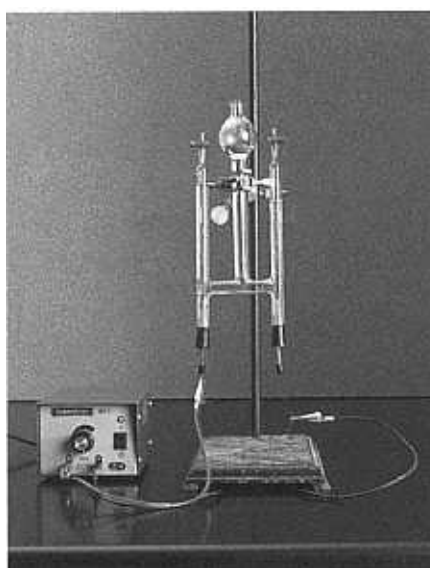
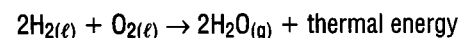


Figure 3.17 Passing electricity through water will decompose it into hydrogen and oxygen. This process is called electrolysis. Compare this reaction to the reaction shown in Figure 3.16.

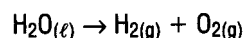
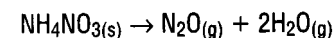
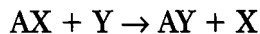
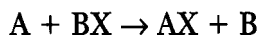


Figure 3.18 Decomposition reactions sometimes occur explosively. For example, when ammonium nitrate is heated, it explodes, forming dinitrogen monoxide and water.

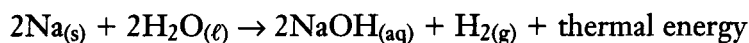


Single-Replacement Reactions

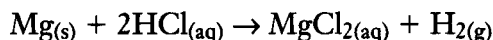
In a **single-replacement reaction**, *one element takes the place of (replaces) another element in a compound*. There are two general forms of equations for a single-replacement reaction:



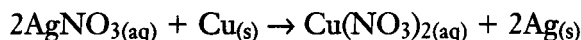
Many single-replacement reactions involve the reaction between a metal and a compound. Some metals react with water to produce hydrogen gas. Other metals are unreactive. All the alkali metals are able to displace hydrogen from water in single-replacement reactions such as the following:



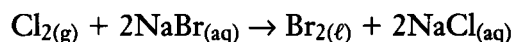
Metals that are not reactive enough to displace hydrogen from water may be able to replace hydrogen in an acid. For example, magnesium does not react significantly with water at room temperature, but it generates hydrogen gas with hydrochloric acid, $\text{HCl}_{(aq)}$:



Valuable silver can be recovered from a solution that contains silver ions by using copper.

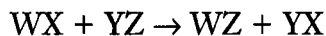


Single-replacement reactions can involve the reaction of a halogen and a halogen-containing compound. The elemental halogen replaces the halogen that is part of the compound. For example, the reaction of chlorine gas and aqueous sodium bromide forms liquid bromine and aqueous sodium chloride.

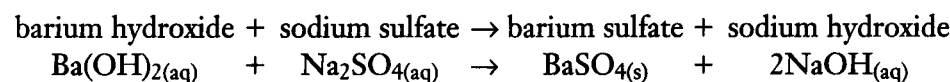


Double-Replacement Reactions

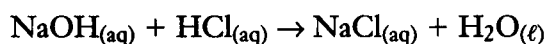
In a **double-replacement reaction**, *the cations of two different compounds exchange places, forming two new compounds*. The general form of the equation is:



In many double-replacement reactions, either a precipitate or water forms as one of the products. For example, aqueous solutions of barium hydroxide and sodium sulfate are both clear and colourless. When the solutions are mixed, a white precipitate of barium sulfate forms.



The reaction between an acid and a base is a special kind of double-replacement reaction called **neutralization**. For example, the reaction between sodium hydroxide solution and hydrochloric acid produces a harmless aqueous solution of sodium chloride (see Figure 3.19):



DidYouKnow?

The single-replacement reaction between sodium and water produces enough thermal energy to ignite some of the substances involved.



STRETCH Your Mind

Think of water as hydrogen hydroxide, $\text{H}-\text{OH}$. When hydrogen hydroxide combines with sodium, a sodium atom takes the place of the hydrogen atom to form sodium hydroxide, NaOH . The displaced hydrogen atoms combine to form hydrogen gas.

Try writing the balanced chemical equation for the single replacement reaction between potassium, $\text{K}_{(s)}$, and water.



Figure 3.19 Aqueous solutions of two dangerous, corrosive compounds, hydrochloric acid and sodium hydroxide, combine to form water and chemically safe sodium chloride.

INVESTIGATION 3-C

Analyzing an Industrial Process

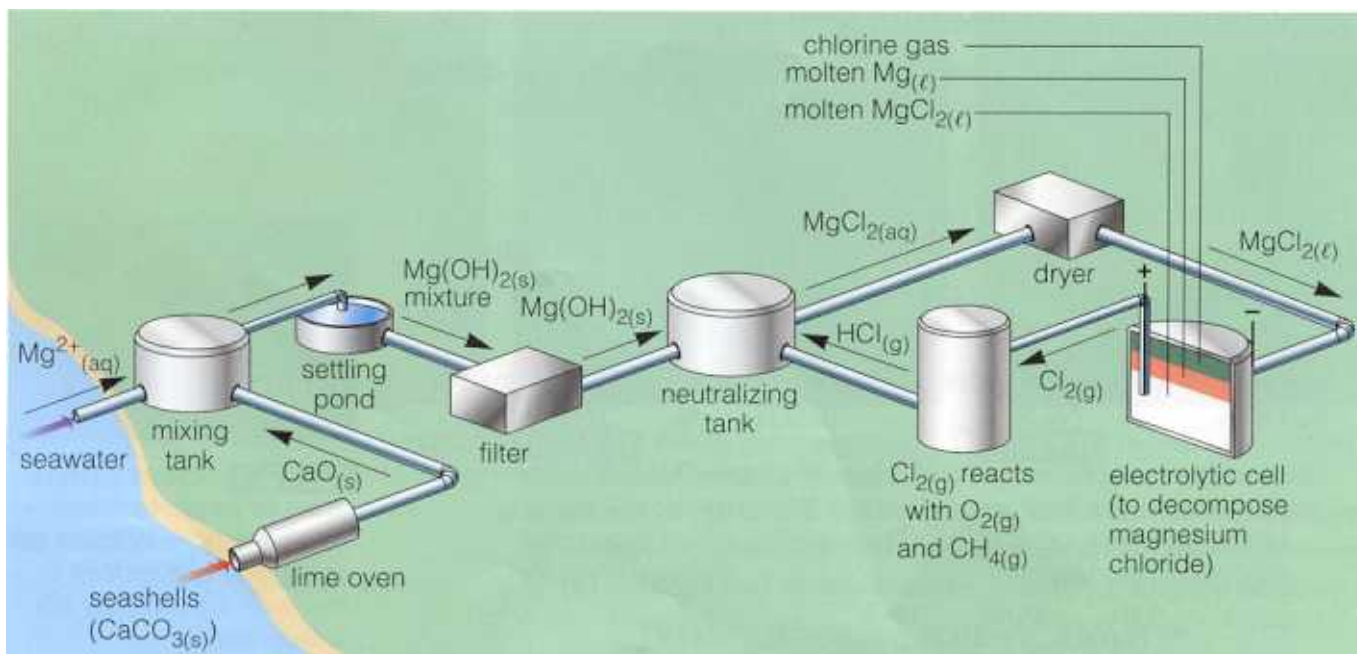
Think About It

Magnesium and its compounds have numerous applications in the world around you. If you have ever flown in a jet airplane, driven in a car, or enjoyed a fireworks display, magnesium has touched your life. Magnesium touches your life in another vital way, as well. It is a nutrient that your body's cells need to release energy from food and perform other life functions. Compounds such as magnesium oxide are also used to make fertilizers and insulation for pipes, refine sugar, and treat waste water.

What to Do

The diagram shows how magnesium is obtained commercially from seawater, using a technique called the Dow process. The raw materials are methane, seawater, and seashells. Examine the diagram, and the numbered steps, to identify the chemical reactions involved.

- 1 Seashells are mostly calcium carbonate, $\text{CaCO}_3(\text{s})$. They are heated to produce calcium oxide and carbon dioxide.
 - (a) Write the word equation and the balanced chemical equation.
 - (b) Identify the type of chemical reaction.
- 2 The calcium oxide is added to seawater, and a number of changes occur. First calcium oxide reacts with water to form calcium hydroxide.
 - (a) Write the word equation and the balanced chemical equation.
 - (b) Identify the type of chemical reaction.



Next the calcium hydroxide reacts with magnesium ions, $\text{Mg}^{2+}_{(\text{aq})}$, in the seawater to produce magnesium hydroxide and calcium ions.

(c) Write the word equation and the balanced chemical equation.

(d) Identify the type of chemical reaction.

- 3 Magnesium hydroxide is insoluble. It is pumped as a suspension through filters. Does separating $\text{Mg}(\text{OH})_{2(\text{s})}$ from the water need to involve a chemical reaction? Explain your answer.

- 4 In the next step, the magnesium hydroxide reacts with hydrochloric acid to produce an aqueous solution of magnesium chloride and water.

(a) Write the word equation and the balanced chemical equation.

(b) Identify the type of chemical reaction.

- 5 Water is evaporated from the magnesium chloride solution. The resulting solid is melted at 700°C and decomposed by passing electric current through it.

(a) What is the name of the physical change that occurs first in the magnesium chloride?

(b) Write the balanced chemical equation for this step.

(c) Identify the type of chemical reaction.

- 6 One of the products in step 5 is chlorine gas. This can be burned with natural gas, which is mostly methane, $\text{CH}_{4(\text{g})}$, and oxygen to provide the hydrochloric acid needed for step 4.



(a) Balance the skeleton equation for this reaction.

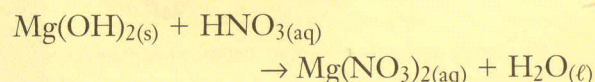
(b) Classify the chemical reaction, if possible. If not, explain why not.

Extend Your Knowledge

When the space shuttle *Challenger* exploded in 1986, scientists recovered the data recorder from the ocean several weeks after the accident. They were not able to analyze the tape at first because magnesium from the recorder case had reacted with the seawater. The tapes were coated with insoluble magnesium hydroxide, $\text{Mg}(\text{OH})_{2(\text{s})}$, which had to be removed.

1. Write a balanced chemical equation for the reaction between water and magnesium to form magnesium hydroxide and hydrogen, and identify the type of reaction.

2. Scientists removed the magnesium hydroxide by reacting it carefully with nitric acid, $\text{HNO}_{3(\text{aq})}$. The skeleton equation is



Balance the equation, and identify the type of reaction.

3. Why was magnesium hydroxide converted to magnesium nitrate?

INTERNET CONNECT

www.mcgrawhill.ca/links/sciencefocus10

What other roles does chemistry play in analyzing and restoring sunken artifacts? Find out by visiting the website above. Click on **Web Links** to find out where to go next. Make a flowchart of one of the chemical processes you discover.

DidYouKnow?

Numerous different hydrocarbons make up crude oil. Crude oil is the second most common liquid on Earth. Most scientists believe that crude oil is formed from the remains of organisms that lived millions of years ago.

Reactions Involving Carbon Compounds

The study of carbon-containing compounds and their properties is called **organic chemistry**. A few carbon-containing compounds (such as carbon dioxide, carbon monoxide, and ionic carbonates) are not considered organic. This still leaves millions of different compounds, however. In fact, organic compounds far outnumber inorganic compounds.

A **hydrocarbon** is an organic compound that contains only the elements carbon and hydrogen. People obtain useful hydrocarbons by refining crude oil and natural gas. About 95 percent of these hydrocarbons are burned as fuels in exothermic combustion reactions. The resulting thermal energy warms homes, businesses, and schools, and provides energy for transportation.

When hydrocarbons such as those in Figures 3.20 and 3.21 are burned in a plentiful supply of oxygen, **complete combustion** occurs. This reaction produces carbon dioxide and water vapour, and releases thermal energy.

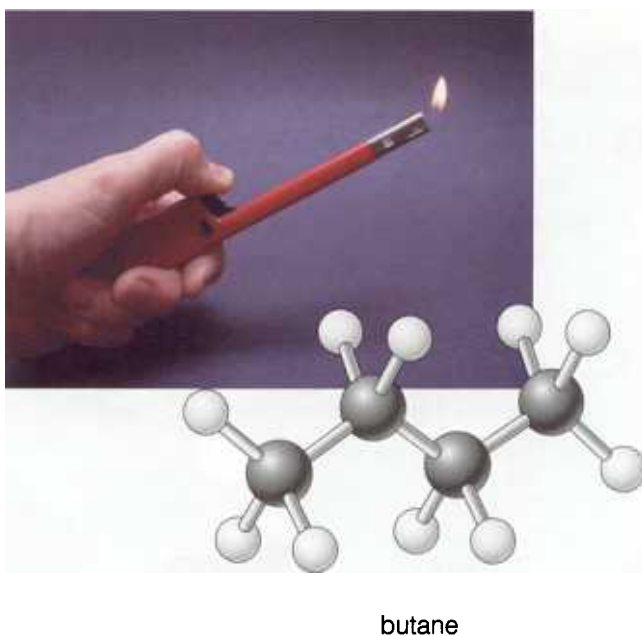
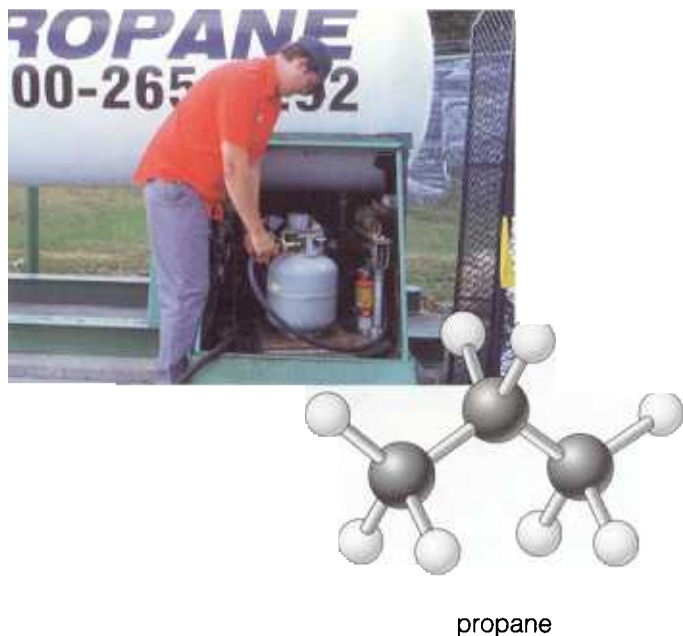
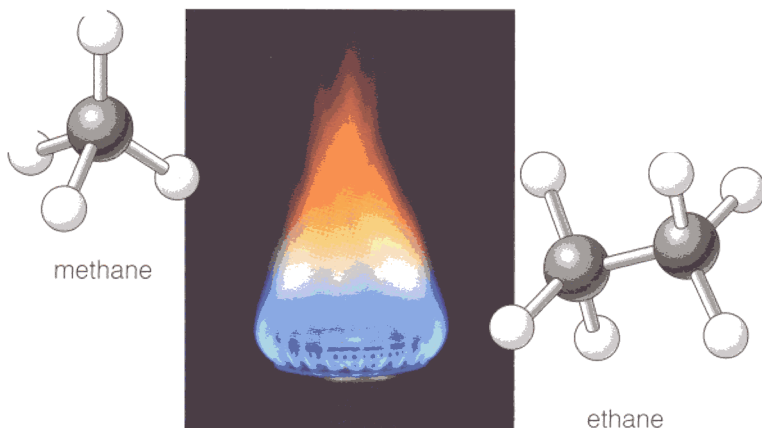


Figure 3.20 These fairly simple hydrocarbon fuels all react with oxygen gas to produce carbon dioxide and water vapour when combustion is complete.

When hydrocarbons are burned in a poor supply of oxygen, **incomplete combustion** results. This reaction is still exothermic, but it does not generate as much thermal energy as complete combustion. The products of incomplete combustion are carbon dioxide and water, as before, but also carbon (soot) and carbon monoxide.

Carbon monoxide is a colourless, odourless, highly toxic gas. Breathing carbon monoxide interferes with your body's oxygen transport system. Blood cells contain a chemical, called hemoglobin, that combines with oxygen in your lungs. The oxygen is later released to other cells in your body. Carbon monoxide bonds about 200 times more strongly than oxygen to hemoglobin. If you breathe carbon monoxide, you reduce the amount of oxygen that can bind to hemoglobin. As a result, cells die. To reduce the danger of carbon monoxide poisoning, never operate fuel-burning apparatus without proper ventilation.

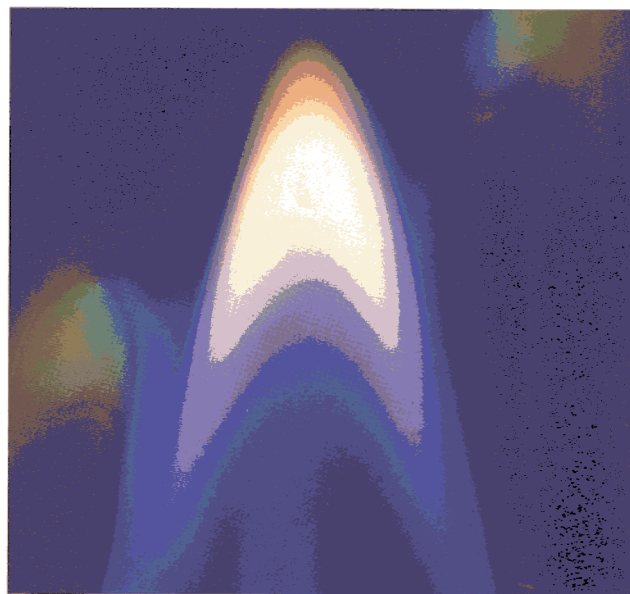
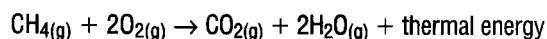


Figure 3.21 The simplest hydrocarbon is methane, $\text{CH}_4(\text{g})$, which is present in natural gas. If you have a gas furnace at home, the following complete combustion reaction keeps you warm during the winter:



One sign that a chemical reaction has occurred is the formation of a gas. Since gases such as hydrogen, oxygen, and carbon dioxide are clear and colourless, chemists have developed standard tests to identify them. **CAUTION:** Hydrogen gas is highly combustible. Oxygen gas, while not combustible itself, supports the combustion of other substances and materials. Take appropriate safety precautions when performing these (or any other) chemical tests. Your teacher will provide you with detailed instructions before you conduct any of these tests yourself.



1. Standard Chemical Test for Hydrogen

A burning wooden splint is lowered into a jar that contains an unknown gas.

- Positive result: If the gas is hydrogen, you will hear an explosive “pop” sound, and the flame will be extinguished.
- Negative result: If the gas is carbon dioxide, the flame will be extinguished (no “pop”). If the gas is oxygen, it will burn more brightly.

2. Standard Chemical Test for Oxygen

A glowing wooden splint is lowered into a jar that contains an unknown gas.

- Positive result: If the gas is oxygen, the splint will ignite.
- Negative result: If the gas is not oxygen, the splint will not ignite and may stop glowing completely.



3. Standard Chemical Test for Carbon Dioxide

Limewater, an aqueous solution of calcium hydroxide, is added to a jar that contains the unknown gas. (Alternatively, the unknown gas is bubbled into a test tube or beaker that contains limewater.)

- Positive result: If the gas is carbon dioxide, the limewater will become milky.
- Negative result: If the gas is not carbon dioxide, no change in the limewater occurs.

4. Standard Chemical Test for Water (not shown)

Cobalt(II) chloride paper can be used to test for the presence of gaseous or liquid water. To test whether a liquid is water or contains water, a drop of the liquid is transferred to the test paper.

- Positive result: If water is present, the blue cobalt(II) chloride paper turns pink.
- Negative result: If water is not present, the cobalt(II) chloride paper stays blue.

Putting It Together: Classifying Chemical Reactions



In this investigation you will combine much of the knowledge you have gained so far in this chapter. You will perform experiments and identify reactants and products. Then, you will balance chemical equations and classify the reactions you observe.

Question

How can you use your knowledge of chemical reactions to classify reactions you carry out in the laboratory?

Predictions

- Read through the entire investigation. For Parts 2, 3, 5, 6, and 8, write a chemical equation to describe the reaction you believe will occur.
- Describe in detail what observations you expect to make for Parts 2, 3, 5, 6, and 8, based on your equations.

Safety Precautions



- Handle all chemicals with care. They may be toxic, irritants, or corrosive.
- Burning magnesium produces an intense white flame that can seriously damage your eyes. You must wear welder's goggles when observing the flame.
- Hydrogen peroxide is an irritant. Avoid contact with your skin.
- Hydrochloric acid, sulfuric acid, and sodium hydroxide are caustic. Rinse any spills on your skin immediately with plenty of cold water, and inform your teacher.
- Copper(II) chloride is a poison. Silver nitrate and potassium permanganate will stain skin and clothing.
- Manganese dioxide, copper nitrate, nickel nitrate, and ammonium nitrate are toxic.
- Phenolphthalein solution is flammable.
- Use the proper technique for smelling chemicals. Waft gases gently toward your nose; do not smell chemicals directly.
- Wash your hands thoroughly at the end of each part of this investigation.

Part 1

Note: Your teacher will demonstrate this reaction.

Apparatus

Bunsen burner or propane blowtorch
heat-resistant pad
crucible tongs

Materials

2 cm strip of magnesium ribbon, $\text{Mg}_{(s)}$

Procedure

- 1 Make a table like the one on the next page, and give it a title. Use several whole pages turned sideways. *Use your table for all parts of the investigation. After each part, fill in the table.*
- 2 Your teacher will ignite the magnesium ribbon using the Bunsen burner or the blow torch.
CAUTION: Burning magnesium produces an intense white flame that can seriously damage your eyes. You must wear welder's goggles when observing the flame.

- 3 In your table, **describe** the magnesium and the way it burns. Is the reaction exothermic or endothermic? In this reaction, magnesium reacts primarily with oxygen. Write a chemical equation for the reaction. Include thermal energy on the correct side of the chemical equation.

Part 3

Apparatus

drip catcher (aluminium dish or a piece of cardboard)
small beaker (50 mL or 100 mL)
large beaker (500 mL or 1 L)
Erlenmeyer flask

Materials

candle
3 strips of cobalt(II) chloride paper
limewater

Part	Reactants	Observations	Word equation	Balanced chemical equation	Type of reaction

Part 2

Apparatus

2 test tubes and a test tube rack

Materials

dilute hydrochloric acid, $\text{HCl}_{(\text{aq})}$
2 cm strip of magnesium, $\text{Mg}_{(\text{s})}$
wooden splint

Procedure

- 1 Place about 3 mL of hydrochloric acid in a test tube. Add a small piece of magnesium to the acid solution. Collect any gas in a second test tube. Test it with a burning splint.
- 2 Dispose of the materials as directed by your teacher.



Procedure

- 1 Practise the test for identifying water. Take two strips of cobalt chloride paper. Moisten one of the strips with water and compare its appearance with that of the dry strip. In your notebook, **summarize** this test for identifying water.
- 2 Place the drip catcher under the candle. Light the candle and place a large beaker over it.
- 3 When the flame goes out, examine the inside of the beaker. **CAUTION:** The beaker may be hot. Test any moisture with a strip of cobalt(II) chloride paper.
- 4 Add 25 mL of limewater to a small beaker. **Describe** its appearance.
- 5 Repeat step 2, but place the Erlenmeyer flask over the burning candle.

- 6 When the flame goes out, quickly turn the flask upright and add the limewater. Swirl the solution. **Record** any change in the appearance of the limewater.
- 7 Waxes are a group of pure substances with varying numbers of carbon and hydrogen atoms. Use the formula $\text{C}_{20}\text{H}_{42}$ to represent wax, and try to balance the combustion equation. Is the reaction exothermic or endothermic?

Part 4

Apparatus

2 test tubes and a test tube rack
scoopula

Materials

hydrogen peroxide, $\text{H}_2\text{O}_2_{(\text{aq})}$
manganese dioxide, $\text{MnO}_{2(\text{s})}$
wooden splint

Procedure

- 1 Place about 2 mL of hydrogen peroxide solution in the test tube. Use the end of the scoopula to add a small amount of manganese dioxide, about the size of a grain of rice, to the test tube.
- 2 Collect the escaping gas with a test tube. Test it with a glowing splint and record the result. The second product of the reaction is water.
- 3 When the reaction has finished, carefully pour off the liquid from the solid in the

CONTINUED ►

test tube. Add another 2 cm depth of hydrogen peroxide solution to the test tube from step 3. Do *not* add more manganese dioxide.

- 4 Record your observations and the result of any test you performed.
- 5 When you write equations to describe this reaction, do *not* include manganese dioxide.
- 6 Dispose of the materials as directed by your teacher.

Part 5

Apparatus

test tube and a test tube rack

Materials

copper(II) chloride solution,
 $\text{CuCl}_{2(\text{aq})}$
2 cm square of freshly cleaned
aluminium, $\text{Al}_{(\text{s})}$

Procedure

- 1 Place about 2 mL of copper(II) chloride solution in the test tube.
- 2 Add a small piece of aluminium to the solution. After a few minutes, **record** any changes you observe.
- 3 Dispose of the materials as directed by your teacher.

Part 6

Apparatus

2 test tubes and a test tube rack
50 mL beaker
medicine dropper
2 labels

Materials

dilute sulfuric acid, $\text{H}_2\text{SO}_{4(\text{aq})}$
dilute sodium hydroxide, $\text{NaOH}_{(\text{aq})}$
dropper bottle containing
phenolphthalein

Procedure

- 1 Label one test tube “acid” and another “base.”
- 2 Pour about 2 mL of sodium hydroxide into the test tube marked “base.” Add two drops of phenolphthalein. Swirl the solution, and **record** the colour.



- 3 Repeat the test using sulfuric acid.
- 4 Use the test tube from step 3. With the medicine dropper, carefully add sodium hydroxide, one or two drops at a time, until you first see a persistent colour change.
- 5 Dispose of the materials as directed by your teacher.

Part 7

Apparatus

2 test tubes and a test tube rack
evaporating dish
2 labels

Materials

dilute solutions of:
ammonium sulfate, $(\text{NH}_4)_2\text{SO}_{4(\text{aq})}$
sodium hydroxide, $\text{NaOH}_{(\text{aq})}$

Procedure

- 1 Pour about 2 mL of ammonium sulfate solution into a labelled test tube. Pour the same quantity of sodium hydroxide solution into another labelled test tube. **Record** your observations of both solutions.
- 2 Mix the solutions in an evaporating dish. Use the proper method for smelling chemicals to obtain evidence of any chemical change. See if you can identify any gas that is produced. The other products of this reaction are water and an aqueous solution of sodium sulfate, $\text{Na}_2\text{SO}_{4(\text{aq})}$.
- 3 Dispose of the materials as directed by your teacher.

Part 8

Apparatus

2 test tubes and a test tube rack

Materials

silver nitrate solution, $\text{AgNO}_{3(\text{aq})}$
sodium chloride solution, $\text{NaCl}_{(\text{aq})}$

Procedure

- 1 Pour about 2 mL of silver nitrate solution into a labelled test tube. Pour the same quantity of sodium chloride solution into another labelled test tube. **Record** your observations of both solutions.

- 2 Pour the contents of one test tube into the other. Note any change.
- 3 Dispose of the materials as directed by your teacher.



Part 9

Apparatus

2 beakers (50 mL)
2 labels

Materials

solution of copper(II) sulfate, $\text{CuSO}_{4(\text{aq})}$
solution of zinc sulfate, $\text{ZnSO}_{4(\text{aq})}$
strip of copper, $\text{Cu}_{(\text{s})}$
strip of zinc, $\text{Zn}_{(\text{s})}$

Procedure

- 1 Prepare two labelled beakers. Pour about 20 mL of copper(II) sulfate into one beaker and the same quantity of zinc sulfate into the other beaker. **Record** your observations of these solutions.
- 2 Add a strip of zinc to the copper(II) sulfate solution. Part of the strip should be above the solution so you can compare it with the part below. After a few minutes, **record** your observations.

- 3 Add a strip of copper to the zinc sulfate solution. As before, part of the strip should be above the solution. After a few minutes, **record** your observations.
- 4 Return the strips of metal to your teacher. Dispose of the liquids as directed.

Part 10

Apparatus

2 test tubes and a test tube rack

Materials

dilute hydrochloric acid, $\text{HCl}_{(\text{aq})}$
marble chip

Procedure

- 1 Place about 3 mL of hydrochloric acid in a test tube. Obtain a marble chip, which is calcium carbonate, $\text{CaCO}_{3(\text{s})}$. **Record** your observations of these substances.
- 2 Add the marble chip to the acid, and observe what happens.
- 3 Collect and test any gas that results. Perform any further tests that may help you understand the reaction. **Record** your observations.
- 4 Dispose of the materials as directed by your teacher.

Analyze

1. Compare the data in your completed table with those of your classmates. Discuss and resolve any discrepancies or disagreements.
2. A catalyst is a substance that increases the rate of a reaction but is unchanged at the end of the reaction. In other words, the catalyst is not consumed or produced in the reaction. In which reaction do you think a catalyst was used? What evidence supports your claim?
3. Which reactions generated gases as products? Summarize the tests for oxygen, hydrogen, and carbon dioxide. What is the name of the gas that smells like household glass cleaner?

Conclude and Apply

4. Were you unsure about how to classify one or more reactions? Which ones were you unsure about? Why? How did you resolve your uncertainty?
5. Which metal is more reactive, copper or aluminium? Summarize your reasoning.
6. In many experiments, aqueous solutions are made using nitrates. What property do nitrates have that makes them suitable for making aqueous solutions?

Section 3.3 Summary

So far in Chapter 3, you have identified, represented, and classified chemical reactions. Table 3.4 reviews the different types of chemical reactions. You have learned how to balance chemical equations. In the next section, you will learn a different way to interpret the coefficients in chemical equations.

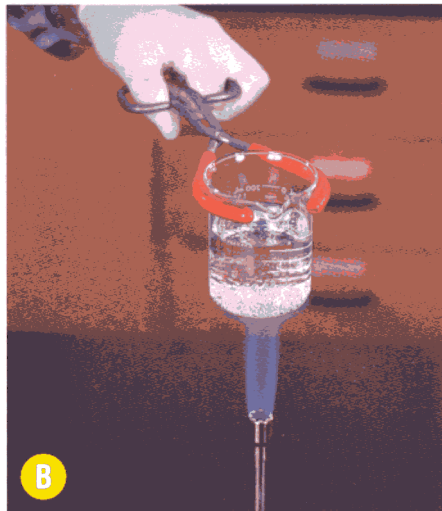
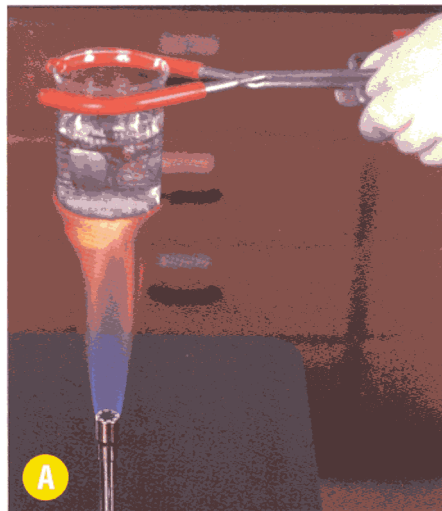
Table 3.4 Summary of Reaction Types

Reaction type	General form	Example
formation reaction	$X + Y \rightarrow XY$	$2\text{Mg}_{(s)} + \text{O}_{2(g)} \rightarrow 2\text{MgO}_{(s)}$
decomposition reaction	$XY \rightarrow X + Y$	$2\text{HI}_{(g)} \rightarrow \text{H}_{2(g)} + \text{I}_{2(s)}$
single-replacement reaction	1. $A + \text{BX} \rightarrow \text{AX} + \text{B}$ 2. $\text{AX} + \text{Y} \rightarrow \text{AY} + \text{X}$	1. $\text{Zn}_{(s)} + \text{HCl}_{(aq)} \rightarrow \text{ZnCl}_{2(aq)} + \text{H}_{2(g)}$ 2. $\text{Cl}_{2(g)} + 2\text{KI}_{(aq)} \rightarrow \text{I}_{2(aq)} + 2\text{KCl}_{(aq)}$
double-replacement reaction	$\text{WX} + \text{YZ} \rightarrow \text{WZ} + \text{YX}$	$2\text{KOH}_{(aq)} + \text{H}_2\text{SO}_{4(aq)} \rightarrow \text{K}_2\text{SO}_{4(aq)} + 2\text{H}_2\text{O}_{(l)}$
complete hydrocarbon combustion	$\text{hydrocarbon} + \text{O}_{2(g)} \rightarrow \text{CO}_{2(g)} + \text{H}_2\text{O}_{(g)}$	$\text{C}_3\text{H}_{8(g)} + 5\text{O}_{2(g)} \rightarrow 3\text{CO}_{2(g)} + 4\text{H}_2\text{O}_{(g)}$

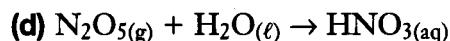
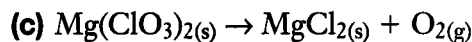
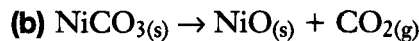
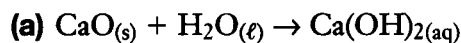
Check Your Understanding

- Ammonium hydrogencarbonate, $\text{NH}_4\text{HCO}_3(s)$, is one of the ingredients used to bake some brands of snack crackers. During baking, this compound decomposes to form ammonia gas, water vapour, and carbon dioxide gas. Write the word equation and a balanced chemical equation for the decomposition of ammonium hydrogen carbonate.
- Write a balanced chemical equation for each of the following word equations. State whether the reaction is a formation or decomposition reaction.
 - solid sodium + liquid bromine $\rightarrow$ solid sodium bromide + thermal energy
 - thermal energy + solid lead(II) oxide $\rightarrow$ solid lead + oxygen gas
 - thermal energy + solid sodium nitride $\rightarrow$ solid sodium + nitrogen gas
 - solid tin + chlorine gas $\rightarrow$ solid tin(IV) chloride + thermal energy
- Balance the following skeleton equations, if necessary. Classify each as a single-replacement reaction or a double-replacement reaction.
 - $\text{Zn}_{(s)} + \text{H}_2\text{SO}_{4(aq)} \rightarrow \text{ZnSO}_{4(aq)} + \text{H}_{2(g)}$
 - $\text{Al}_{(s)} + \text{CuSO}_{4(aq)} \rightarrow \text{Al}_2(\text{SO}_4)_{3(aq)} + \text{Cu}_{(s)}$
 - $\text{Na}_2\text{S}_{(aq)} + \text{HBr}_{(aq)} \rightarrow \text{NaBr}_{(aq)} + \text{H}_2\text{S}_{(g)}$
 - $\text{HNO}_{3(aq)} + \text{Mg}(\text{OH})_{2(aq)} \rightarrow \text{Mg}(\text{NO}_3)_{2(aq)} + \text{H}_2\text{O}_{(l)}$
- Write a word equation and a balanced chemical equation showing the complete combustion of butane, $\text{C}_4\text{H}_{10(g)}$.

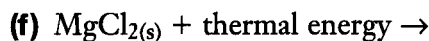
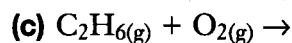
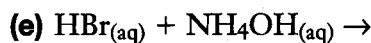
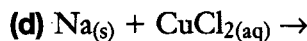
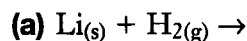
5. **Apply** Do the photographs below show complete or incomplete combustion? On what evidence do you base your answer?



6. Balance the following skeleton equations, if necessary. Identify each reaction as a formation or a decomposition reaction.



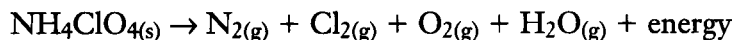
7. **Apply** Predict the type of reaction that the following reactants will undergo. Then predict the products and write balanced chemical equations for each reaction.



8. **Apply** During World War II, lithium hydride helped to save lives. If an airplane crashed at sea, the pilot used the reaction between lithium hydride and seawater to generate hydrogen to fill a flotation device and lifeboat. Write the balanced chemical equation for the reaction.

9. **Thinking Critically** Ammonium perchlorate, NH_4ClO_4 , is a white crystalline solid at room temperature. It is commonly used as a solid propellant in missiles.

- (a) Balance the skeleton equation and identify the type of reaction.



- (b) Based on the reaction equation, suggest two reasons why ammonium perchlorate is used to propel missiles.

- (c) Suggest a reason why gaseous water, not liquid water, is produced in this reaction.

- (d) Suggest a drawback of using ammonium perchlorate as a propellant.

DidYouKnow?

Alberta holds one of the world's two largest deposits of oil sands. The other large deposit is in Venezuela. Oil sands contain bitumen, which is a thick, sticky form of fossil fuel. At room temperature, bitumen has a consistency similar to molasses. Bitumen must be processed before it is sent to a refinery as crude oil.

Pause & Reflect

You may have been familiar with the term "combustion" before reading this section. Summarize what you now know about combustion. Write any questions you have about combustion, and look for information that will answer your questions.