Chapter 6.1-6.5

CHAPTER

6 Understanding Chemical Reactions

Getting Started

WHAT CHEMICAL REACTIONS DO YOU CONDUCT EVERY MORNING? Brushing your teeth, eating breakfast, and getting a ride all qualify as chemical reactions. The fluoride compounds in your toothpaste react with compounds in your teeth to produce new, harder compounds that can resist decay. Acids and other chemicals in your digestive system react with food to produce the nutrients that your body needs. Hydrocarbons in the fuel that powers the family car react with oxygen from the air to produce new gas molecules and energy.

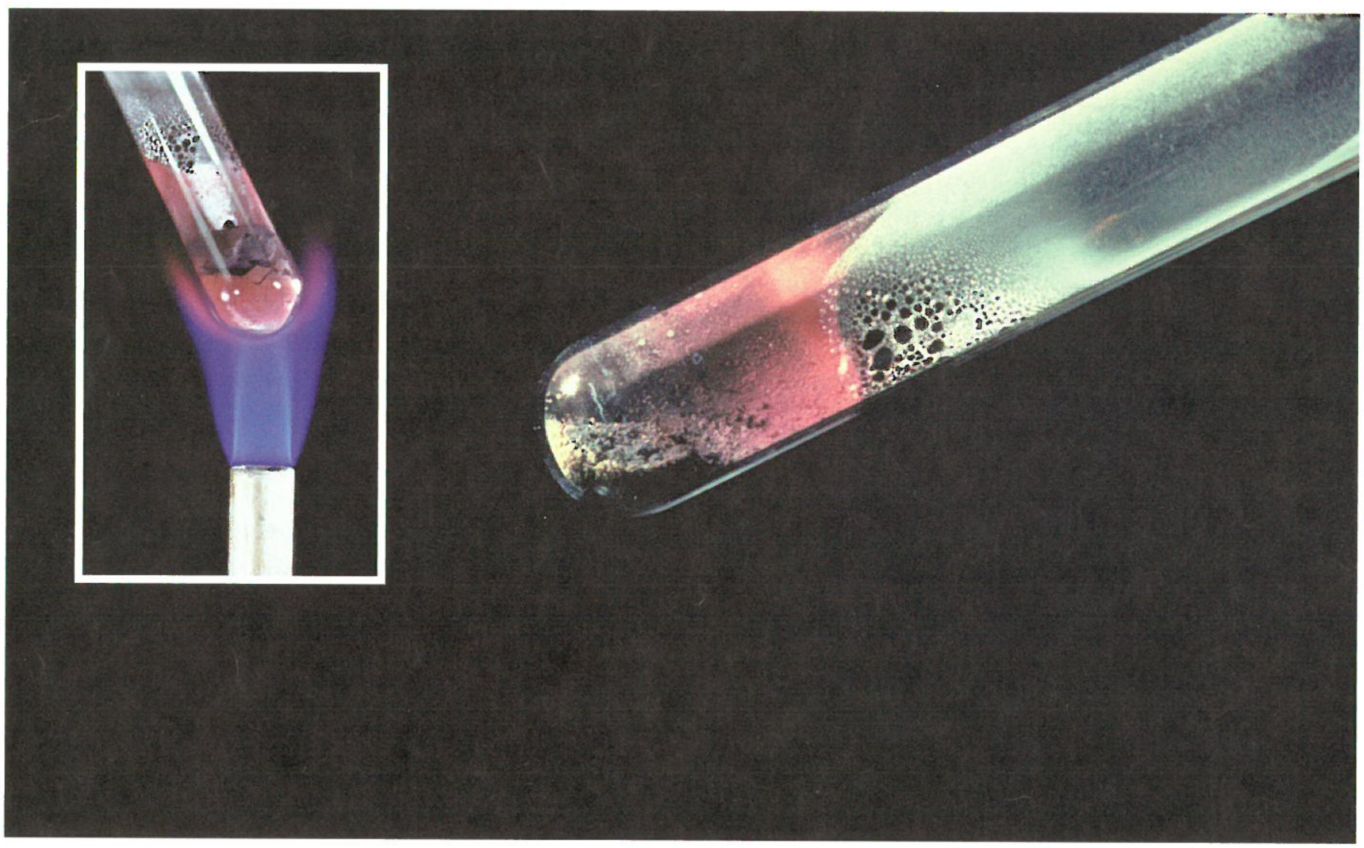

Figure 1

Mercury oxide produces a liquid and a gas (inset) when heated by a flame. This is a decomposition reaction. What are the products of this reaction?

Chemical reactions are also used to make many of the chemical compounds that are part of our lives. The plastic containers that hold your lunch and the synthetic fibres used to make some of your clothes have been made by the chemical industry. When you get a bacterial infection, the antibiotics that the doctor may prescribe are the products of the pharmaceutical chemical industry. Children's toys, whether dolls or plastic miniblocks or in-line skates, are almost all made of synthetic products. But chemical reactions may have negative effects as well. The combustion of gasoline gives us the freedom to travel large distances, but produces polluting gases that can cause respiratory and other health problems.

How do chemical reactions happen? How do chemists categorize the thousands of different chemical reactions? In Chapter 5, you saw patterns in how chemical compounds can be categorized as ionic or molecular. Using your understanding of these patterns, you were able to name different chemical compounds. In this chapter, you will learn to recognize patterns that will help you understand and predict different types of chemical reactions.

Reflect on your Learning

1. What happens to matter in chemical changes?
2. How can we represent chemical reactions?
3. How can chemical reactions be classified or grouped?
4. What are some examples of different types of chemical reactions?

Throughout this chapter, note any changes in your ideas as you learn new concepts and develop your skills.

Try This Activity: Looking at a Chemical Reaction

Can you classify the changes that occur during a chemical reaction?

- Put on goggles and an apron.
- Obtain a piece of magnesium metal and a beaker containing 10 mL of vinegar from your teacher. Note that vinegar is a solution of the compound acetic acid in water.
- Examine and describe the starting materials.

(a) How could you classify the starting materials according to their physical properties?

(b) How could you classify the starting materials according to their structure or formula, or type of matter?

- Think about laboratory safety procedures and how you can use your five senses to make observations. Note that the sense of smell must be used with caution.

(c) How can you safely test the odour of a substance?

(d) Which sense should you never use in a laboratory?

- Add the magnesium to the vinegar and observe the changes that occur. Use three of your senses to make your observations.

(e) How could you classify the products according to their physical properties?

(f) How could you classify the products according to their structures or formulas?

(g) Describe some other chemical changes. How would you classify these changes?

- Dispose of the materials as instructed by your teacher.
- Wash your hands.

Word Equations

Chemical reactions may involve sophisticated chemicals, as in the explosive reaction of dynamite, or simple household materials, as in the reaction of a bathroom cleaner with a stain. They may occur constantly, as in the growth of your body, or occasionally, as in the changing colour of leaves in the fall. How can you describe such a wide range of reactions? For convenience, chemists use a word equation. A **word equation** is one way of representing a chemical reaction: it tells you what reacts and what is produced. Word equations are an efficient way to describe chemical changes, to help chemists recognize patterns, and to predict the products of a chemical reaction.

Writing Word Equations

Word equations are written in a particular format. The left side of a word equation lists the names of all the reactants (the substances present initially), and the right side lists the names of all the products (the substances present at the end). An arrow points from the reactants to the products:

all the reactants → all the products

The reactants, as well as the products, are separated by a plus sign (+):

reactant 1 + reactant 2 → product 1 + product 2

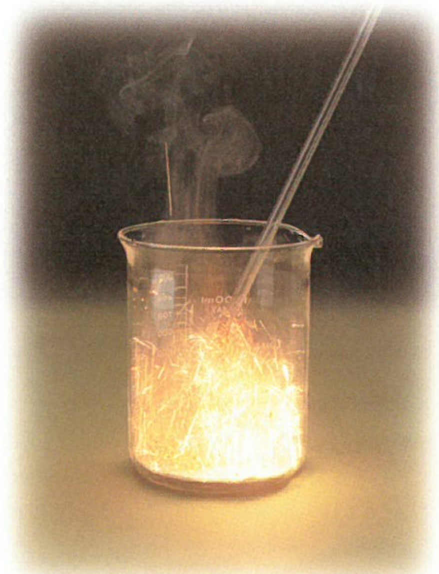

Figure 1
Iron(III) oxide forms when steel wool and oxygen react.

Word Equations for Some Chemical Reactions

You know that the rusting of iron is a slow process — it takes a car a long time to rust. However, when hot steel wool (iron) is plunged into a bottle of oxygen, a spectacular chemical reaction occurs (**Figure 1**). The reactants are iron and oxygen, and the product is iron(III) oxide. The word equation for this reaction is written as

iron + oxygen → iron(III) oxide

The reaction that occurs when a coil of copper wire is placed in a beaker of colourless silver nitrate solution is shown in **Figure 2**. The word equation for this chemical reaction is

copper + silver nitrate → silver + copper(II) nitrate

In Chapter 5, you investigated several chemical reactions. These reactions can be described using word equations. For example, when zinc metal is added to a hydrochloric acid solution, a flammable gas and a colourless solution result:

zinc + hydrochloric acid → hydrogen + zinc chloride

In the chemical test for hydrogen, the gas "pops" as it reacts explosively with oxygen from the air:

hydrogen + oxygen → water vapour

Challenge

1,2,3 What word equations represent the reactions in your Challenge?

Figure 2

When a coil of copper is dipped in silver nitrate solution, a furry deposit of silver metal forms on the coil. The solution also turns blue as a copper(II) nitrate solution forms.

Try This Activity Completing Word Equations

Chemists use word equations to summarize what they observe. Copy and complete the word equations that describe the following observations.

(a) Aluminum resists corrosion because it reacts with a gas found in air to form a protective coating of aluminum oxide.

aluminum + ? → aluminum oxide

(b) Zinc metal, used as a coating in galvanized iron, also reacts with air to form a coating that resists further corrosion.

zinc + oxygen → ?

(c) When aluminum foil is placed in a solution of copper(II) chloride, copper metal and another solution are formed.

aluminum + copper(II) chloride → copper + ?

(d) When sodium sulfate and calcium chloride solutions are mixed, a precipitate of calcium sulfate and another substance is formed.

sodium sulfate + calcium chloride → calcium sulfate + ?

Understanding Concepts

1. What is the purpose of writing a word equation?
2. Examine the following word equation:

   propane + oxygen → carbon dioxide + water

   (a) List all the reactants in this reaction.

   (b) List all the products in this reaction.

   (c) What is the purpose of the arrow in the word equation?
3. Write word equations for the following reactions:

   (a) $CaCl_2$ and Na_2SO_4 react to form $CaSO_4$ and NaCl.

   (b) $BaCO_3$ reacts when heated to produce BaO and CO_2.

   (c) $AgNO_3$ reacts with KCl to produce AgCl and KNO_3.
4. Write word equations to represent the following chemical reactions:

   (a) Carbon dioxide and water are produced in human cell respiration. The reactants are sugar and an important gas that humans need to survive.

   (b) Stalactites form in caves when calcium bicarbonate reacts to form calcium carbonate, water, and carbon dioxide gas.

Reflecting

5. Write your own word equation for the production of a peanut butter sandwich.
6. How would you classify the reactions you see in the Try This?

6.2 Investigation

INQUIRY SKILLS MENU

- ○ Questioning
- ● Hypothesizing
- ● Predicting
- ○ Planning
- ● Conducting
- ● Recording
- ○ Analyzing
- ● Evaluating
- ● Communicating

Measuring Masses in Chemical Changes

You know how to represent the changes that occur when elements and compounds undergo chemical changes. But what happens to the quantities of these substances in a chemical reaction? When matter changes, does the mass of matter also change? For example, if two solutions are mixed together to form a solid, does the mass increase? In this investigation, you will measure the masses of reactants and products to find out.

Question

Does the mass of a substance change when it undergoes a chemical reaction?

Hypothesis

In a group, discuss how a chemical reaction might affect the total mass of reactants and products.

(a) Write a hypothesis explaining whether the mass (K3) should increase, decrease, or stay the same.

Design

In this investigation, you will work in a group to test your hypothesis by measuring the masses of substances in a closed system (a stoppered flask).

(b) Make a data chart as shown in **Table 1** and be prepared to record the group's data on a class chart.

Table 1 **Measuring Masses in a Chemical Reaction**

Total mass of reactants and apparatus (g)	Predicted mass of products and apparatus (g)	Measured mass of products and apparatus (g)	Qualitative observations of reactants and products

Materials

- apron
- safety goggles
- small test tube
- 250-mL Erlenmeyer flask
- stopper for the flask
- iron(III) chloride solution (3% or 0.2 mol/L)
- graduated cylinder
- sodium hydroxide solution (3% or 0.8 mol/L)
- paper towel
- balance

Procedure

1. Put on your apron and safety goggles.
2. Check that your test tube is the correct size for your flask (see **Figure 1**).
3. Remove the test tube from the flask. Pour about 10–15 mL of iron(III) chloride solution into the flask.

Figure 1

Iron(III) chloride is a strong irritant, corrosive, and toxic. Any spills on the skin, in the eyes, or on clothing should be washed immediately with cold water. Report any spills to your teacher.

4. Fill your test tube about one-half full with sodium hydroxide solution. Carefully dry off the outside of the test tube with a paper towel. Gently place the test tube in the flask, being careful not to spill the solutions.

   (c) Describe the properties of the starting materials.

Sodium hydroxide is corrosive. Any spills on the skin, in the eyes, or on clothing should be washed immediately with cold water. Report any spills to your teacher.

5. Put the stopper firmly in the flask. Check that the outside of the flask is dry. If it is not, dry it off with a paper towel.

SKILLS HANDBOOK: (K3) Developing the Prediction and Hypothesis

6 Determine the total mass of the reactants, the test tube, and the flask. Record your measurement.

(d) Record your prediction of what the final mass will be in the data table.

7 Holding the stopper firmly in place, gently invert the flask. This will mix the iron(III) chloride solution from the flask with the sodium hydroxide from the test tube (**Figure 2**).

Figure 2

8 Observe the reaction that occurs.

9 Measure the mass of the flask and its contents using the same balance you used for the first measurements. Record your measurements. Record your qualitative observations, such as the appearance of any products if or when a reaction occurs.

10 Dispose of the contents of your flask and clean and put away your materials as directed by your teacher. Clean up your work station. Wash your hands.

Analysis and Evaluation

(e) Compare your group's results with those of the rest of your class.
(f) Total the mass changes from each group, and calculate the average mass change.
(g) How do you think the procedure in this experiment could have been improved?
(h) Answer the initial question.
(i) Communicate your findings in a lab report.

Understanding Concepts

1. Write a general statement to summarize the results of this investigation.

2. What evidence do you have that a chemical reaction occurred in your flask?

3. (a) The products of the reaction are iron(III) hydroxide and sodium chloride. Write a word equation for this reaction.

(b) Write the same equation again using the correct chemical formula for each chemical compound.

4. Which product(s) could you see in the flask after the reaction? Explain your answer.

5. Explain why the measurement of the mass of the products might differ for each group. Does this indicate that any of the groups made a mistake?

6. Explain why an average change in mass was calculated and used in (e).

Exploring

7. Repeat this investigation using a different pair of reactants: sodium carbonate solution and calcium chloride solution. Before you begin, predict the products of this reaction and write its word equation.

Reflecting

8. (a) List possible factors that might explain why the mass of the products is not equal to the mass of the reactants in some student investigations.

(b) What effect would each of these factors have on the observed results? For example, would the spilling of some solution produce a higher or lower value in the final mass?

6.3

Conserving Mass

In Investigation 6.2, you saw that when two solutions react to form a solid precipitate, the mass stays the same. Is the mass constant for other types of reactions? Are there any reactions where mass is gained or lost?

In some chemical reactions, matter may appear to be destroyed. For example, you might think that the burning of a forest destroys matter, reducing the trees to a mere handful of ashes (**Figure 1**). What happens in a chemical reaction when one or more of the reactants or products is a gas?

For more than 200 years, scientists tried to devise methods to trap the gases that were used or produced in reactions, and to find ways to measure their masses. After years of experimenting, scientists agreed that mass is neither gained nor lost in any chemical reaction. This conclusion is stated as a law. A **scientific law** is a general statement that sums up the conclusions of many experiments, or a statement that summarizes an observed pattern in nature.

Figure 1
The biomass in trees seems to "disappear" when a forest fire destroys a forest.

The Law of Conservation of Mass

The Law of Conservation of Mass states that, in a chemical reaction, the total mass of the reactants is always equal to the total mass of the products.

Since the mass of the products is always the same as the mass of the reactants, what does this tell us about the atoms that make up the reactants and products?

Experiments have shown that atoms in a chemical reaction are not changed — the number of each kind of atom is the same before and after a reaction. In chemical reactions, the atoms of the reactants are simply rearranged. Molecules may be broken apart and new molecules may be formed, but the atoms in the products are the same atoms that were in the reactants.

For example, look at the burning of methane or natural gas (**Figure 2**). The word equation for this reaction is

methane + oxygen → water + carbon dioxide

The reactants are two molecules of oxygen gas (O_2) and one molecule of methane (CH_4), as shown in **Figure 3**. As the molecules collide, a chemical reaction occurs that produces two molecules of

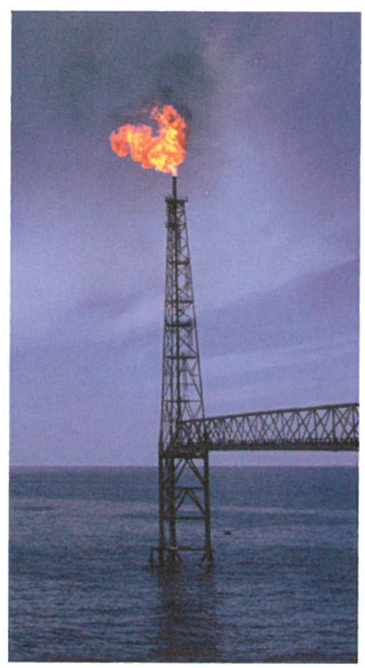

Figure 2
When natural gas burns, it reacts with oxygen in the air. The mass of every gas must be taken into account when calculating the final mass of a chemical reaction.

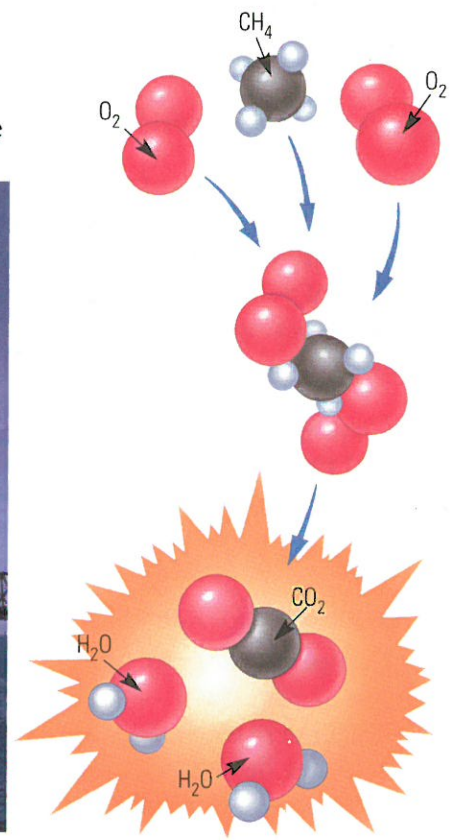

Figure 3
Atoms are not destroyed in a chemical reaction, just rearranged.

water (H_2O), one molecule of carbon dioxide (CO_2), heat, and light.

As you can see in **Figure 3**, all the atoms present at the beginning of a chemical reaction are present after the reaction. Thus, the total mass of the atoms in the reactants remains equal to the total mass of the atoms in the products; the atoms in the reactants recombine to form new molecules.

An Environmental View

The Law of Conservation of Mass has implications far beyond the laboratory. Think about engines that use fuels as a source of energy. When cars burn gasoline, energy is released during the chemical reaction of combustion. However, since mass is conserved, all of the mass of the fuel is still present in some form after combustion occurs (**Figure 4**).

Figure 4
Every kilogram of fuel mixed with oxygen in an internal combustion engine produces 3 to 4 kg of water vapour and carbon dioxide gas, as well as pollutant gases such as nitrogen oxides and unburned hydrocarbons.

Challenge

3 How does the Law of Conservation of Mass relate to your Challenge?

Work the Web

What is being done to reduce the amounts of pollutants in vehicle exhausts? Visit www.science.nelson.com and follow the links from Science 10, 6.3 to research this issue.

Understanding Concepts

1. State the Law of Conservation of Mass. How is this law explained in terms of atoms?
2. When a log burns in a fire, the ashes have a much lower mass than the log. Explain.
3. **(a)** Make a table with three columns and four rows as follows:

Number of atoms	Reactants	Products
carbon		
oxygen		
hydrogen		

   (b) Using **Figure 3**, count the number of atoms of each type in the reactants and record them in the table. Count the number of atoms of each type in the products and record them in the table.
   (c) What do your results suggest about the Law of Conservation of Mass?
4. A solid has a mass of 35 g. When it is mixed with a solution, a chemical reaction occurs. If the final total mass of products is 85 g, what was the mass of the solution?
5. Solution A has a mass of 60 g. Solution B has a mass of 40 g. When they are mixed, a chemical reaction occurs in which gas is produced. If the mass of the final mixture is 85 g, what mass of gas was produced?
6. Have you ever noticed that if you weigh yourself immediately before bed and immediately after getting up in the morning, you weigh less in the morning? Does this mean that the Law of Conservation of Mass is not true? Suggest an explanation for the difference in mass.
7. Why does bread rise when it is baked? How do you think the mass of the bread would compare to the original total mass of the ingredients in the recipe?

Exploring

8. Design an apparatus that would allow you to compare the mass of reactants with the mass of products when a small amount of wood burns.

Reflecting

9. How have your ideas about matter and mass changed? Did you know that gases had mass? Did you know that matter could not be created or destroyed? Write a short paragraph describing how your ideas may have changed.

6.4 Investigation

INQUIRY SKILLS MENU

- ○ Questioning
- ○ Hypothesizing
- ● Predicting
- ○ Planning
- ● Conducting
- ● Recording
- ● Analyzing
- ● Evaluating
- ● Communicating

Finding the Missing Mass

In Investigation 6.2, you investigated the masses of reactants and products for a chemical change in which a precipitate (solid) was formed from two solutions. What happens when gases are produced in chemical reactions? Like any other type of matter, gases are made of atoms and molecules, and have mass. But they can easily escape from a container used for a reaction. In this investigation, you will compare the mass of reactants with the mass of products in a reaction that produces a gas.

Question

Can the Law of Conservation of Mass be applied to a chemical reaction in which a gas is produced?

Prediction

(a) Write a prediction, describing how the mass of (K3) the products will compare to the mass of the reactants.

Design

You will measure the total mass of reactants and total mass of products, and compare them.

(b) Make a table to record your observations of masses during the investigation. Include a column in your table for your qualitative observations.

Materials

- apron
- safety goggles
- test tube
- 250-mL beaker
- hydrochloric acid solution (3% or 0.4 mol/L)
- graduated cylinder
- sodium bicarbonate (baking soda)
- 2-mL measuring scoop
- balance

Hydrochloric acid is corrosive. Any spills on the skin, in the eyes, or on clothing should be washed immediately with plenty of cold water. Report any spills to your teacher.

Procedure

1 Put on your apron and safety goggles.

2 Be sure that the test tube and beaker are clean and dry before you begin. Pour 10 to 15 mL of hydrochloric acid into the test tube (**Figure 1**).

Figure 1

3 Put one scoop (about 2 g) of sodium (L3) bicarbonate into the beaker. Place the test tube in the beaker. Measure the total mass of the beaker, test tube, and reactants (**Figure 2**). Record your measurement.

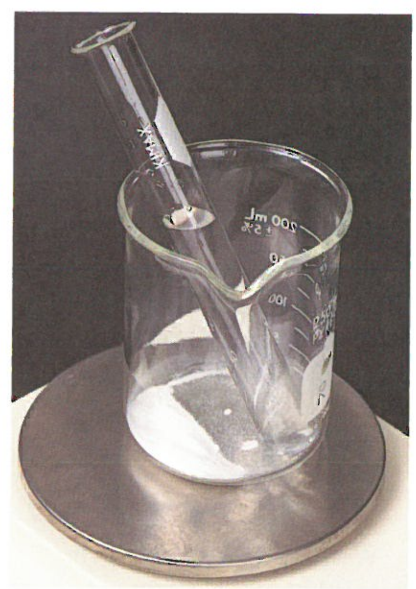

Figure 2

SKILLS HANDBOOK: (K3) Developing the Prediction and Hypothesis (L3) Using a Mass Balance

Remove the beaker from the balance. Slowly pour the acid from the test tube into the beaker (**Figure 3**). Record your qualitative observations.

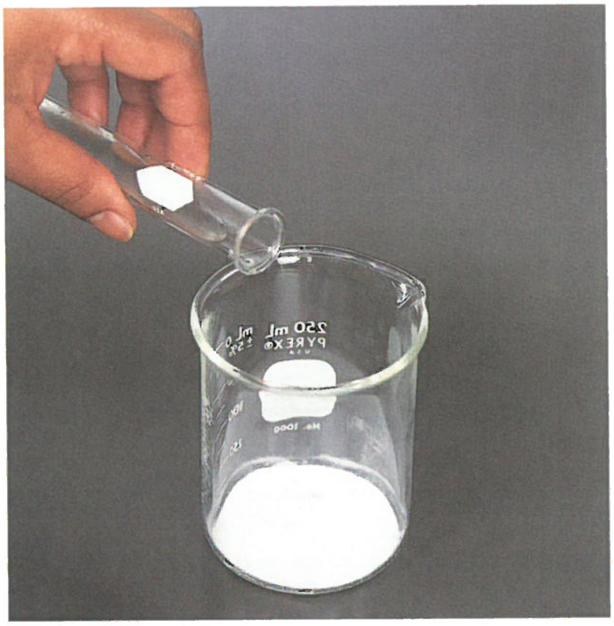

Figure 3

5 Put the test tube back into the beaker. Measure and record the total mass of the beaker, test tube, and products.

6 Dispose of the contents of your beaker and clean and put away your materials as directed by your teacher. Clean up your work station. Wash your hands.

Analysis and Evaluation

(c) What were the names of the reactants?
(d) What was the difference in mass between the reactants and the products?
(e) What might account for any difference in mass you observed?
(f) Why does the glassware have to be dry?
(g) What improvements could you suggest in the experimental design?
(Q) (h) Write up your findings in a lab report.

Understanding Concepts

1. What evidence do you have that a chemical change took place after you poured the dilute acid into the beaker?
2. (a) What were the three products of this reaction?
   (b) Which of these products remained in the beaker? Explain.
   (c) Write a word equation to represent the chemical reaction.
   (d) Write the same equation again, but replace each word with a correct chemical formula, using your knowledge of naming chemical compounds.
3. Suggest why you were told to remove the beaker from the balance before mixing the two reactants.
4. A senior science student carried out an experiment to examine the burning of magnesium. She determined the mass of a piece of magnesium ribbon. Then she burned it, being careful to collect all the pieces of white ash. Finally, she determined the mass of the ash. Look at her results in **Table 1** and explain them. Write a word equation for the reaction. There are two reactants and one product.

Table 1 **Burning of Magnesium**

mass of magnesium	3.0 g
mass of ash	5.0 g
difference	2.0 g

Exploring

5. (a) Suppose that you wanted to use the acid–baking soda reaction to prove the Law of Conservation of Mass. How would you modify your procedure and apparatus?
   (b) How might this modification be dangerous?
   (c) What property of which product causes the potential danger?

Work the Web

Some people think that gases have no mass or even that gases have negative mass. They look at hot air balloons rising into the air and say that the gas inside a balloon makes it weigh less. How can you explain this observation? Visit the Nelson web site at www.science.nelson.com and follow the Science 10, 6.4 links to conduct your research.

(Q) Lab Reports

6.5

Balancing Chemical Equations

How do scientists in different countries, speaking different languages, communicate the results of their experiments to each other (**Figure 1**)? How do they represent information about elements, compounds, and chemical equations? You have learned that chemical substances can be represented with names and formulas. You have also learned that chemical reactions can be represented by word equations. Can we describe chemical reactions in symbolic form?

A **skeleton equation** is a representation of a chemical reaction in which the formulas of the reactants are connected to the formulas of the products by an arrow. Consider the example of the burning of methane. We can describe this reaction in a word equation as follows:

La réaction du méthane, brulant avec l'oxygène, produit de l'eau et du gaz de dioxyde de carbone.

$$CH_4 + 2O_2 \rightarrow 2H_2O + CO_2$$

Methane burns in air by reacting with oxygen to produce water and carbon dioxide gases.

$$CH_4 + 2O_2 \rightarrow 2H_2O + CO_2$$

甲烷在空氣中燃燒是因爲甲烷和氧反應產生水和二氧化碳。

$$CH_4 + 2O_2 \rightarrow 2H_2O + CO_2$$

Figure 1

A chemical equation is written the same way in any language, making it universally understandable.

methane + oxygen → carbon dioxide + water

We can then write a skeleton equation by replacing each name with a formula:

$$CH_4 + O_2 \rightarrow CO_2 + H_2O$$

However, there is a problem. The Law of Conservation of Mass states that the mass of the reactants equals the mass of the products. In other words, atoms can be neither created nor destroyed in a chemical change. If we look at the reactants and products, we can record the numbers of atoms of each type in a table like **Table 1**.

Table 1 **Combustion of Methane**

Type of atom	Reactants	Products
C	1	1
H	4	2
O	2	2 + 1 = 3

There is an apparent imbalance between the numbers of atoms in the reactants and the numbers of atoms in the products. We have seemingly created an oxygen atom and destroyed two hydrogen atoms (**Figure 2**).

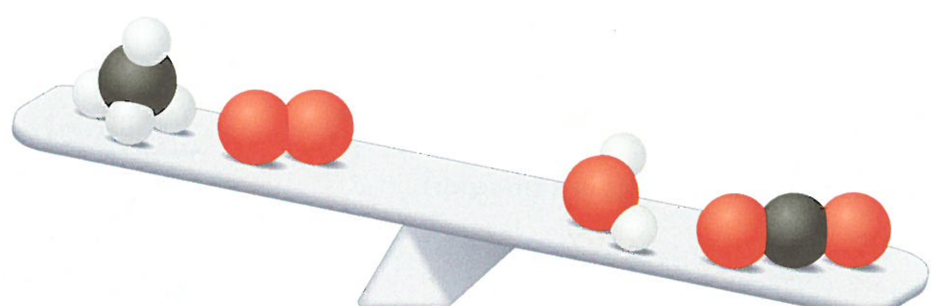

Figure 2

The numbers of atoms of reactants and products are out of balance. The total masses of reactants and products are also out of balance. The see-saw tilts to the product side because of the greater mass.

We cannot change the types or formulas of the molecules. So how can we solve this imbalance?

The answer is to change the numbers of molecules rather than their formulas. If we add an oxygen molecule to the reactants and a water molecule to the products, this balances the equation (**Figure 3**).

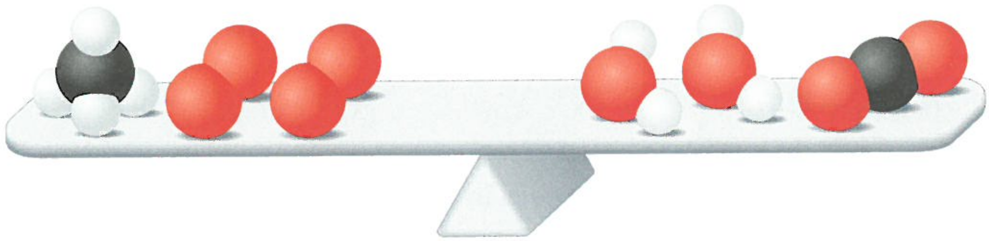

Figure 3

The numbers of atoms are now in balance. The mass of the reactants also equals the mass of the products.

$$CH_4 + O_2 + O_2 \rightarrow CO_2 + H_2O + H_2O$$

An equation in which the reactants and the products contain equal numbers of atoms of each type is a **balanced chemical equation**. The usual way to write a balanced equation is to use coefficients. A **coefficient** is a number written in front of a chemical symbol or formula. It indicates the number of atoms or molecules of that substance. The coefficients are shown in red in the following equation.

$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

Note that by balancing an equation, the mass of the reactants will be equal to the mass of the products.

How to Balance an Equation

Let's look at an example to see how an equation can be balanced. Iron reacts with oxygen to form magnetic iron oxide (Fe_3O_4) (**Figure 4**). What is the balanced chemical equation for this reaction?

Step 1. Write the word equation for the reaction.

iron + oxygen → magnetic iron oxide

Figure 4

Iron reacts with oxygen to form rust or magnetic iron oxide.

Did You Know?

When iron reacts with oxygen, it forms two oxides. Magnetic iron oxide is an equal mixture of iron(II) oxide (FeO) and iron(III) oxide (Fe_2O_3). Add up the atoms to get the formula Fe_3O_4.

Step 2. Write the skeleton equation by replacing each name with a correct formula.

$Fe + O_2 \rightarrow Fe_3O_4$

Step 3. Count the numbers of atoms of each type in reactants and products.

The numbers of atoms may be recorded in a table (**Table 2**).

Table 2 Rusting of Iron

Type of atom	Reactants	Products
Fe	1	3
O	2	4

Step 4. Multiply each of the formulas by the appropriate coefficients to balance the numbers of atoms.

To balance the three iron atoms on the right side, multiply the iron atoms on the left side by 3. To balance the four oxygen atoms on the right side, multiply the oxygen atoms on the left side by 2. Check that the atoms on each side are balanced.

$3Fe + 2O_2 \rightarrow Fe_3O_4$

A balanced chemical equation has been written. The formulas are unchanged, and the numbers of atoms are balanced.

The same steps are used to balance equations that involve more complex molecules. For example, what is the balanced chemical equation for the reaction of magnesium metal with nitric acid?

Step 1. Write the word equation for the reaction.

magnesium + nitric acid → hydrogen + magnesium nitrate

Step 2. Write the skeleton equation by replacing each name with a correct formula.

$Mg + HNO_{3(aq)} \rightarrow H_2 + Mg(NO_3)_2$

> The following subscripts are used to indicate the state of each substance: (s) indicates a solid; (l) indicates a liquid; (g) indicates a gas; and (aq) indicates an aqueous solution (in water).

Try This Activity Equation Balancing for "Smarties"

Use candies to represent the process of balancing equations. For example, consider the balanced chemical equation for the combustion of methane in oxygen to produce carbon dioxide and water:

$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$

- Start with one black (or brown) candy, four yellow candies, and four red candies. Arrange the candies to represent the reactants. For example, methane could be a black candy with four yellow candies just touching it, and the two oxygen molecules could each be two red candies just touching.
- You can represent the chemical reaction by mixing all the candies together.
- The products could then be represented with a carbon dioxide molecule (one black candy with two red candies) and two water molecules (each molecule is one red candy with two yellow candies).
- Use the candies to represent other chemical reactions that you have encountered in this chapter. For a challenge, try to represent the burning of ethane (C_2H_6) in oxygen gas to produce carbon dioxide and water.

Step 3. Count the numbers of atoms of each type in reactants and products. This example is complicated by the polyatomic nitrate ion.

The compound magnesium nitrate contains a total of six oxygen atoms because there are two NO_3 groups, each of which has three oxygen atoms. The numbers of atoms may be recorded in a table (**Table 3**).

Table 3 Magnesium Reacts with Nitric Acid

Type of atom	Reactants	Products
Mg	1	1
H	1	2
N	1	2
O	3	6

Step 4. Multiply each of the formulas by the appropriate coefficients to balance the numbers of atoms.

To balance the number of hydrogen atoms, the coefficient 2 is placed in front of the HNO_3 molecule. Note that this coefficient affects the number of nitrogen and oxygen atoms as well.

$$Mg + 2HNO_{3(aq)} \rightarrow H_2 + Mg(NO_3)_2$$

The equation is now balanced.

Challenge

1,2,3 What balanced chemical equations represent the reactions in your Challenge?

Work the Web

Visit www.science.nelson.com and follow the Science 10, 6.5 links to web sites that show how to balance chemical equations. Choose a reaction and show it as a word equation, a skeleton equation, and as a balanced equation.

Understanding Concepts

1. (a) Why is the following equation not balanced?

$N_2 + H_2 \rightarrow NH_3$

(b) The following is an attempt to balance the above equation. What is wrong with the way that the equation is balanced?

$N_2 + H_3 \rightarrow N_2H_3$

2. Copy the following skeleton equations into your notebook. Then balance the equations:

(a) $Na + Cl_2 \rightarrow NaCl$

(b) $K + O_2 \rightarrow K_2O$

(c) $H_2 + O_2 \rightarrow H_2O$

(d) $H_2 + Cl_2 \rightarrow HCl$

(e) $N_2 + H_2 \rightarrow NH_3$

(f) $CO + O_2 \rightarrow CO_2$

(g) $Al + Br_2 \rightarrow AlBr_3$

(h) $N_2H_4 + O_2 \rightarrow H_2O + N_2$

(i) $CH_4 + O_2 \rightarrow CO_2 + H_2O$

3. For each of the following, write the correct skeleton equation, and then balance it to form a chemical equation:

(a) copper(II) oxide + hydrogen → copper + water

(b) lead(II) nitrate + potassium iodide → lead(II) iodide + potassium nitrate

(c) calcium + water → calcium hydroxide + hydrogen gas

(d) lead(II) sulfide + oxygen → lead + sulfur dioxide

(e) hydrogen sulfide → hydrogen + sulfur

4. Imagine that you are an engineer trying to determine how much air had to be supplied to burn gasoline in a car engine. Assuming that gasoline is heptane (C_7H_{16}), the word equation is

heptane + oxygen → carbon dioxide + water vapour

(a) Write the skeleton equation for the reaction.

(b) Balance the equation by adding coefficients as necessary.

(c) How many molecules of oxygen are required for every molecule of heptane that burns?

Making Connections

5. Nitrogen oxides are a group of air pollutants produced by internal combustion engines in automobiles. These pollutants are formed by the reaction of atmospheric nitrogen (N_2) and oxygen (O_2) to form various combinations, including NO, NO_2, N_2O_4, N_2O_3, and N_2O_5. Write balanced chemical equations to represent the production of each of these substances.

6.6

Combustion

Figure 1

A match provides the heat to start the combustion of the wax in the candle.

What chemical reactions are involved when you strike a match? What further reactions happen when the match is brought close to a candle and the wax burns? Chemists use their knowledge of types of reactions to decide on the chemical composition of matches and to explain how these chemicals react (**Figure 1**).

There are different categories of chemical reactions. One possible category is combustion. **Combustion** is the very rapid reaction of a substance with oxygen to produce compounds called oxides. We often call this process burning. One way to represent combustion is using the following word equation:

fuel + oxygen $\rightarrow$ oxides + energy

The energy produced is mainly in the form of heat and light. The fuel can be a variety of elements and compounds.

The most important fuels that we burn are hydrocarbons. Gasoline in our automobiles, natural gas in our home furnaces, kerosene in jet airplanes, and even the candles on a birthday cake are all made of hydrocarbons (**Figure 2**). When these fuels burn, the products are carbon dioxide and water. The word equation for the combustion of a hydrocarbon can be represented as

hydrocarbon + oxygen $\rightarrow$ carbon dioxide + water vapour + energy

The complete combustion of hydrocarbon fuels results in the production of millions of tonnes of water and carbon dioxide, which are released into the atmosphere. The carbon dioxide that we produce as a society is a significant contributor to the greenhouse effect discussed in Chapter 16. An example of the combustion of hydrocarbons is the burning of butane in a lighter. Butane (C_4H_{10}) is a gas at room temperature, but it is a liquid under pressure.

Figure 2

Jet aircraft engines burn hydrocarbons to produce energy.