Science Year 10	
Chemical Reactions	
Term 2 Week 2 (4th May to 8th May)	
Note to students: Hi Year 10's. This week you will be starting work from the Year 10 Science Curriculum. You will begin with another chemistry unit called Chemical Reactions. The skills that will be covered this week are writing word equations and balanced chemical equations. You will need to read the text supplied very carefully and follow the instructions given. Please contact me if you have problems. **My email: lorraine.cave@education.wa.edu.au** **Due date for this week's work is: Friday 15th May.**	
Lesson	**Content**
1	**Chemical Equations** Read page 229, then complete the worksheet for Lesson 1.
2	**Chemical Equations continued** Read pages 230 to 233. Please pay special attention to the information and examples given. The skillbuilder and worked example on pages 232 and 233 gives you very clear instructions on how to balance equations. Try questions 1 and 2 on page 233. Then worksheets for Lesson 2 needs to be done.
3 & 4	**Review questions** Please complete the review questions 1 to 15. I have allocated 2 lessons for this.
5	**Energy in Chemical Reactions 6.2** Read pages 237 to 239 then complete the worksheets on Combustion of Magnesium.

CHAPTER 6 Chemical reactions

6.1 Knowledge preview

Science understanding

FOUNDATION	STANDARD	ADVANCED

1 Fill in the table below with the names and formulas for each substance.

Name of substance	Chemical Formula
hydrogen gas	
water	
oxygen gas	
carbon dioxide	
hydrochloric acid	HCl

Name of substance	Chemical Formula
	NaCl
	$CaCO_3$
	H_2SO_4
	CH_4

2 Explain what the following terms mean:

(a) chemical reaction ______________________________

(b) reactants ______________________________

(c) products. ______________________________

3 List the ions that would form from the following elements. The first one has been done for you:

Element	Name of ion that it forms	Symbol for ion
hydrogen	hydrogen ion	H^+
sodium		
chlorine		

Element	Name of ion that it forms	Symbol for ion
oxygen		
beryllium		
aluminium		

4 Name the following ions:

(a) NO_3^- ______________________________

(b) OH^- ______________________________

(c) SO_4^{2-} ______________________________

6.8 Balancing chemical equations

Science understanding

FOUNDATION	STANDARD	ADVANCED

Atoms are not created or destroyed in a chemical reaction. Therefore, there must be the same number of atoms in the reactants as in the products of a chemical reaction. This law of science is known as the conservation of mass and is shown by the use of balanced chemical equations.

1 State the number of each type of atom in the reactants and products of the following equations. Identify if the equations are balanced.

(a) C_3H_8 + $5O_2$ → $3CO_2$ + $4H_2O$

propane, oxygen, carbon dioxide, water

Reactants: carbon (C) = ____________

hydrogen (H) = ____________

oxygen (O) = ____________

Products: carbon (C) = ____________

hydrogen (H) = ____________

oxygen (O) = ____________

Balanced/unbalanced: ____________

(b) H_2SO_4 + $2NaOH$ → Na_2SO_4 + H_2O

sulfuric acid, sodium hydroxide, sodium sulfate, water

Reactants: hydrogen (H) = ____________

sulfur (S) = ____________

oxygen (O) = ____________

sodium (Na) = ____________

Products: hydrogen (H) = ____________

sulfur (S) = ____________

oxygen (O) = ____________

sodium (Na) = ____________

Balanced/unbalanced: ____________

6.8 Balancing chemical equations

2 State whether the following chemical equations are balanced or unbalanced.

(a) SO_3 (sulfur trioxide) + H_2O (water) → H_2SO_4 (sulfuric acid)

Balanced/unbalanced: ______________________

(b) HCl (hydrochloric acid) + Na (sodium) → NaCl (sodium chloride) + H_2 (hydrogen)

Balanced/unbalanced: ______________________

(c) C_4H_{10} (butane) + $6O_2$ (oxygen) → $4CO_2$ (carbon dioxide) + $5H_2O$ (water)

Balanced/unbalanced: ______________________

3 Produce balanced chemical equations by filling in the blanks.

(a) $3H_2$ (hydrogen) + N_2 (nitrogen) → _______ NH_3 (ammonia)

(b) _______ Mg (magnesium) + P_4 (phosphorus) → $2Mg_3P_2$ (magnesium phosphide)

(c) _______ HCl (hydrochloric acid) + $CuSO_4$ (copper(II) sulfate) → H2SO$_4$ (sulfuric acid) + $CuCl_2$ (copper(II) chloride)

(d) 2Al (aluminium) + _______ CuO (copper(II) oxide) → Al_2O_3 (aluminium oxide) + _______ Cu (copper)

(e) 3C (carbon) + _______ HNO_3 (nitric acid) → _______ CO_2 (carbon dioxide) + $2H_2O$ (water) + _______ NO (nitric oxide)

RATE MY UNDERSTANDING
Shade the face that shows your rating ☺ 😐 ☹

MODULE 6.1

Review questions

Remembering

1 Define the terms:
- a formula equation
- b chemical equation
- c balanced equation.

2 What term best describes each of the following?
- a the chemicals that are used up in a chemical reaction
- b the chemicals that are produced by a chemical reaction.

3 In a chemical equation what does the symbol → mean?

4 What is the law of conservation of mass?

Understanding

5 Explain how the law of conservation of mass applies to chemical equations.

6 If a chemical equation contained the formula $2CH_4$, what is the meaning of the number 2 and the number 4?

Applying

7 a Use word equations to describe the following reactions.

b Identify the state of the reactants and products.

- i When copper is added to dilute nitric acid, copper nitrate, nitrogen monoxide and water are formed.
- ii Magnesium burns easily in oxygen gas, producing magnesium oxide.
- iii When sodium metal is placed in water, it reacts to produce sodium hydroxide and hydrogen gas.

8 Identify the chemical formula for each of these substances.
- a carbon dioxide
- b dilute sulfuric acid
- c hydrogen
- d potassium carbonate crystals
- e dilute nitric acid
- f calcium.

9 Identify the equation that is not balanced.
- A $4Al + 3O_2 \rightarrow 2Al_2O_3$
- B $Mg + 2HCl \rightarrow MgCl_2 + H_2$
- C $2Zn + O_2 \rightarrow 2ZnO$
- D $C_5H_{12} + 8O_2 \rightarrow CO_2 + 6H_2O$

Evaluating

10 Jessica heated some blue copper(II) nitrate crystals in a test-tube. She noticed that brown nitrogen dioxide gas was produced. When a glowing splint was held at the top of the test-tube, it relit, proving that oxygen gas was also produced. A fine black solid, copper(II) oxide, was left in the test-tube.
- a Determine the reactants and products of the reaction.
- b What is the word equation for this reaction?
- c What is the balanced chemical equation?

11 David added dilute hydrochloric acid to solid calcium carbonate in a beaker. When he weighed the beaker after the bubbling had stopped, he noticed a reduction in mass. Why don't David's results appear to agree with the law of conservation of mass?

Creating

12 Juan burns different masses of magnesium metal (Mg) with oxygen (O_2) to form magnesium oxide (MgO). He measures the mass of the reactants and product before and after, as shown in the table.

Mass of magnesium reacting (g)	Mass of oxygen reacting (g)	Mass of magnesium oxide produced (g)
2.00	0.70	2.70
3.00	1.04	4.04
4.00	1.39	5.39

- a What is the word equation for this reaction?
- b What is the balanced chemical equation?
- c Modify the equation to include the states of the reactants and products.
- d Explain how the above results demonstrate the law of conservation of mass.

6.2 Combustion of magnesium

Science inquiry skills

FOUNDATION	STANDARD	ADVANCED

Processing & Analysing | Communicating

Before scientists understood the atomic theory of matter, people thought that the process of combustion involved the release of a material they called 'phlogiston'. Today, scientists know that phlogiston does not exist—combustion occurs when chemicals combine vigorously with oxygen.

failings (*n*) fault, problem
vigorously (*adj*) with a lot of energy

One of the failings of the phlogiston theory was that it could not explain the combustion of metals. The phlogiston theory predicted that everything that combusts should decrease in mass, due to the release of phlogiston. However, when metals burn they increase in mass. This is because they combine with oxygen to form a metal oxide, which is heavier than the metal.

Experiment

Zac designed an experiment to measure the mass of 1 g of magnesium (Mg) as it burnt in oxygen gas (O_2) to produce magnesium oxide (MgO). His results are summarised in Table 6.2.1.

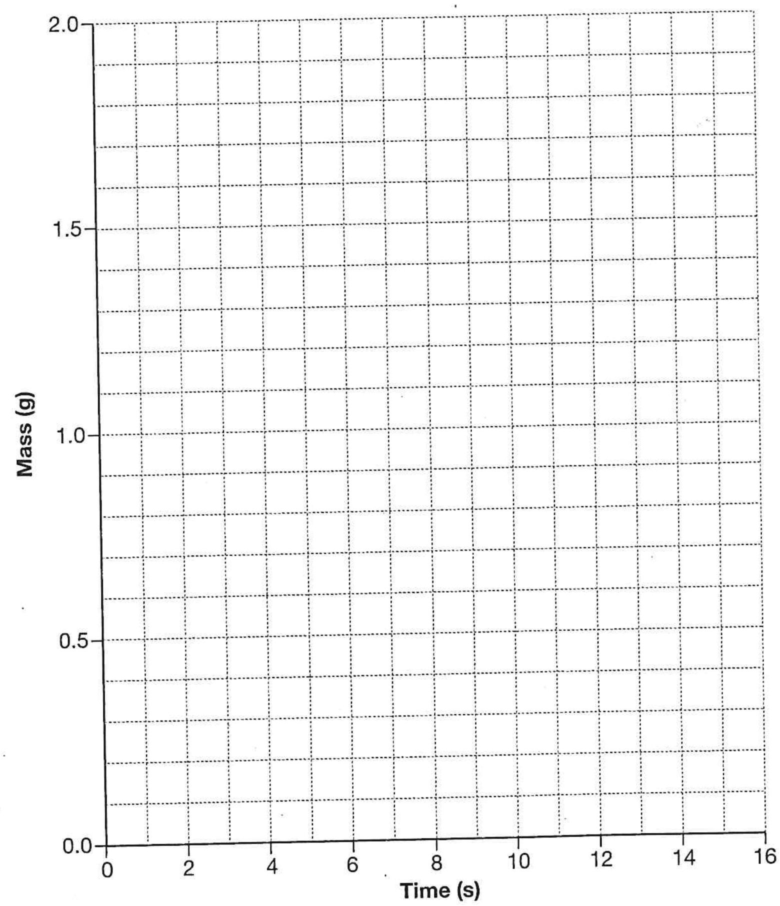
Table 6.2.1 Mass of magnesium as measured over 16 seconds as it is burnt

Time (s)	0	1	2	3	4	5	6	7	8
Mass (g)	1.00	1.04	1.08	1.12	1.16	1.20	1.24	1.29	1.34

Time (s)	9	10	11	12	13	14	15	16
Mass (g)	1.39	1.44	1.49	1.55	1.61	1.67	1.67	1.67

1. Plot the data points on the axes below to construct a graph and draw a line of best fit.

Mass of magnesium as it is burnt



6.2 Combustion of magnesium

(2) Construct particle model diagrams showing the atoms in the reactants and products before and after the reaction in Zac's experiment.

Before	After
O_2 and Mg	MgO

(3) Construct a word equation and a formula equation for the chemical reaction.

(a) word equation: ______________________________

(b) formula equation: ______________________________

(4) Describe how the mass changed as the magnesium burnt in oxygen.

____

____

(5) **(a)** From the graph, state how much time the chemical reaction took to complete.

____

(b) Explain your answer.

____

____

(6) Calculate the mass of oxygen that was used in the reaction. __________ g

(7) The chemical formula for magnesium oxide, MgO, indicates that there are equal numbers of magnesium and oxygen atoms in the compound. Calculate how much heavier a magnesium atom is compared to an oxygen atom using the equation:

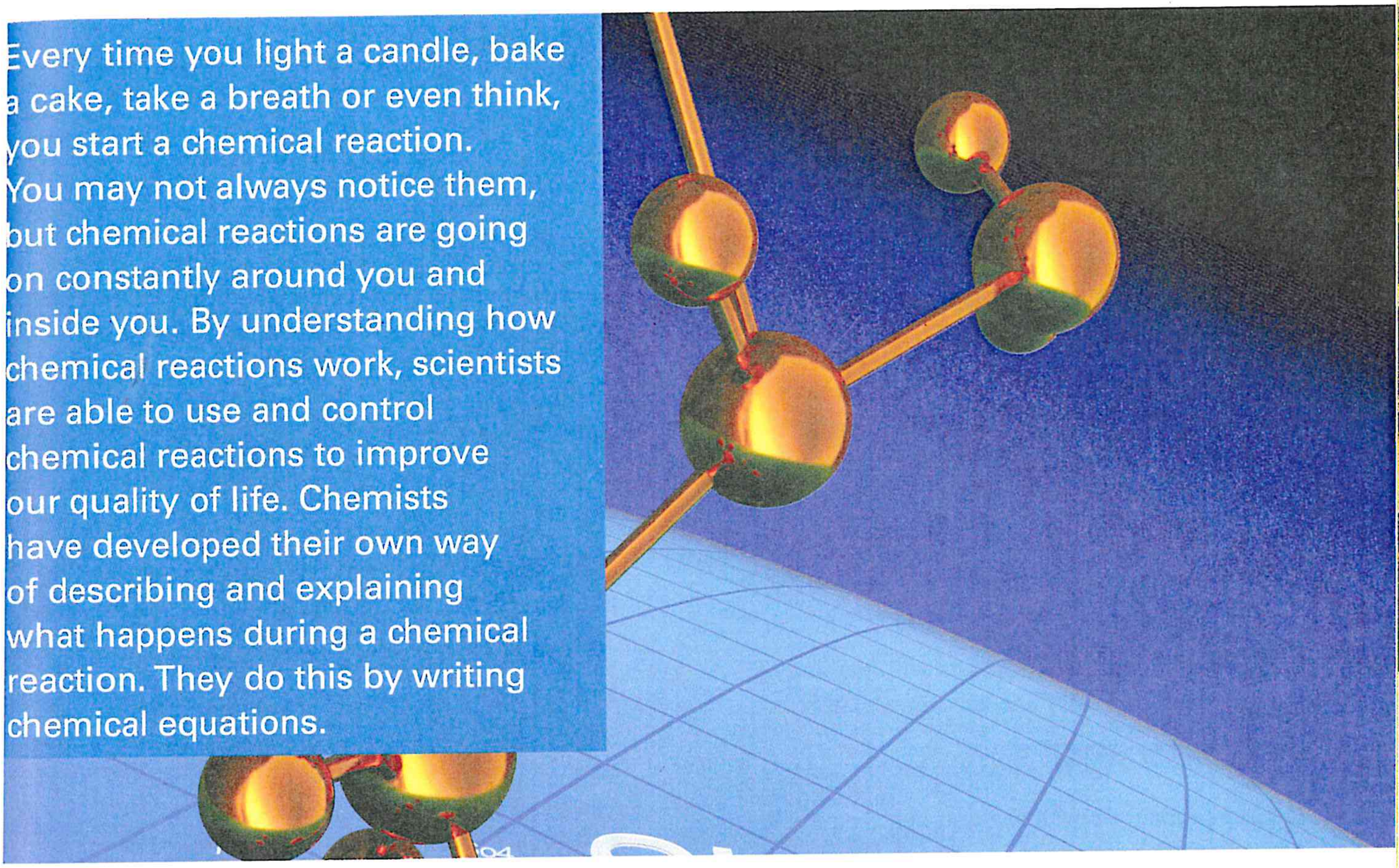
$$\frac{\text{Mass of Mg in MgO}}{\text{Mass of O in MgO}} = \_\_\_\_\_\_\_\_ = \_\_\_\_\_\_\_\_$$

(8) Given that the atomic mass of an oxygen atom is 16, calculate the atomic mass of a magnesium atom. Do the calculation in the space below.

RATE MY UNDERSTANDING
Shade the face that shows your rating

MODULE

6.1 Chemical equations



Every time you light a candle, bake a cake, take a breath or even think, you start a chemical reaction. You may not always notice them, but chemical reactions are going on constantly around you and inside you. By understanding how chemical reactions work, scientists are able to use and control chemical reactions to improve our quality of life. Chemists have developed their own way of describing and explaining what happens during a chemical reaction. They do this by writing chemical equations.

What is a chemical equation?

Chemical equations are one of the most basic tools that scientists use to describe what's happening during a chemical reaction. A chemical equation can communicate detailed information about any chemical reaction in a single line. The general formula of a chemical equation looks like this:

reactants → products

where the arrow (→) shows that a chemical reaction has taken place.

Word and formula equations

Replacing the **reactants** and **products** with their chemical names produces a **word equation**. For example, when calcium carbonate reacts with sulfuric acid it produces calcium sulfate, water and carbon dioxide. In this reaction, you have:

Reactants = calcium carbonate, sulfuric acid

Products = calcium sulfate, water, carbon dioxide

So the general form of an equation:

reactants → products

becomes the word equation:

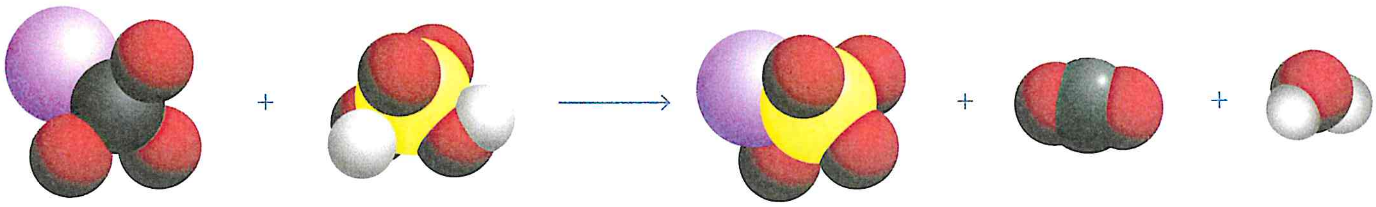
calcium carbonate + sulfuric acid → calcium sulfate + carbon dioxide + water

This is much simpler than trying to explain the chemical reaction with sentences. However, word equations are still quite long.

Scientists can write the equation even more accurately simply by replacing the chemical names with their chemical formulas. The chemical equation for the previous example then becomes:

$$CaCO_3 + H_2SO_4 \rightarrow CaSO_4 + CO_2 + H_2O$$

This type of chemical equation is known as a **formula equation**. The formula equation is shorter to write yet it contains more information as it shows exactly what atoms (or ions) are involved in the chemical reaction. Figure 6.1.1 on page 230 shows how the atoms in the reactants rearrange to form the products.



calcium carbonate + sulfuric acid → calcium sulfate + carbon dioxide + water

$CaCO_3$ + H_2SO_4 → $CaSO_4$ + CO_2 + H_2O

FIGURE 6.1.1 The atoms from the calcium carbonate combine with the atoms from the sulfuric acid to produce calcium sulfate, carbon dioxide and water.

Balanced chemical equations

The formula equation shown in Figure 6.1.1 for the reaction of calcium carbonate with sulfuric acid is a **balanced equation**. This means that it has the same number of atoms of each element on both sides of the equation. This can be checked by counting the number of atoms in the reactants and products:

Reactants = 1 × Ca, 1 × C, 7 × O, 2 × H, 1 × S

Products = 1 × Ca, 1 × C, 7 × O, 2 × H, 1 × S

Balanced equations are consistent with the **law of conservation of mass**. The law states that:

During a chemical reaction, atoms cannot be created or destroyed.

You cannot create or destroy atoms in a chemical reaction. But you can rearrange them. As a result, the number of atoms in the reactants must equal the number of atoms in the products. Also, the mass of the reactants must equal the mass of the products. This is shown in Figure 6.1.2.

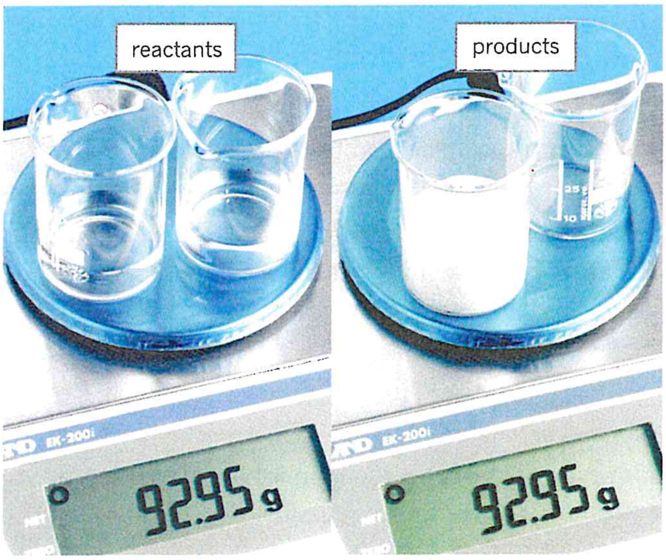


FIGURE 6.1.2 The total mass of these beakers does not change despite a chemical reaction having taken place. The law of conservation of mass says that the total mass of the reactants and the total mass of the products must be the same.

However, not all formula equations will be balanced when you first write them. For example, when hydrogen gas reacts with oxygen gas, the product is water. The word and formula equations for this reaction are:

hydrogen gas + oxygen gas → water

$H_2 + O_2 \rightarrow H_2O$

Counting the number of atoms on both sides of the equation shows that the equation is not balanced.

Reactants = 2 × H, 2 × O

Products = 2 × H, 1 × O

This means that if one molecule of hydrogen reacted with one molecule of oxygen, then an oxygen atom would be left over. This is shown in Figure 6.1.3.

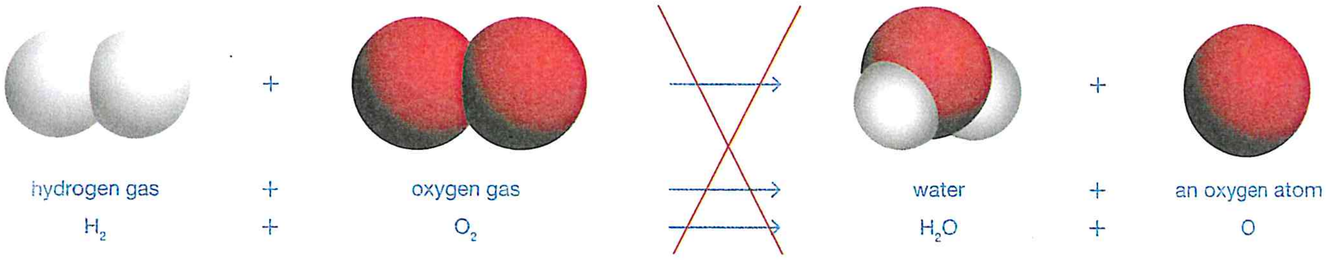
However, if two hydrogen molecules react with one oxygen molecule, then the atoms can rearrange to produce two complete molecules of water. This is shown in Figure 6.1.4. Chemists represent this reaction as a balanced formula equation by writing:

$2H_2 + O_2 \rightarrow 2H_2O$

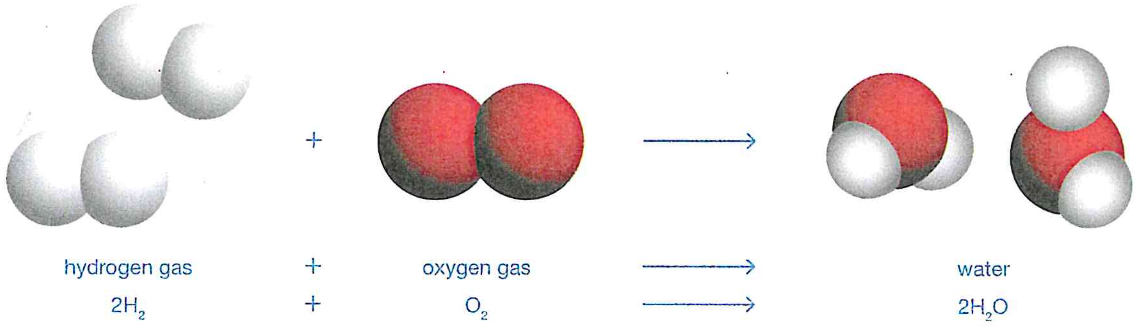
Placing a 2 in front of the chemical formula for hydrogen and water indicates that the reaction uses two hydrogen molecules and produces two water molecules. Re-counting the number of atoms in the reactants and products shows that this equation is now balanced.

Reactants = 4 × H, 2 × O

Products = 4 × H, 2 × O



IGURE 6.1.3 A single hydrogen molecule will not react with a single oxygen molecule ecause there would be an extra oxygen atom left over.



IGURE 6.1.4 It takes two hydrogen molecules for each oxygen molecule, and this roduces two water molecules.

SciFile

Big burners

The fuel tanks that supply fuel to power space rockets into orbit do not use petrol. Some use oxygen and hydrogen that react explosively to produce large amounts of energy very quickly. The equation is:

$$2H_2 + O_2 \rightarrow 2H_2O$$

This creates the enormous plume of exhaust gases that exit from the rocket motors. The rockets accelerate the massive weight to reach escape velocity of about 11 km/s.

Consider another chemical reaction in which calcium metal (Ca) reacts with oxygen gas (O_2) to produce solid calcium oxide (CaO). The reactants in this reaction are calcium and oxygen gas. The only product is calcium oxide. Therefore, the general equation:

reactants → products

becomes the word equation:

calcium + oxygen gas → calcium oxide

Replacing the chemical names with their formulas gives the formula equation:

$$Ca + O_2 \rightarrow CaO$$

Checking the atoms of each element on both sides shows that the equation is unbalanced:

Reactants = 1 × Ca, 2 × O

Products = 1 × Ca, 1 × O

However, it will be balanced if two calcium atoms react with one oxygen molecule to produce two molecules of CaO.

So the final balanced equation can be written as:

$$2Ca + O_2 \rightarrow 2CaO$$

STEM 4 fun

Conserving mass in chemical reactions

PROBLEM

Can you conserve mass in a chemical reaction?

SUPPLIES empty plastic water bottle, balloon, funnel, vinegar, baking soda, electronic balance, measuring cylinder.

PLAN AND DESIGN Design the solution, what information do you need to solve the problem? Draw a diagram. Make a list of materials you will need and steps you will take.

CREATE Follow your plan. Create your solution to the problem.

IMPROVE What works? What doesn't? How do you know it solves the problem? What could work better? Modify your design to make it better. Test it out.

REFLECTION

1 What field of STEM did you work in? Are there other fields where this activity applies?
2 In what career do these activities connect?
3 How did you use mathematics in this task?

SkillBuilder

Balancing equations

Balancing chemical equations can be tricky, but if you follow some simple steps you should arrive at the right answer. Let's look at the reaction between potassium carbonate (K_2CO_3) and nitric acid (HNO_3). This reaction produces potassium nitrate (KNO_3), water (H_2O) and carbon dioxide (CO_2).

STEP 1

Write the word equation.

potassium carbonate + nitric acid → potassium nitrate + water + carbon dioxide

STEP 2

Write the unbalanced equation by replacing the chemical names with the chemical formulas.

$$K_2CO_3 + HNO_3 \rightarrow KNO_3 + H_2O + CO_2$$

STEP 3

Balance each element one by one.

Step 3a: Balance the number of potassium (K) atoms. There are two on the left and only one on the right, so put a 2 in front of the potassium nitrate (KNO_3). This is sensible because you cannot destroy atoms—if you start with 2, you must end up with 2.

$$K_2CO_3 + HNO_3 \rightarrow 2KNO_3 + H_2O + CO_2$$

Step 3b: Balance the number of carbon (C) atoms. There is one on the left and one on the right, so you don't need to change anything.

Step 3c: Balance the number of oxygen (O) atoms. There are six on the left (three from the K_2CO_3 and three from the HNO_3). However, there are nine on the right:

- 1 from the H_2O
- 2 from the CO_2
- 6 from the $2KNO_3$

Putting a 2 in front of the HNO_3 solves the problem:

$$K_2CO_3 + 2HNO_3 \rightarrow 2KNO_3 + H_2O + CO_2$$

Now everything balances. Note that, when trying to balance by adding numbers, this adds multiple lots of everything in the formula. For example, adding a 2 in front of the K_2CO_3 would also balance the oxygen atoms but it would unbalance the potassium and carbon atoms.

Step 3d: Balance the number of hydrogen (H) atoms. There are now two on the left and two on the right, so this balances.

Step 3e: Balance the number of nitrogen (N) atoms. There are now two on the left and two on the right, so this balances.

STEP 4

Double check the numbers of atoms on both sides of the equation.

Reactants = 2 × K, 1 × C, 9 × O, 2 × H, 2 × N

Products = 2 × K, 1 × C, 9 × O, 2 × H, 2 × N

The equation is now balanced.

Worked example

Balancing equations

Problem 1

Construct a balanced chemical equation for the combustion of propane (C_3H_8) in oxygen (O_2) to produce carbon dioxide (CO_2) and water (H_2O).

Solution

Thinking: Write the word equation.

propane + oxygen → carbon dioxide + water

Replace the chemical names with their chemical formulas to get the formula equation.

$$C_3H_8 + O_2 \rightarrow CO_2 + H_2O$$

Working: Balance the number of carbon atoms. There are three in the reactants so multiply the CO_2 by 3 to have three in the products.

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

Balance the number of hydrogen atoms. There are eight in the reactants so multiply the H_2O by four to have eight in the products.

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

Balance the number of oxygen atoms. There are 10 in the products (six from the $3CO_2$ and four from the $4H_2O$) so multiply the O_2 by 5 to have 10 in the reactants.

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

Double check that the number of atoms is the same on both sides of the equation.

Reactants = 3 × C, 8 × H, 10 × O

Products = 3 × C, 8 × H, 10 × O

The equation is balanced.

Problem 2

Construct a balanced chemical equation for the corrosion of aluminium (Al) in oxygen gas to form aluminium oxide (Al_2O_3).

Solution

Thinking: Write the word equation.

aluminium + oxygen gas → aluminium oxide

Replace the chemical names with their chemical formulas to get the formula equation.

$$Al + O_2 \rightarrow Al_2O_3$$

Working: Balance the number of aluminium atoms. There are two in the products so multiply the Al in the reactants by 2 to get two.

$$2Al + O_2 \rightarrow Al_2O_3$$

Balance the number of oxygen atoms. There are three in the products so multiply the O_2 in the reactants by 1.5 to get three.

$$2Al + 1.5O_2 \rightarrow Al_2O_3$$

Check that the number of atoms is the same on both sides of the equation.

Reactants = 2 × Al, 3 × O

Products = 2 × Al, 3 × O

The equation is balanced. However, 1.5 oxygen molecules makes no sense.

Multiply everything by 2.

$$4Al + 3O_2 \rightarrow 2Al_2O_3$$

Double-check that the equation is still balanced.

Reactants = 4 × Al, 6 × O

Products = 4 × Al, 6 × O

The equation is balanced.

Try yourself

Construct a balanced formula equation for the following reactions.

1 Methane (CH_4) burns in oxygen gas (O_2) to produce carbon dioxide (CO_2) and water vapour (H_2O).

2 Calcium carbonate ($CaCO_3$) dissolves in hydrochloric acid (HCl) forming a solution of calcium chloride ($CaCl_2$), carbon dioxide (CO_2) and water (H_2O).

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Prac 2 p. 236

AB 6.8

MODULE

6.2 Energy in chemical reactions

One of the most important features of chemical reactions is that many can produce large amounts of energy. The energy from chemical reactions powers the modern world, with more than 80% of our energy needs coming from the burning of fossil fuels. You also use the energy from chemical reactions to light a birthday candle, cook food, start a car and to breathe. Even your smartphone is powered by the chemical reactions taking place in its battery.

science 4 fun

Acrobatic flame

Can a flame travel along a candle's fumes? YES

Collect this ...

- candle
- box of matches

Do this ...

1. Light the candle and let it burn for a couple of minutes.
2. Strike another match and then blow out the candle.
3. Put the flame of the lit match into the fumes coming from the unlit candle.
4. The candle should reignite as if by magic. See how far you can get the flame to jump.

SAFETY

Be very careful when using matches and candles. Be careful to blow matches out and rinse with water to make sure they are out before disposing of them.

Record this ...

1. Describe what you saw.
2. Explain why you think this happened.

Chemical energy

All molecules store energy in the form of chemical potential energy. **Chemical potential energy** is the source of energy we get from fossil fuels, batteries and food.

The chemical energy is stored in the molecules. However, during a chemical reaction the atoms in the molecules are rearranged and so energy may be released. This is shown by the reaction between hydrogen and oxygen in Figure 6.2.1.

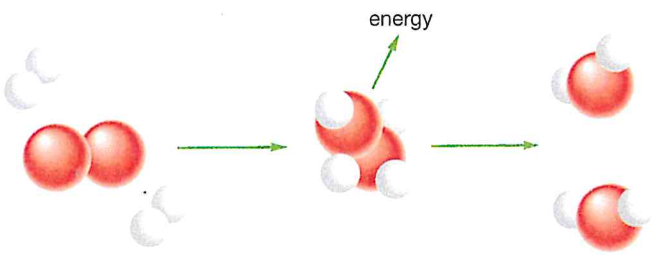


FIGURE 6.2.1 When two molecules of hydrogen (white) react with one molecule of oxygen (red), the atoms rearrange and release energy to form two water molecules.

For example, when octane (C_8H_{18}) in petrol reacts with oxygen it releases energy as heat and a flash of light. The word equation for this reaction is:

octane + oxygen gas → carbon dioxide + water + energy

and its balanced formula equation is:

$$2C_8H_{18} + 25O_2 \rightarrow 16CO_2 + 18H_2O + \text{energy}$$

The chemical reactions in glow sticks and glow-worms are referred to as exothermic reactions because they release energy in the form of light. However, not all exothermic reactions are as impressive as these. Some exothermic reactions may just feel warm to the touch or produce only tiny amounts of heat or light.

Exothermic and endothermic reactions

If the amount of energy stored in the reactants is greater than the energy stored in the products, then energy will be released as heat or light. This type of reaction is known as **exothermic**. Examples include fireworks, explosions, the flame of a Bunsen burner and even glowsticks.

However, in some chemical reactions the amount of energy stored in the reactants is less than the energy stored in the products. In these cases, energy will need to be absorbed from the environment to form the products. These reactions are known as **endothermic** and include chemical ice-packs and photosynthesis.

Endothermic reactions usually feel cold because they absorb the heat energy from your skin and the surroundings. Chemical ice packs use an endothermic reaction between ammonium chloride and water to make the pack icy cold without refrigeration. A chemical ice pack is shown in Figure 6.2.2.

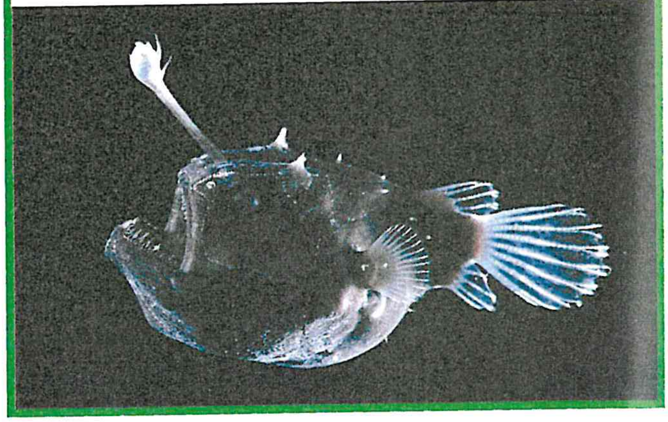
FIGURE 6.2.2 Sports people often use chemical ice packs to soothe injuries. When the endothermic chemical reaction starts, the pack suddenly cools.

Prac 1
p. 243

SciFile

An attractive glow

Many animals, including some deep sea fish and glow-worms, use exothermic chemical reactions that produce light to attract a mate or food. This is called bioluminescence. An example of bioluminescence is the deep sea anglerfish. This fish has a long, bioluminescent antenna that attracts smaller fish while it waits in the darkness to attack.



Reactions with oxygen

Reactions that have oxygen as one of the reactants tend to be exothermic. The fire in Figure 6.2.3 needs oxygen to burn and releases heat so it is an obvious example of an exothermic reaction. Other exothermic reactions involving oxygen are less obvious. These include reactions such as respiration and corrosion.

FIGURE 6.2.3 A fire is an example of a combustion reaction. It releases heat and so is an exothermic reaction.

Combustion reactions

Combustion describes any chemical reaction in which a substance burns in oxygen to produce light and heat. Therefore, all combustion reactions can also be classified as exothermic reactions.

Combustion reactions are some of our most important and useful reactions. Lighting a match, burning gas on a stove top, igniting fuel in a car engine and burning coal in a power station are all examples of combustion. All of these chemical reactions involve oxygen gas and all produce heat and light. Some processes then convert that energy into other forms such as electrical energy.

For example, some spacecraft use hydrogen fuel cells for their propulsion (forward push). These fuel cells release energy because of a combustion reaction. In this reaction, hydrogen gas (H_2) combusts explosively with oxygen gas (O_2) to produce water vapour (H_2O). Its word and chemical equations are:

$$\text{hydrogen gas} + \text{oxygen gas} \rightarrow \text{water vapour}$$
$$2H_2 + O_2 \rightarrow 2H_2O$$

Very reactive metals such as sodium and magnesium can also combust in oxygen. When magnesium is burnt, it combines with the oxygen in the air to produce magnesium oxide. The equations for this reaction are:

$$\text{magnesium} + \text{oxygen} \rightarrow \text{magnesium oxide}$$
$$2Mg + O_2 \rightarrow 2MgO$$

This reaction is exothermic and produces large amounts of heat and bright light as shown in Figure 6.2.4.

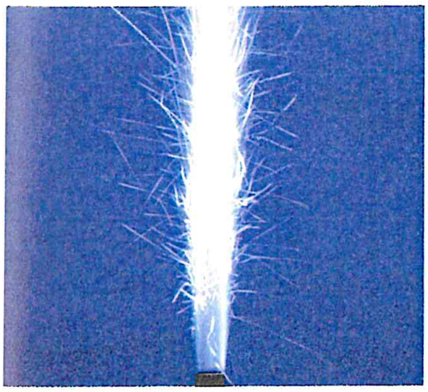


FIGURE 6.2.4 As powdered magnesium burns in this Bunsen burner, a spectacular white light is produced.

Hydrocarbons are substances that are made of only hydrogen and carbon atoms. They can be a gas such as natural gas or methane (CH_4), a liquid like the octane in petrol (C_8H_{18}) or a solid like candle wax ($C_{20}H_{42}$), as shown in Figure 6.2.5. In the case of a candle, the flame continuously heats the wax to form a liquid and vapour that act as fuels for the flame.

AB 6.2

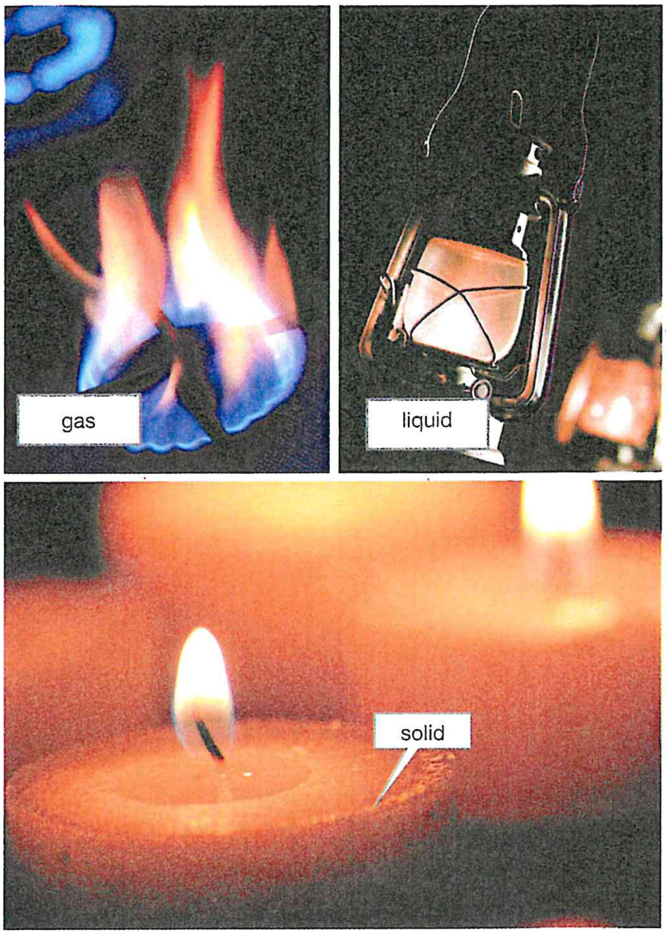


FIGURE 6.2.5 Hydrocarbons come in solid, liquid and gas forms. Most make excellent fuels.

Hydrocarbons make excellent fuels because they burn in oxygen to produce large amounts of energy. The combustion of hydrocarbons produces carbon dioxide and water. For example, the combustion of butane (C_4H_{10}) used as lighter fluid can be presented with the following balanced equations:

$$\text{butane} + \text{oxygen gas} \rightarrow \text{carbon dioxide} + \text{water}$$
$$2C_4H_{10} + 13O_2 \rightarrow 8CO_2 + 10H_2O$$

The chemical reaction changes when the supply of oxygen is limited. In limited oxygen, the combustion of butane proceeds as two reactions, producing a mix of poisonous carbon monoxide and sooty carbon:

$$\text{butane} + \text{oxygen gas} \rightarrow \text{carbon monoxide} + \text{water}$$
$$2C_4H_{10} + 9O_2 \rightarrow 8CO + 10H_2O$$

$$\text{butane} + \text{oxygen gas} \rightarrow \text{carbon} + \text{water}$$
$$2C_4H_{10} + 5O_2 \rightarrow 8C + 10H_2O$$

Combustion in a limited oxygen supply is known as **incomplete combustion**.

Respiration

Respiration is a chemical reaction that goes on inside the cells of all living things. It involves the combination of glucose ($C_6H_{12}O_6$) with oxygen to produce carbon dioxide and water:

glucose + oxygen gas → carbon dioxide + water

$$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$$

The energy produced by respiration is used by the organism to live, move and grow. Respiration is slow compared with combustion, so it doesn't produce large amounts of heat or light. However, it is fast enough to keep your body warm. You get hot when exercising because of respiration. As you require more energy when exercising, you respire more and so you produce more heat (Figure 6.2.6).

FIGURE 6.2.6 Respiration releases energy for the body. Some of this is heat that keeps the body warm. During exercise, more heat than is required is produced.

Corrosion

Most metals will combine with oxygen gas in the air to form metal oxides. This process is known as **corrosion**. The general word equation for corrosion reactions with oxygen is:

metal + oxygen gas → metal oxide

The most common example of corrosion is the rusting of iron and its alloy, steel (Figure 6.2.7). In this process, iron metal combines with oxygen gas and moisture in the air to produce rust, hydrated iron(III) oxide.

iron + oxygen gas + water → hydrated iron(III) oxide

$$4Fe + 3O_2 + 2H_2O \rightarrow 2Fe_2O_3{\cdot}H_2O$$

FIGURE 6.2.7 Corrosion is clearly shown in these abandoned ships.

This reaction is usually written more simply as:

iron + oxygen gas → iron(III) oxide

$$4Fe + 3O_2 \rightarrow 2Fe_2O_3$$

Corrosion and the combustion of metals are very similar chemical reactions. Both reactions involve the combination of metals with oxygen to form metal oxides and both are exothermic. The difference is that corrosion occurs much more slowly than combustion. For example, the combustion of metals produces spectacular amounts of heat and light whereas corrosion produces heat so slowly that it is almost unnoticeable.

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SCIENCE AS A HUMAN ENDEAVOUR

Use and influence of science

Biofuels

As the world's fossil fuel resources start to run out, scientists around the world are looking for alternative fuels and resources. Biofuels may be the answer.

FIGURE 6.2.8 Most biofuels come from crops and so they are a form of renewable energy that can help replace fossil fuels.

Biofuels are a type of fuel that is also a renewable resource. The **biofuel** can be manufactured by fermenting the sugars in crops such as sugar cane, potato and the corn (maize) shown in Figure 6.2.8. The fermentation process uses microorganisms such as yeast to convert the sugars into ethanol according to the reaction:

$$\text{glucose} \rightarrow \text{ethanol} + \text{carbon dioxide}$$

$$C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$$

Ethanol is the alcohol found in alcoholic drinks. It is also found in different petrol blends around the world. For example, in Australia fuel labelled E10 contains 10% ethanol. In Brazil, the only fuel available is E25 (25% ethanol/75% petrol), while E85 (85% ethanol/15% petrol) is sometimes available in Europe and USA. **Biodiesel** (Figure 6.2.9) is another type of biofuel made from plant-based or animal-based fatty acids blended with 'normal' diesel fuel.

The current world production of biofuels is more than 120 billion litres per year and is increasing rapidly. Most of this production comes from corn in the USA and sugar cane in Brazil.

Biofuels provide a renewable alternative to fossil fuels and could make up 25% of the fuels used across the world for transportation. However, biofuels are unlikely to ever be our only source of fuels, as it would require huge areas of land to grow the raw materials required to supply all of our fuel needs.

FIGURE 6.2.9 Biodiesel is a biofuel made by combining plant-based or animal-based fatty acids with 'normal' diesel fuel.

The rapid increase in the demand for biofuels has brought new problems. Crops and farmlands that would once have been used for food are now being used for the production of biofuels. This means that there is less food available and so the price of food increases.

REVIEW

1. List three crops that can be used to produce biofuels.
2. What is the chemical name of the biofuel produced by fermentation?
3. Explain how biofuels can affect the price of food.
4. Explain why biofuels are unlikely to be our only fuel source in the future.