Reaction types

3

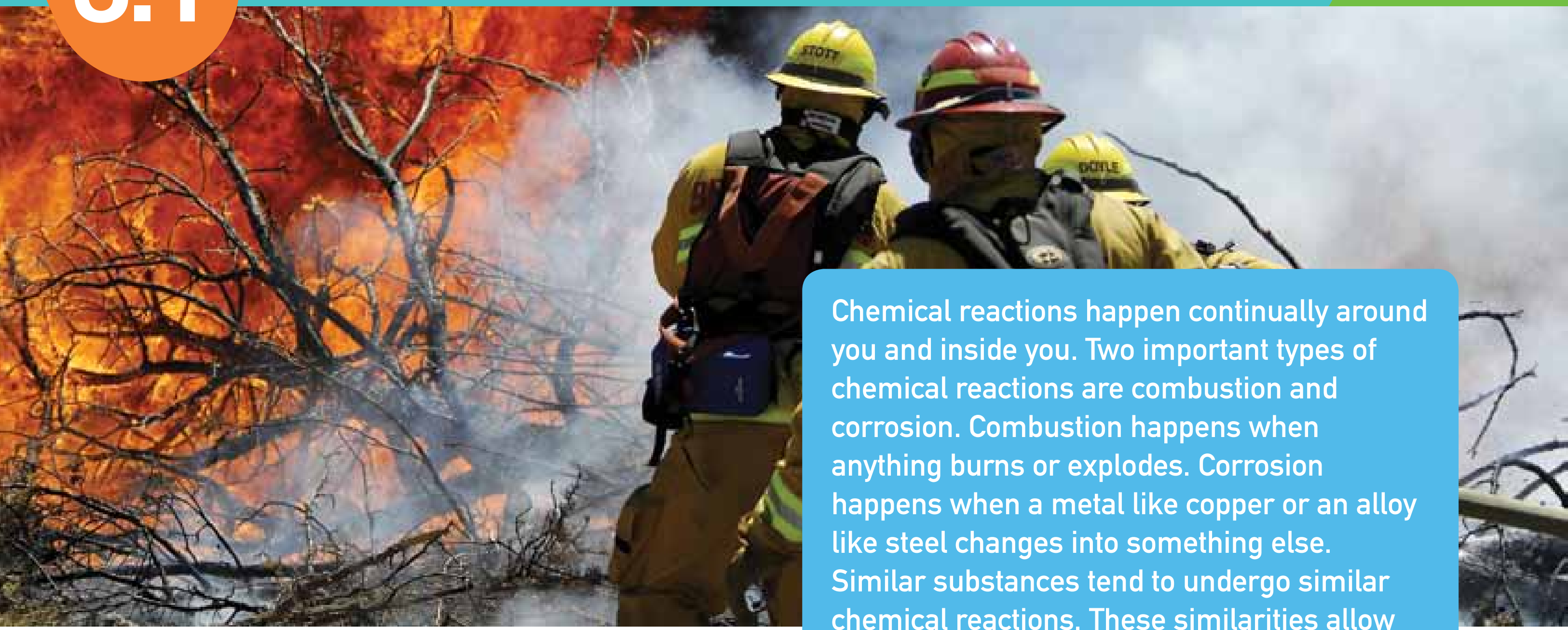
HAVE YOU EVER WONDERED . . .

- what causes iron to rust?
- why some fires are smoky while others aren't?
- how plants can survive when they don't eat anything?
- why we breathe out carbon dioxide and not oxygen?

After completing this chapter students should be able to:

- identify reactants and products in chemical reactions
- describe chemical reactions as a rearrangement of atoms
- describe chemical reactions using word equations
- demonstrate that mass is conserved in a chemical reaction
- classify different reactions as exothermic or endothermic
- outline the role of energy in chemical equations
- describe the role of oxygen in combustion reactions
- compare combustion with other oxidation processes
- describe how the products of combustion reactions affect the environment
- describe reactions of acids with metals, bases and carbonates
- evaluate claims relating to products such as indigestion tablets
- compare respiration and photosynthesis and their roles in biological processes.

3.1 Combustion and corrosion reactions



Chemical reactions happen continually around you and inside you. Two important types of chemical reactions are combustion and corrosion. Combustion happens when anything burns or explodes. Corrosion happens when a metal like copper or an alloy like steel changes into something else. Similar substances tend to undergo similar chemical reactions. These similarities allow you to predict what might happen if two chemicals are mixed. The similarities become more obvious when chemical reactions are expressed as chemical equations.

Endothermic and exothermic reactions

Chemical equations are used to explain what happens to substances when they undergo chemical change in a chemical reaction. **Reactants** are the substances you started with before the chemical reaction. **Products** are the substances that are formed by the chemical reaction.

In some reactions, the products have more energy than the reactants. These reactions need energy to proceed and they get their energy from their surroundings. Reactions like this are known as **endothermic** reactions. An example is what happens in a chemical cold pack that you apply when you have an injury. Packets of ammonium nitrate and water are broken, allowing these substances to mix and react. As they do so, they absorb energy from their surroundings, cooling them down. The sherbet in Figure 3.1.1 acts in a similar way.

Figure 3.1.1

Sherbet leaves your tongue cold and tingling because an endothermic reaction absorbs heat from your mouth.

INQUIRY science 4 fun

Eating sherbet

What does an endothermic reaction in your mouth feel like?

Yes

Collect this . . .

- ½ teaspoon citric acid
- ¼ teaspoon baking soda (bicarbonate of soda, $NaHCO_3$)
- 3 teaspoons icing sugar
- clean mixing bowl, cup or mug
- teaspoon

Do this . . .

1. Add all the ingredients to the small mixing bowl or mug.
2. Use the back of the teaspoon to crush any lumps and to mix everything together.
3. Keep it in a dry place until ready to eat!

Record this . . .

Describe what happened in your mouth when you ate the sherbet.

Explain why you think this happened.

Writing chemical equations

To write a chemical equation, follow the four steps below.

Step 1: Identify the reactants and products

As an example, consider the chemical reaction between copper and sulfur dioxide. This reaction forms copper sulfide and oxygen gas. We started with copper and sulfur dioxide, so these are the reactants. Copper sulfide and oxygen gas were produced. These are the products.

Step 2: Write a word equation

A **word equation** is a simple written description of what is happening in the reaction. The reactants are placed on the left side of the arrow and the products on the right.

reactants → products

copper + sulfur dioxide → copper sulfide + oxygen gas

Step 3: Write an unbalanced formula equation

The next step is to replace the names of each substance in the word equation with their element symbols or chemical formulas. This gives you an unbalanced formula equation. For the above reaction, you need to know that copper has the element symbol Cu and the chemical formula of sulfur dioxide is SO_2, copper sulfide is Cu_2S and oxygen gas is O_2.

This gives you the following equation:

copper + sulfur dioxide → copper sulfide + oxygen gas

$$Cu + SO_2 \rightarrow Cu_2S + O_2$$

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Step 4: Balance the equation

An equation is unbalanced if it has unequal numbers of atoms of a particular element on both sides of the arrow. The above equation starts with one copper atom, one sulfur atom and two oxygen atoms. However, the equation ends up with two copper atoms, one sulfur atom and two oxygen atoms. This suggests that a copper atom appeared from nowhere! That is impossible because atoms never just appear in chemical reactions. Nor do they disappear. They only change in the way they are arranged. This fundamental principle of chemistry is known as the **law of conservation of mass**. Formula equations need to be balanced, to describe accurately the rearrangement that is happening in the reaction.

A **balanced formula equation** has the same numbers of each atom on both sides of the arrow. The above reaction would be balanced if the reaction used up two atoms of copper instead of just one. This is indicated by inserting a 2 in front of the Cu, as shown here:

$$2Cu + SO_2 \rightarrow Cu_2S + O_2$$

Figure 3.1.2 shows what is happening to the atoms in this reaction.

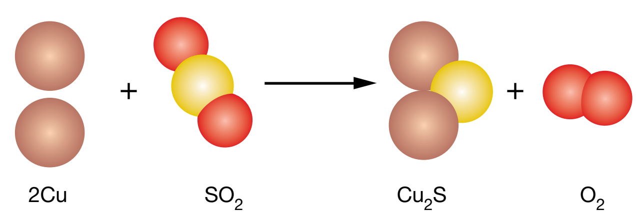

Figure 3.1.2 Atoms can't appear from nothing and can't disappear. This is why chemical equations must be balanced.

Photosynthesis is the reaction that green plants use to form a sugar known as **glucose** ($C_6H_{12}O_6$). This reaction absorbs energy from sunlight (Figure 3.1.3) and so it is another example of an endothermic reaction. The photosynthesis reaction is shown below.

carbon dioxide + water → glucose + oxygen

$$6CO_2 + 6H_2O \xrightarrow[\text{chlorophyll}]{\text{sunlight}} C_6H_{12}O_6 + 6O_2$$

Figure 3.1.3 Without energy from the Sun, the photosynthesis reaction in these leaves would never happen and the plant would die.

Combustion

While endothermic reactions absorb energy, **exothermic** reactions release energy. In exothermic reactions, the reactants have more energy than the products. During the reaction, the difference in these energies is released into the surroundings, usually as heat and/or light.

Combustion reactions are examples of exothermic reactions. **Combustion** occurs whenever something reacts with oxygen gas (O_2), burning or exploding as it does so. A bushfire is a series of combustion reactions. The chemicals in living plants and dead twigs and leaves burn in oxygen, releasing huge amounts of heat and light as they react.

Oxygen gas is always needed for combustion to occur. For this reason, combustion reactions can also be classified as a type of oxidation reaction.

Figure 3.1.4 A gas stove uses combustion to release its heat (and light).

> **That's shocking!**
> Explosions generate hot gases that suddenly expand at speeds of up to 8 kilometres per second! These expanding gases form blasts of wind called shockwaves, which can be as deadly as the explosion itself. A shockwave leaves a vacuum at the site of the explosion, and air flowing into this carries rubbish and debris.
>
> SciFile

Combustion of fossil fuels

Bunsen burners, gas stoves (like the one in Figure 3.1.4), water heaters and central heating furnaces produce a hot blue flame by burning methane or ethane gas in oxygen. The reactions are:

methane gas + oxygen gas → carbon dioxide + water vapour

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

ethane + oxygen gas → carbon dioxide + water vapour

$$2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O$$

> **Suffocating fires**
> Fires consume oxygen, so there is less of it to breathe in the region of the fire! During World War II, the German city of Dresden was firebombed. Many of the 25 000 people killed in the attack are thought to have suffocated because of this lack of oxygen.
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Petrol is a mixture of highly combustible chemicals called **hydrocarbons**, the most important of which is octane. Octane combusts via the chemical equation:

octane + oxygen gas → carbon dioxide + water vapour

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

Incomplete combustion

The above combustion reactions all need oxygen fed into them. These reactions are known as **complete combustion**. If the oxygen supply is restricted, other reactions occur instead. This is known as **incomplete combustion**. Incomplete combustion is still exothermic but does not release as much heat or light energy as complete combustion does.

The reactions below show what happens to methane if oxygen is restricted.

methane + oxygen gas → carbon monoxide + water vapour

$$2CH_4 + 3O_2 \rightarrow 2CO + 4H_2O$$

At the same time another reaction occurs.

methane + oxygen gas → carbon + water vapour

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

Incomplete combustion reactions are 'dirty' because they produce carbon, which is left behind as soot, charcoal or smoke, like that seen in Figure 3.1.5. They also produce the poisonous gas carbon monoxide. In contrast, complete combustion reactions are 'clean'.

A Bunsen burner can show both complete and incomplete combustion. If the flow of oxygen to it is good (open airhole), then the flame is hot, clean and blue. If the air flow is restricted (closed airhole), then a cooler dirty yellow flame is produced.

Figure 3.1.5 Smoke and soot are an indication of incomplete combustion.

Figure 3.1.6 Respiration gives your body the energy it needs. The reaction needs glucose (from your food) and oxygen (breathed in). You breathe out its product, carbon dioxide.

Pollution and climate change

Water vapour and carbon dioxide are released into the atmosphere whenever fossil fuels like gas, petrol, oil, coal, and diesel and aviation fuel are burnt. Carbon dioxide is a greenhouse gas that traps heat within the atmosphere. Over the past 150 years, humans have burned huge quantities of fossil fuels to power their cars, ships and aircraft, and to heat their homes and generate electricity. For this reason, the amount of carbon dioxide in the atmosphere has increased to levels that most scientists agree are increasing the atmosphere's average temperature. If this view is correct, it could be affecting Earth's climate.

If the combustion of these fossil fuels is incomplete, then carbon monoxide and carbon are released. Carbon adds relatively harmless but dirty soot to the atmosphere. However, carbon monoxide gas has no smell and is so poisonous that even small amounts of it can kill. Petrol also contains additives that release other poisonous chemicals when burnt. These include oxides of nitrogen and sulfur, both of which can combine with moisture in the air to form smog and acid rain.

Other combustion reactions

A much slower and controlled combustion reaction occurs within the cells of your own body. **Aerobic respiration** combines a type of sugar called glucose from the digestion of your food with the oxygen you breathe in. This reaction releases the energy that the cells of your body need. A waste product is carbon dioxide, which you breathe out. This is what is happening in Figure 3.1.6.

glucose + oxygen gas → carbon dioxide + water vapour

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

Not all combustion reactions produce carbon dioxide and water vapour. When burnt, magnesium reacts to form magnesium oxide. No other products form.

magnesium + oxygen gas → magnesium oxide

$$2Mg + O_2 \rightarrow 2MgO$$

You can see this reaction happening in Figure 3.1.7.

Figure 3.1.7 The light released by the combustion of magnesium is so bright that it can quickly damage your eyes.

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Corrosion reactions

Another type of oxidation reaction is corrosion. Most metals corrode when exposed to water, air or other chemicals. **Corrosion** is the chemical reaction that breaks these metals down to form other compounds.

For example, the iron/steel body of a car slowly reacts with water and oxygen in the air and will corrode until all that's left is a pile of rust.

In a similar way, copper corrodes by reacting with gases in the air to form green **verdigris** (shown in Figure 3.1.8), a mixture of copper hydroxide and copper carbonate. The chemical equation is:

copper + water + carbon dioxide + oxygen gas → copper hydroxide + copper carbonate

$$2Cu + H_2O + CO_2 + O_2 \rightarrow Cu(OH)_2 + CuCO_3$$

Figure 3.1.8

This copper roof has corroded to form a green coating called verdigris.

Pure silver reacts with sulfur to form a black coating called **tarnish** (silver sulfide). This sulfur comes from hydrogen sulfide in air pollution or from foods such as eggs, fish, onions and pea soup.

silver + hydrogen sulfide → silver sulfide + hydrogen gas

$$2Ag + H_2S \rightarrow Ag_2S + H_2$$

Pure sodium and potassium react with just about anything. Their corrosion is very quick and often explosive because of the hydrogen gas that their reactions produce. Their chemical reactions with water are shown below.

sodium + water → sodium hydroxide + hydrogen gas

$$2Na + 2H_2O \rightarrow 2NaOH + H_2$$

potassium + water → potassium hydroxide + hydrogen gas

$$2K + 2H_2O \rightarrow 2KOH + H_2$$

Rusting

Iron and its alloy, steel, are common and relatively cheap, making them the most commonly used metals on Earth. Unfortunately, iron and most grades of steel react with air and water to form **rust**, known chemically as hydrated iron(III) oxide (chemical formula $Fe_2O_3{\cdot}H_2O$). Rust is flaky and easy to dislodge. This allows the rusting process to continue into the next layer, making the iron or steel thinner and weaker. Figure 3.1.9 shows what can happen.

Figure 3.1.9 Rust forms when iron is exposed to oxygen and water.

Although an extremely complex reaction, rusting can be summarised by the chemical equation:

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

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

This equation is often simplified to:

iron + oxygen gas → iron(III) oxide

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

Corrosion of aluminium

Aluminium is very reactive. The surface metal reacts almost immediately with the air, forming a fine layer of dull grey aluminium oxide (Al_2O_3).

aluminium + oxygen gas → aluminium oxide

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

Unlike rust, this layer does not flake but acts instead like a tightly bound layer of paint, protecting the aluminium from further corrosion.

Anodising is a process that deliberately builds up a layer of aluminium oxide to protect the aluminium underneath (Figure 3.1.10).

Figure 3.1.10 These cups are made of anodised aluminium. Their surface is a layer of aluminium oxide that was deliberately built up on the surface of the metal and then coloured. This layer protects the aluminium underneath from corroding any further.

3.1 Unit review

Remembering

1 **State** what substance is always required for combustion to occur.

2 **Name** the sugar made in the process of photosynthesis.

3 **Recall** the following reactions by writing the word equations for:
  a the combustion of ethane
  b the corrosion of iron.

4 **Recall** the following reactions by writing the word equation and balanced formula equation for:
  a the combustion of octane
  b the corrosion of copper.

5 **Name** the process that is often used to protect aluminium from further corrosion.

Understanding

6 **Explain** where the energy comes from in an exothermic reaction.

7 **Explain** how a Bunsen burner can display both complete and incomplete combustion.

8 Gary's campfire was 'dying' so he fanned it with a newspaper. Flames soon appeared once more. **Explain** how his actions helped the fire build again.

9 **Explain** why the rusting of iron makes it get thinner and thinner.

Applying

10 The combustion of butene is shown by the following word and balanced equations.

butene + oxygen gas $\longrightarrow$ carbon dioxide + water

$$C_4H_8 + 6O_2 \longrightarrow 4CO_2 + 4H_2O$$

Identify:
  a the chemical formula for butene
  b reactants for the reaction
  c products for the reaction.

11 **Identify** the missing numbers that would balance the following equations.
  a $2Ca + O_2 \longrightarrow .....CaO$
  b $C_3H_8 + 5O_2 \longrightarrow 4H_2O + ...CO_2$
  c $2Li + ...H_2O \longrightarrow ....LiOH + H_2$

Analysing

12 **Classify** the following reactions as endothermic or exothermic.
  a A bushfire burns down a forest.
  b Photosynthesis uses energy from the Sun.
  c Aerobic respiration releases energy for use in cells.
  d Sherbet tingles in your mouth.
  e Magnesium burns in oxygen and releases light.
  f A chemical cold pack cools sore muscles.

13 **Contrast** complete and incomplete combustion.

14 **Contrast** the corrosion of iron with the corrosion of aluminium.

15 **Compare** combustion with corrosion.

Evaluating

16 A flat sheet of paper burns quickly and with little smoke. In contrast, a tightly crumpled sheet of paper will smoulder, with few flames but a lot of smoke. **Propose** reasons why.

17 Bushfires tend to be hotter and more fierce when a strong wind is blowing. **Propose** reasons why.

Creating

18 Benzene (C_6H_6) burns in oxygen gas (O_2) to produce carbon dioxide (CO_2) and water (H_2O).
  a **Identify** the reactants of this reaction.
  b **Identify** the products of this reaction.
  c **Construct** a word equation for the reaction.
  d **Construct** its unbalanced formula equation.
  e **Construct** its balanced equation.

Inquiring

1 Research the products of combustion reactions (such as those in car exhausts or industrial emissions) and the effects of these products on the environment.

2 Use the key words *balancing chemical equations games* to find websites that do the balancing for you!

3 Antoine Lavoisier developed the law of conservation of mass. Research his life and achievements and construct a simple biography outlining what you found out.

4 Use the key words *chemical reaction video, corrosion video* or *combustion video* to find internet videos of different types of chemical reactions.

3.1 Practical activities

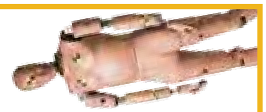
1 Conservation of mass

Purpose

To demonstrate that mass is conserved in a chemical reaction.

Materials

- 0.1 M copper sulfate solution
- 0.1 M sodium hydroxide solution
- 0.1 M sodium carbonate solution
- ammonia solution
- four 250 mL beakers
- marking pen
- electronic balance



SAFETY

All chemicals should be treated as toxic.

Do not taste any chemicals.

Procedure

1. Pour copper sulfate solution into one of the beakers until it reaches the 50 mL mark. Use the marking pen to label this beaker BLUE.
2. To the other beaker add 50 mL of sodium hydroxide solution.
3. Place both beakers on the electronic balance and determine their total mass. Record this mass in a table like the one in the Results section.
4. Carefully pour the copper sulfate into the sodium hydroxide and observe what happens.
5. Place the beaker with the solutions in it and the empty beaker labelled BLUE back on the electronic balance. Once again determine their total mass. Record their mass.
6. To a clean beaker, add 50 mL of sodium carbonate. Add another 50 mL of copper sulfate to the beaker labelled BLUE. Once again, find their total mass.
7. Carefully pour the copper sulfate solution into the sodium carbonate solution. As before, find the total mass of the full and empty beakers.
8. Repeat steps 6 and 7 but this time use ammonia solution instead of sodium carbonate.

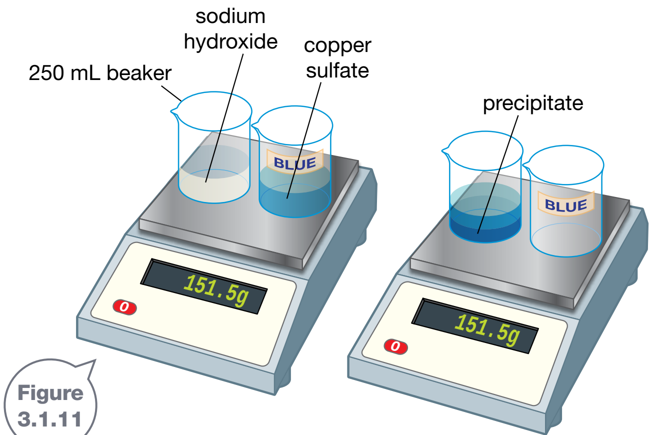


Figure 3.1.11

Extension

9. Allow each of the mixed solutions to settle. The powdery solid that settles on the bottom of the beaker is known as a precipitate. Design a way of filtering each solution so that you can determine the mass of the precipitate formed (trapped in the filter paper) and the filtrate (the liquid that passes through the filter paper).

Results

Record all your observations and masses in a table like the one shown here.

	Total mass before mixing (g)	Total mass after mixing (g)	Observations
Sodium hydroxide + copper sulfate			
Sodium carbonate + copper sulfate			
Ammonia + copper sulfate			

Discussion

1. **List** evidence that chemical reactions took place once the solutions were mixed.
2. **Compare** the total masses before and after mixing.
3. **State** the law of conservation of mass.
4. **Assess** whether or not your results support this law.

2 Conservation of mass in combustion reactions

Purpose

To show that combustion reactions obey the law of conservation of mass.

Materials

- electronic balance
- clean steel wool

Part A: Combustion in the open air

- evaporating dish or watch-glass
- 9V battery

Part B: Combustion in a sealed container

- large Pyrex test-tube
- test-tube tongs
- balloon
- Bunsen burner and bench mat

SAFETY

Sparks will fly in Part A. Make sure they don't hit you or your clothes.

In Part B if sparks enter the balloon it could partly melt or catch fire.

Procedure

Part A: Combustion in the open air

1. Tease out the strands of a small piece of steel wool (about 1 gram) and place it in an evaporating dish or watch-glass.
2. Use the electronic balance to find the combined mass of both the evaporating dish/watch-glass and the steel wool. Record the total mass in a results table like the one shown in the Results section.
3. Pass an electric current through the steel wool by lowering a 9 V battery until both of its terminals touch the steel. Record your observations in the table.
4. Shift the battery around to other parts of the steel wool so that as much of the steel as possible is burnt.
5. When completed, find the mass of the evaporating dish/watch-glass and the burnt steel wool. Record the new mass in the table.

Part B: Combustion in a sealed container

6. Tease out a strand of steel wool (about 0.5 gram) and slide it into the test-tube.
7. Squeeze all the air out of the balloon and fit it over the opening of the test-tube, as shown in Figure 3.1.12.
8. Find the total mass of the test-tube, balloon and steel wool combined and record it in your table.
9. Use tongs to hold the test-tube over a blue Bunsen burner flame. Make sure that you move the test-tube back and forth in the flame and that the flame gets nowhere near the balloon. Stop heating after about 5 minutes. Record what you saw happen in the test-tube and to the balloon.
10. Allow the test-tube to cool completely. When the test-tube is cool, again find the total mass of the test-tube, steel wool and balloon.

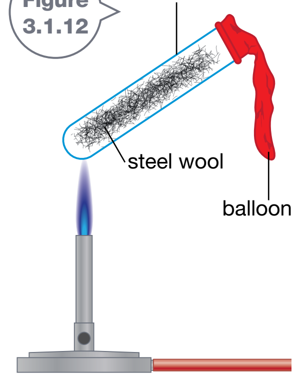


Figure 3.1.12

Results

Record all your measurements in a table like this one.

	Total mass before (g)	Total mass after (g)	Observations
Part A			
Part B			

Discussion

1. The reactions in both Part A and Part B were combustion reactions. **State** what other substance is needed for combustion to occur.
2. The reactions in both Part A and Part B could also be classified as corrosion reactions. **Explain** why.
3. The total mass in Part A most likely increased. **Propose** where this increase in mass came from.
4. The total mass at the end of Part B was most likely the same or very similar to the total mass at the start. **Propose** reasons why.
5. **Assess** which set of results (Part A or Part B) best demonstrated the law of conservation of mass.

3.1 Practical activities

3 Cracker combustion

Purpose

To observe how combustion releases heat energy.

Materials

- dry biscuits (such as Clix crackers)
- large test-tube
- thermometer
- retort stand, bosshead and clamp
- bench mat
- metal tongs
- Bunsen burner
- electronic balance

SAFETY

An open flame can be dangerous. The room should be well ventilated.

Biscuits containing nuts should not be used in case of nut allergies.

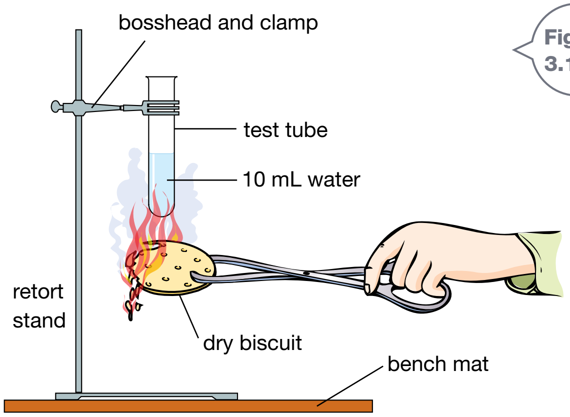


Figure 3.1.13

Procedure

1. Set up the apparatus as shown in Figure 3.1.13.
2. Use the measuring cylinder to measure out 10 mL of water. Add it to the test-tube.
3. Measure the temperature of the water in the test-tube.
4. Measure the mass of the dry biscuit.
5. Use the tongs to hold the biscuit in a blue Bunsen burner flame. Heat the biscuit until it catches fire.
6. Quickly hold the biscuit under the test-tube. Re-light the biscuit if it goes 'out'.
7. Measure the temperature of the water again once the biscuit has changed completely into ash.

Extension

8. Test what happens if the amount or number of biscuits is increased. For example, do two biscuits cause the temperature to rise twice as far?

Results

1. Record all your measurements in a table like the one shown here.

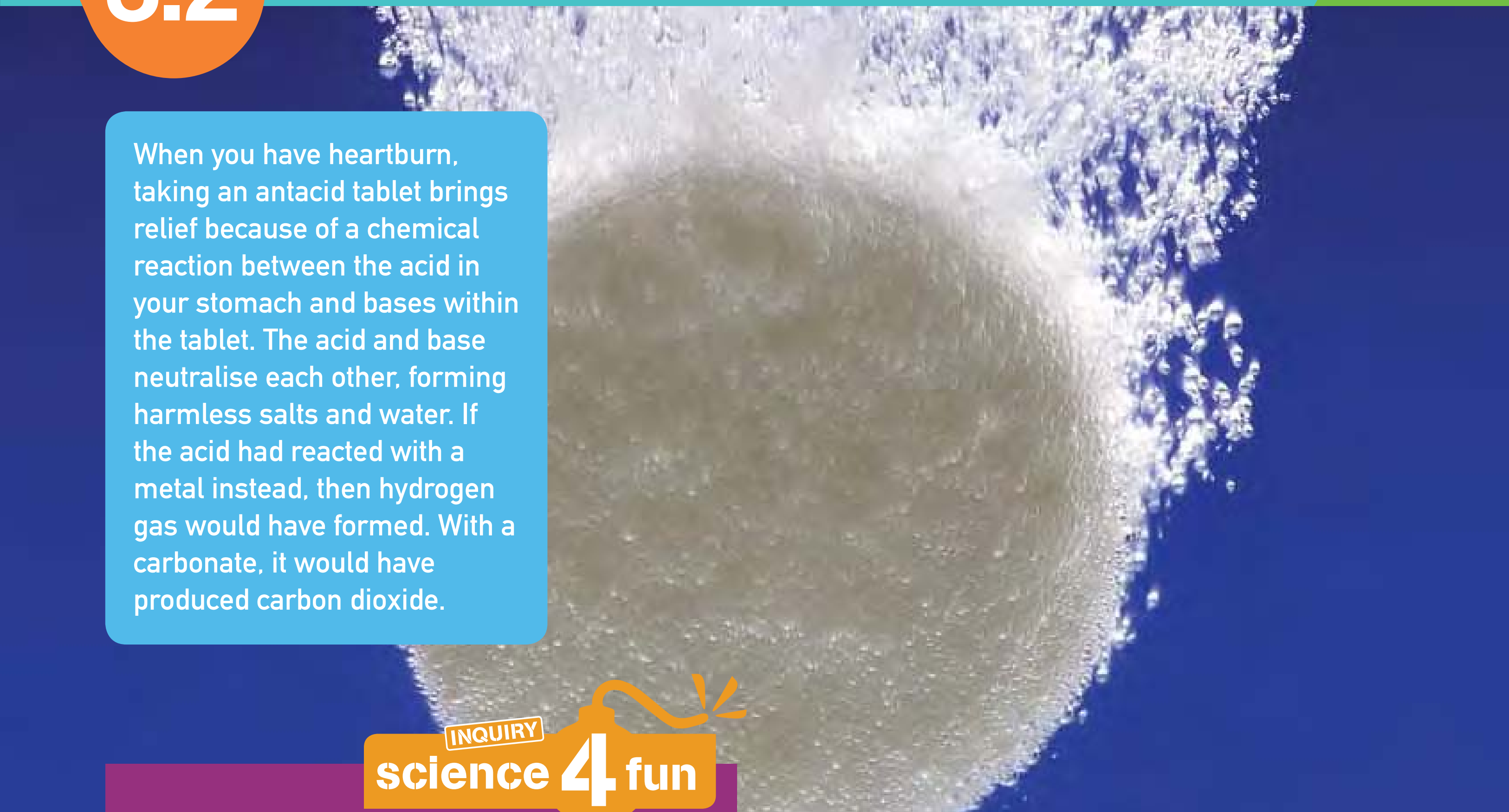
	Number of biscuits		
	1	2	3
Mass (g)			
Temperature before (°C)			
Temperature after (°C)			
Temperature rise (°C)			
Energy absorbed (J) = temperature rise x 42			

2. Determine how much energy was absorbed by the water, by multiplying the temperature rise by 42. (It takes 42 J of heat energy to raise the temperature of 10 mL of water by 1°C.)

Discussion

1. a **Identify** whether the biscuit underwent complete or incomplete combustion.
   b **Justify** your answer.
2. The amount of energy absorbed by the water is less than the amount of energy released by the biscuit. **Explain** why.
3. **Construct** a conclusion for what happened when the mass or number of biscuits increased.
4. **Evaluate** your experiment to determine ways in which it could be improved.

3.2 Acid reactions



When you have heartburn, taking an antacid tablet brings relief because of a chemical reaction between the acid in your stomach and bases within the tablet. The acid and base neutralise each other, forming harmless salts and water. If the acid had reacted with a metal instead, then hydrogen gas would have formed. With a carbonate, it would have produced carbon dioxide.

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Exploding bags

Can acids and bases mix together to produce an explosion?

Collect this …

- 1 zip-lock plastic bag
- a few squares of toilet paper
- baking soda (bicarbonate of soda, $NaHCO_3$)
- vinegar
- warm water
- tablespoon
- measuring cup

Do this …

1 Measure out a tablespoon of baking soda and wrap it up in few sheets of toilet paper. Twist the paper to hold it all in place.
2 Pour ¼ cup of vinegar and ¼ cup of warm water into the zip-lock bag.
3 Zip up the bag but leave a gap big enough for your baking soda parcel to fit through.
4 Go outside and push the parcel in. Quickly zip up the gap and place it on the ground. Stand clear!

Record this …

Describe what happened.

Explain why you think this happened.

Acids and metals

Acids can corrode metals, usually breaking them down into a salt and hydrogen gas. An example of this type of reaction is shown in Figure 3.2.1.

Figure 3.2.1

Iron reacts with hydrochloric acid, forming bubbles of hydrogen gas.

The general equation for the reaction between an acid and a metal is:

acid + metal → a salt + hydrogen gas

Examples are:

hydrochloric acid + magnesium → magnesium chloride + hydrogen gas

$2HCl + Mg \rightarrow MgCl_2 + H_2$

sulfuric acid + iron → iron sulfate + hydrogen gas

$H_2SO_4 + Fe \rightarrow FeSO_4 + H_2$

Salt is normally the term used for sodium chloride (NaCl). In these reactions, however, it is used in a much more general way. Here the term salt means any compound formed by a metal taking the place of the hydrogen atom in an acid. For example, potassium nitrate (KNO_3), magnesium sulfate ($MgSO_4$) and calcium chloride ($CaCl_2$) are all salts.

1 p83

Neutralisation reactions

Acids and bases neutralise each other when mixed, changing each other into harmless substances such as water and a salt. **Neutralisation** reactions take the form:

acid + base → a salt + water

Examples are:

nitric acid + potassium oxide → potassium nitrate + water

$2HNO_3 + K_2O \rightarrow 2KNO_3 + H_2O$

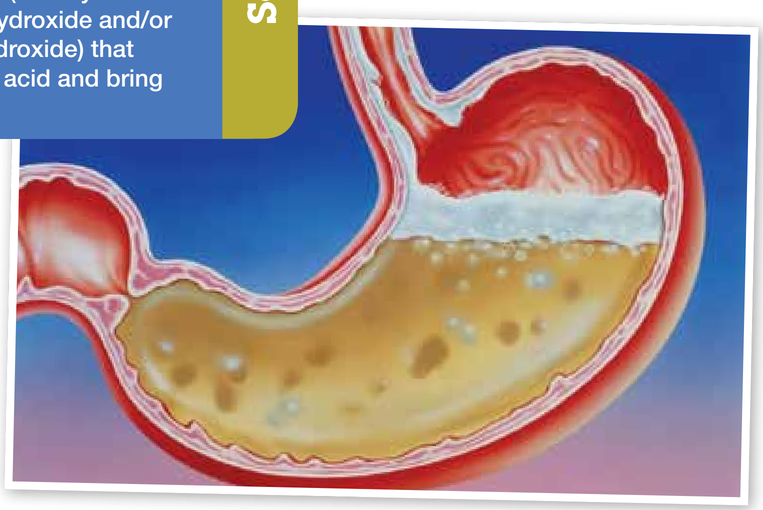
sulfuric acid + sodium hydroxide → sodium sulfate + water

$H_2SO_4 + 2NaOH \rightarrow Na_2SO_4 + 2H_2O$

SciFile

That feels better!

Heartburn is caused by hydrochloric acid from your stomach rising into your oesophagus (foodpipe) and burning it. Antacid tablets contain bases (usually magnesium hydroxide and/or aluminium hydroxide) that neutralise the acid and bring quick relief.



Acids and carbonates

When the base is a carbonate, the reaction between it and an acid produces carbon dioxide as well as a salt and water. The general equation is:

acid + carbonate → a salt + water + carbon dioxide

Figure 3.2.2 shows the reaction between the calcium carbonate in chalk and hydrochloric acid. Its reaction is:

hydrochloric acid + calcium carbonate → calcium chloride + water + carbon dioxide

$2HCl + CaCO_3 \rightarrow CaCl_2 + H_2O + CO_2$

Figure 3.2.2 Chalk contains the base calcium carbonate. Here hydrochloric acid reacts with the calcium carbonate to form bubbles of carbon dioxide.

Carbon dioxide is also produced when acids react with hydrogen carbonates. For example, vinegar (ethanoic or acetic acid) and baking soda (sodium hydrogen carbonate) mix and form a froth of carbon dioxide bubbles. You can see this in Figure 3.2.3. Its equations are:

ethanoic acid + sodium hydrogen carbonate → sodium acetate + water + carbon dioxide

$$CH_3COOH + NaHCO_3 \rightarrow NaCH_3COO + H_2O + CO_2$$

Figure 3.2.3

Bicarbonate of soda (sodium hydrogen carbonate) is a base. Vinegar contains acetic acid. When mixed, these chemicals react rapidly, neutralising each other and producing lots of bubbles of carbon dioxide.

INQUIRY science 4 fun

Acid rain

Chalk contains calcium carbonate, the same compound that is in marble. Can you use it to imitate the action of acid rain on marble?

Collect this …

- 3 identical glasses
- 3 identical sticks or pieces of chalk
- lemon juice
- vinegar
- water

Do this …

1. Fill the three glasses with identical amounts of lemon juice, vinegar and water.
2. Put a stick or piece of chalk in each glass, making sure each stick or piece is identical in size.
3. Leave the glasses somewhere where they won't be disturbed.
4. After three days (or more), inspect what has happened to the chalk in each glass.

Record this …

Describe what happened.

Explain why you think this happened.

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Ease the pain

The acid of a bee sting should be relieved by neutralising it with a base, like bicarbonate of soda. Likewise, the alkaline sting of a wasp should be neutralised by vinegar or even urine. Unfortunately, these usually don't work because they rarely go deep enough into the tissues inflamed by the sting.

SCIENCE AS A HUMAN ENDEAVOUR

Nature and development of science

Acid rain

Figure 3.2.4 Acid rain has killed many forests in North America and Europe.

Rainwater is naturally slightly acidic, with a pH between 5 and 6.

This is because rainwater reacts with some of the carbon dioxide in the air to form carbonic acid.

$$\text{water} + \text{carbon dioxide} \rightarrow \text{carbonic acid}$$

$$H_2O + CO_2 \rightarrow H_2CO_3$$

Pollution can cause rainwater to become even more acidic. The combustion of fossil fuels (particularly coal) releases carbon dioxide, sulfur dioxide (SO_2) and nitrogen oxides (mainly nitrogen dioxide, NO_2) as pollutants into the atmosphere. As a result, rainfall has more carbonic acid in it. It also has strong acids in it formed by the combination of sulfur dioxide and nitrogen dioxide with water vapour in the atmosphere. These form via a series of chemical equations that can be summarised as:

$$\text{sulfur dioxide} + \text{water vapour} \rightarrow \text{sulfurous acid}$$

$$SO_2 + H_2O \rightarrow H_2SO_3$$

$$\text{sulfur dioxide} + \text{water vapour} + \text{oxygen gas} \rightarrow \text{sulfuric acid}$$

$$2SO_2 + 2H_2O + O_2 \rightarrow 2H_2SO_4$$

$$\text{nitrogen dioxide} + \text{water} \rightarrow \text{nitrous acid} + \text{nitric acid}$$

$$2NO_2 + H_2O \rightarrow HNO_2 + HNO_3$$

Rainwater dissolves these acids and returns them to Earth as **acid rain**. Depending on the weather, it may return instead as acid dew, fog, sleet, hail or snow. The pH of acid rain is much lower and more acidic than that of normal rain (pH 6), and has been measured as low as 3.3 (strongly acidic).

SciFile

Natural acid rain

Volcanoes spew out huge quantities of sulfur and sulfur-based gases every time they erupt. Lightning produces nitrogen-based gases. These gases react with water vapour in the atmosphere and produce their own acids and acid rain. Studies of ancient ice samples from Antarctic glaciers show that some natural acid rain has always fallen.

3.4

The effect on the environment

Although acid rain is not yet a significant concern in Australia, its effects are particularly evident in highly populated and industrialised areas such as the United States, southern Canada, Europe and China.

- Acid rain has killed forests. As Figure 3.2.4 shows, acid rain, fog and snow can kill trees. It also leaches aluminium from the soil, which then runs into rivers and lakes and percolates downwards into the groundwater. These increased aluminium levels are often enough to kill the plants, animals and fish that use or live in that water.
- Acid rain has killed fish, frogs, water snails, insects and other organisms living in lakes or around lakes. These lakes have increased acidity (decreased pH). As Figure 3.2.5 shows, pH has different effects on different animals.

- Acid rain has destroyed buildings and sculptures, like the one in Figure 3.2.6. Calcium carbonate is the major component of the marble and limestone that make up many old buildings and sculptures. Calcium carbonate is a base and so it reacts with the acids in rainfall, making the rock thinner and more likely to flake or break off. A typical reaction is shown below.

$$\text{calcium carbonate} + \text{sulfuric acid} \longrightarrow \text{calcium sulfate} + \text{water} + \text{carbon dioxide}$$

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

Range of pH able to be tolerated

Figure 3.2.5 Frogs are least likely to be affected by acid rain. The eggs of most fish will not hatch at pH of less than 5.

Figure 3.2.6 The fine details of this marble sculpture have been destroyed because its calcium carbonate reacted with acid rain.

Controlling acid rain

Taller chimneys (like those in Figure 3.2.7) mean that local areas are less likely to be affected by the chemicals released by them and the acid rain that forms. However, this doesn't solve the problem. It just pushes the problem onto more distant areas.

Coal-fired power plants are now fitted with 'scrubbers' that remove sulfur-based pollutants from the gases they release. In a similar way, modern cars use catalytic converters to remove nitrogen-based gases from their exhausts.

Figure 3.2.7 Pollution can cause acid rain to form. Tall chimneys minimise the damage in the area around them but increase the damage further away.

3.2 Unit review

Remembering

1 **Recall** acid reactions by copying and completing the following:

- a acid + metal $\longrightarrow$ ...... + ...
- b acid + carbonate $\longrightarrow$ ..... + ... + ...
- c nitric acid + potassium oxide $\longrightarrow$ ..... + ...
- d ethanoic acid + sodium hydrogen carbonate $\longrightarrow$ ..... + ... + ...
- e $H_2SO_4 + Fe \longrightarrow$ ..... + ...
- f $2HCl + CaCO_3 \longrightarrow$ ..... + ... + ...

2 **State** the pH of natural unpolluted rainwater.

3 Pollution can cause acids to form. **Recall** how this happens, by writing word equations and/or balanced formula equations.

4 **List** the two factors that cause acid rain to kill organisms in lakes.

Understanding

5 **Explain** what causes the pain of heartburn.

6 Antacids relieve heartburn.

- a **State** the type of substance in antacids.
- b **Explain** how antacids work.

7 a **Recall** what happens when vinegar is added to bicarbonate of soda, by writing its word equation and/or balanced formula equation.

- b **Explain** why froth forms in this reaction.

Applying

8 The acidity of a lake increases, and animals in it die. **Use** Figure 3.2.5 on page 81 to **list** the animals in order from the most likely to die to the least likely.

Analysing

9 **Analyse** the following word and balanced formula equation.

phosphoric acid + aluminium $\longrightarrow$ aluminium phosphate + hydrogen gas

$2H_3PO_4 + 2Al \longrightarrow 2AlPO_4 + 3H_2$

Identify:

- a the reactants
- b the products
- c the chemical formula for phosphoric acid
- d the name and chemical formula of the salt produced
- e whether the reaction is an example of an acid/metal reaction, a neutralisation reaction, or an acid/carbonation reaction.

Evaluating

10 **Propose** reasons why forests are more likely to be damaged by acid rain if they are:

- a near cities
- b on the foggy upper slopes of mountains.

11 In the Palace of Versailles near Paris (France), the marble garden statues are covered with bags in winter, as shown in Figure 3.2.8.

- a **Propose** a reason why they are covered in winter.
- b **Propose** a reason why they are not covered in summer.

Figure 3.2.8

12 Tall chimneys may help to minimise the effects of acid rain on a local area, but they are unlikely to be an effective solution for a whole city or a country. **Propose** reasons why.

Creating

13 Calcium carbonate ($CaCO_3$) reacts with hydrochloric acid (HCl) to produce calcium chloride ($CaCl_2$), carbon dioxide (CO_2) and liquid water (H_2O). For this reaction, **construct** its:

- a word equation
- b unbalanced formula equation
- c balanced formula equation.

Inquiring

1 Design an experiment to determine whether the reaction between vinegar or citric acid and bicarbonate of soda is endothermic or exothermic. Present your plan to your teacher and obtain approval to run your experiment.

2 Research ways of constructing a rocket using a mixture of vinegar and bicarbonate of soda.

3 Use the search terms *acid-base video* to find internet videos of different acid reactions.

3.2 Practical activities

1 Making hydrogen

Purpose

To prepare and test hydrogen gas.

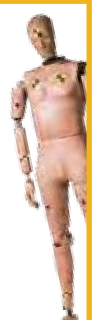
Materials

- 5 cm strip of magnesium ribbon
- 2 M hydrochloric acid
- 1 test-tube, rubber stopper with opening and glass tube to fit
- 2 additional test-tubes
- test-tube rack
- 5 cm magnesium ribbon
- eyedropper
- wax taper

SAFETY

2 M HCl is a strong and concentrated acid.

Wear safety glasses, a laboratory coat or apron and rubber gloves.



Procedure

1. Place the test-tube with the rubber stopper in the test-tube rack.
2. Roll the magnesium ribbon and drop it into the test-tube.
3. Use the eyedropper to add about 2 cm of hydrochloric acid.
4. Immediately turn another test-tube upside down and collect the hydrogen gas produced, as shown in Figure 3.2.9.
5. After about a minute, remove the upper test-tube, stopper it and stand it upside down in a test-tube rack.
6. Use the remaining test-tube to collect another sample of hydrogen gas. Stopper it and stand it upside down in a test-tube rack.
7. Stop the reaction by carefully adding water to the tube containing the acid.
8. Stand well away from the test-tube rack and light the wax taper.

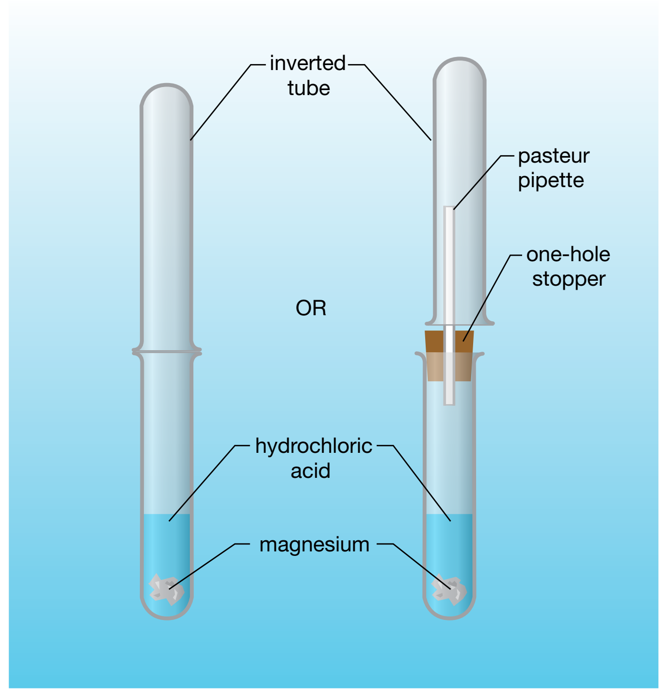


Figure 3.2.9

9. Hold the flame to the mouth of the inverted test-tube of hydrogen gas and remove the stopper.
10. Record what happens.

Results

Record all your observations, including the smell as hydrogen was wafted towards you.

Discussion

1. **Explain** how you knew this reaction was producing a gas.
2. **Identify** the type of reaction happening here. (Is it acid/base, acid/metal, neutralisation etc?)
3. **Construct** a word equation and a balanced formula equation for this reaction.

3.2 Practical activities

2 Evaluating antacids

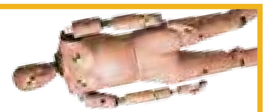
Antacids contain a base that neutralises some of the excess hydrochloric acid in your stomach.

Purpose

To evaluate how effective different antacids are at reducing acidity.

Materials

- 0.1 M hydrochloric acid solution
- 250 mL beaker
- liquid universal indicator or pH meter
- eye dropper
- different antacid tablets



SAFETY

Hydrochloric acid will burn and irritate open cuts and your eyes.

Do not taste any chemicals.

Procedure

1. Pour about 50 mL of hydrochloric acid into the beaker.
2. Measure the pH of the solution with the pH meter or by putting a couple of drops of the universal indicator in it. Record your observations and pH in a table like the one shown in the Results section.
3. Add an antacid tablet and allow it to dissolve completely.
4. Determine the new pH of the solution with the pH meter or by using the new colour of the solution.
5. Rinse out the beaker and then repeat the experiment with another antacid tablet.

Results

Record all your measurements in a table like the one shown here.

	Tablet 1	Tablet 2	Tablet 3
Colour of universal indicator before antacid was added			
pH of solution before antacid was added			
Colour of universal indicator after antacid was added			
pH of solution after antacid was added			

Discussion

1. **Name** the acid that is in your stomach.
2. **Explain** how this acid can cause the pain known as heartburn.
3. **Analyse** your results and determine which antacid tablet was most effective.
4. Heartburn has nothing to do with the heart. **Propose** a reason why it got this name.

3.3 Reactions of life

Almost all life on Earth depends on two processes, called photosynthesis and respiration. Plants use photosynthesis to make glucose, which stores energy for later use. Respiration is needed to release that stored energy. Respiration is also used by animals (including humans) to release energy from the glucose they have absorbed from their food.

Photosynthesis

Photosynthesis is a series of chemical reactions that produce a type of sugar called glucose ($C_6H_{12}O_6$). Glucose is a molecule that stores energy that green plants absorb from sunlight. Glucose can be thought of as a plant's food.

Photosynthesis can be summarised by the following chemical equations:

$$\text{carbon dioxide} + \text{water} \xrightarrow[\text{chlorophyll}]{\text{sunlight}} \text{glucose} + \text{oxygen gas}$$

$$6CO_2 + 6H_2O \xrightarrow[\text{chlorophyll}]{\text{sunlight}} C_6H_{12}O_6 + 6O_2$$

As long as a plant has enough sunlight, carbon dioxide and water, it can manufacture all the food it needs. Photosynthesis takes place in any part of the plant that is green and exposed to sunlight. Leaves are the most exposed parts of a plant and so most photosynthesis takes place there. To maximise this exposure, most plants have flattened leaves that don't overlap. You can see this in Figure 3.3.1.

Figure 3.3.1 Leaves are arranged to catch as much sunlight as possible.

SciFile

Maximising, minimising

Exposure to sunlight also dries out plants. Different leaf shapes have evolved for plants in different environments, to maximise their exposure to the sun while minimising water loss. For example, plants in hot, bright environments often have small or needle-shaped leaves. Plants near the ground in dark, wet rainforests don't get much sunlight and so have large, flat leaves to capture as much light as possible. Most rainforest plants have large leaves with deep channels in them to drain heavy rainfall.

Leaf structure

To understand how leaves carry out photosynthesis, you need to look at the internal structure of a leaf using a scanning electron microscope (SEM). A typical image is shown in Figure 3.3.2. You can see what each part does in Figure 3.3.3.

Figure 3.3.2 An SEM image of a slice through a leaf

Obtaining the raw materials for photosynthesis

Photosynthesis needs carbon dioxide and water as reactants. It also needs sunlight to power its reactions (Figure 3.3.4).

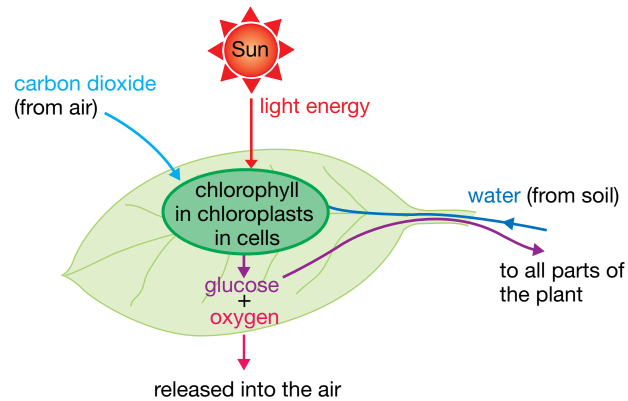


Figure 3.3.4 All the raw materials need to be brought together in the chloroplasts before photosynthesis can take place.

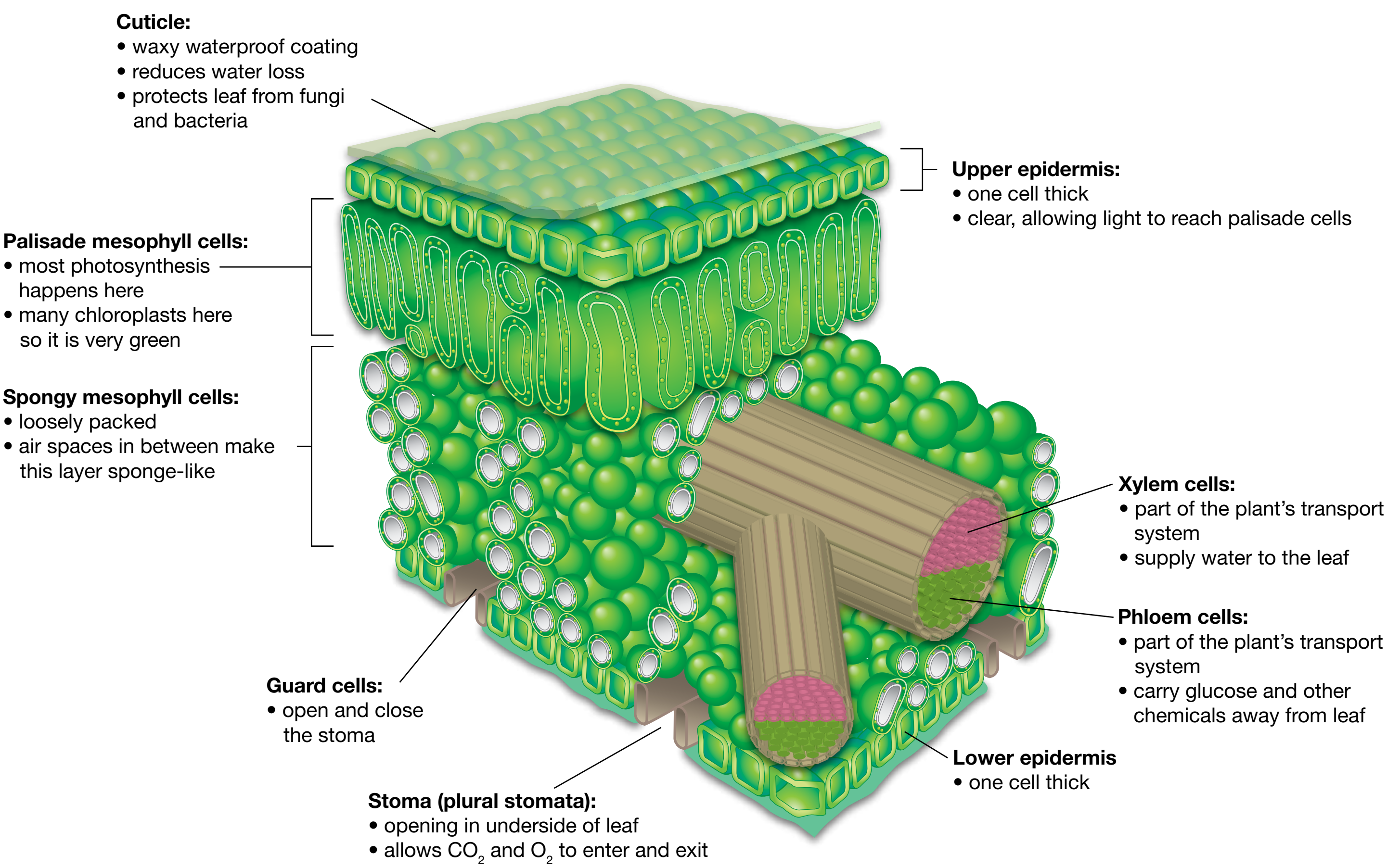


Figure 3.3.3 The internal structure of a typical leaf

Sunlight

Sunlight passes through the colourless cuticle and upper epidermis of the leaf into the cells of the palisade mesophyll layer. Within the chloroplasts is a green-coloured chemical called **chlorophyll**, which converts light energy from sunlight into chemical energy that the plant can use. The chloroplasts also contain **enzymes** (biological catalysts) that speed up the photosynthesis reactions happening there.

Water

Water is carried from the roots up the veins and into the leaf. It moves from the veins into the cells of the palisade mesophyll layer and then into the chloroplasts.

Carbon dioxide

Carbon dioxide moves by a process called **diffusion** from the air through tiny openings in the leaf called stomata (Figure 3.3.5). The concentration of carbon dioxide in the air is higher than in the leaf because photosynthesis has used it up in the leaf. Carbon dioxide continues to move by diffusion through the air spaces of the spongy mesophyll to the palisade mesophyll, where it passes into the cells and then into the chloroplasts.

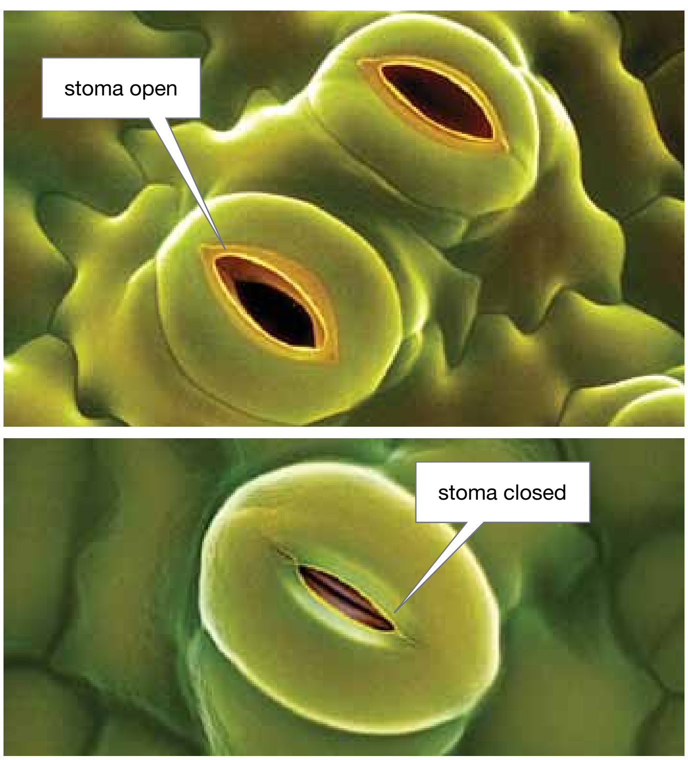


Figure 3.3.5 These stomata provide an entry for carbon dioxide, which is needed for the plant to carry out photosynthesis. The stomata also provide an exit for the water vapour and carbon dioxide produced by respiration to leave the plant. In hot weather, the stomata close to stop dehydration through losing too much water.

1 p91 2 p92 3.5 3.6

SciFile

No photosynthesis required!

Sunlight can't penetrate the ocean beyond 300 metres and so photosynthesis doesn't happen there. However, at the edges of the tectonic plates are vents called 'black smokers'. Chemosynthetic bacteria collect energy and nutrients from superheated water erupting from them. These bacteria provide the basis for a food chain, and include giant tube worms, spider crabs and mussels.

Respiration

Plant and animal cells need a constant supply of energy in order to function. They get this from a process called **respiration**, which releases energy from glucose. Plants get their glucose from photosynthesis. Animals get glucose through digestion of the food they eat.

Glucose molecules are made up of carbon, hydrogen and oxygen atoms. Energy is released when these molecules are broken into smaller ones. This energy is then available to the organism for tasks like growth, repair, movement and reproduction.

Plants use a form of respiration called aerobic respiration to release this energy. Animals also use aerobic respiration most of the time. Aerobic respiration needs a supply of oxygen as well as glucose. This is why you breathe. When exercising, the increased rate and depth of breathing removes carbon dioxide waste while supplying more oxygen to the bloodstream. This flow of gases is what is being measured in Figure 3.3.6 on page 88.

The reaction can be represented by the following chemical equation:

$$\text{glucose + oxygen gas} \longrightarrow \text{carbon dioxide + water + energy}$$

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O + \text{energy}$$

Aerobic respiration begins once the oxygen and glucose get to the cells. The glucose and oxygen react together in parts of the cells called mitochondria. Carbon dioxide and water are produced and energy is released. Enzymes enable this reaction to occur at a rate that meets the cell's requirements.

Figure 3.3.6 Aerobic respiration needs oxygen. Breathing provides oxygen and gets rid of the carbon dioxide produced.

- converted into cellulose for the manufacture of plant cell walls
- converted to substances used to make plant oils or proteins (the olive oil in Figure 3.3.8 was formed this way)
- converted into a more complex sugar called sucrose ($C_{12}H_{22}O_{11}$) and transported to other parts of the plant where photosynthesis cannot occur (such as the roots). Sucrose is 'normal' table sugar and is used to sweeten coffee and tea
- used in the process of making vitamins.

Respiration in plants

Glucose is brought to the cells of a plant by the phloem. Oxygen diffuses into the plant from the atmosphere through the stomata in the green parts of stems and leaves.

The products of respiration are carbon dioxide and water. Carbon dioxide diffuses out of the mitochondria into the cytoplasm, a thick liquid sap that fills much of the rest of the cell. Some of the carbon dioxide is taken in by the chloroplasts and used in photosynthesis. The rest exits the cells and eventually exits the plant through the stomata.

Water also diffuses from the plant cell and evaporates. It exits the plant through the stomata in the form of water vapour.

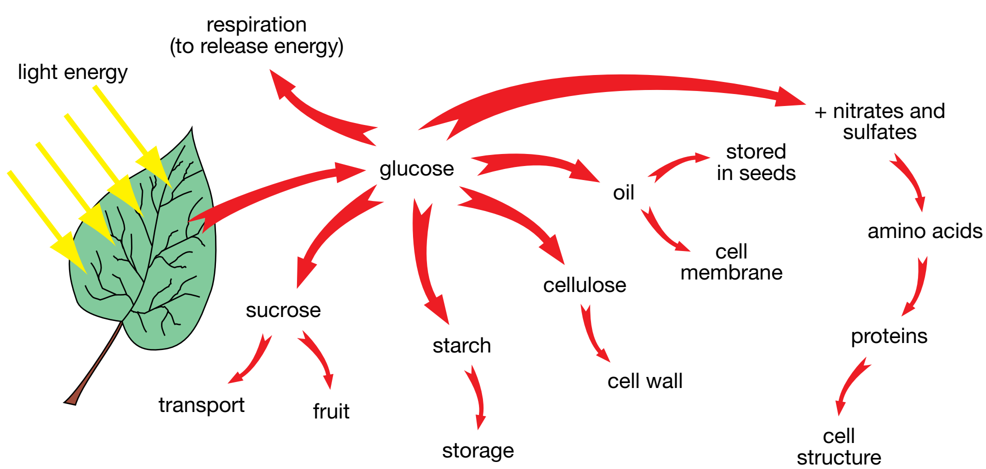


Figure 3.3.7 Glucose is not used just for respiration.

Carbon sinks

Plant respiration releases carbon dioxide back into the atmosphere, but in smaller quantities than that used by photosynthesis. This is because the glucose produced by a plant is not used just for respiration.

As Figure 3.3.7 shows, glucose is also:

- converted to starch for short-term storage. During the night the starch may be converted back into glucose and then used as a source of energy
- stored long-term as starch in the stems or roots, like those in Figure 3.3.8

Figure 3.3.8 Potatoes and sweet potatoes are their plant's long-term store of starch. Likewise, a plant's energy can be stored as oil, some of which can be used for cooking.

By doing all this, plants store carbon that has been removed from the atmosphere by photosynthesis. Every tree, forest, field and crop can therefore be thought of as a **carbon sink**, effectively 'burying' the carbon. For this reason, some environmentalists are encouraging the preservation of existing forests and the planting of new ones to reduce carbon dioxide in the atmosphere and to reduce the effects of climate change. At present, huge areas of rainforest in South America and South-East Asia are being chopped down or burned. When they are dead, the trees cannot take in any more carbon. Rotting returns their carbon to the soil. Burning them releases much of the stored carbon back into the atmosphere as smoke, soot and carbon dioxide. Habitats for animals like the orang-utan are also destroyed.

Another important carbon sink are the diatoms that live in the ocean. **Diatoms** are single-celled organisms. Together with seaweeds, diatoms carry out 90% of all photosynthesis on Earth. When diatoms die, they drop to the bottom of the ocean, taking their carbon with them.

3 p93

Respiration in humans

The bloodstream of animals such as humans carries glucose and oxygen to the cells. Glucose is one of the products of digestion of food. Oxygen is breathed in, then passes through narrower and narrower tubes until it diffuses through the lungs' alveoli into the blood. You can see this network of tubes in Figure 3.3.9. The blood also carries away the waste water and carbon dioxide from the cells. Some water is re-absorbed into the body. Some is removed by the kidneys to be stored in the bladder and later expelled as urine. Other water is breathed out as water vapour. Carbon dioxide diffuses from the blood into the alveoli in the lungs. It too is then breathed out.

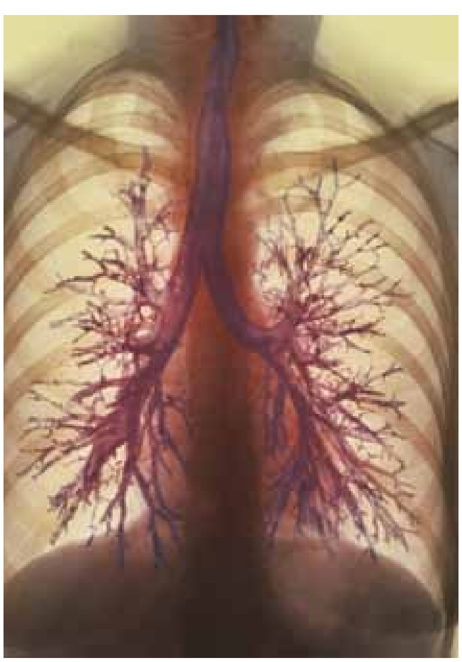


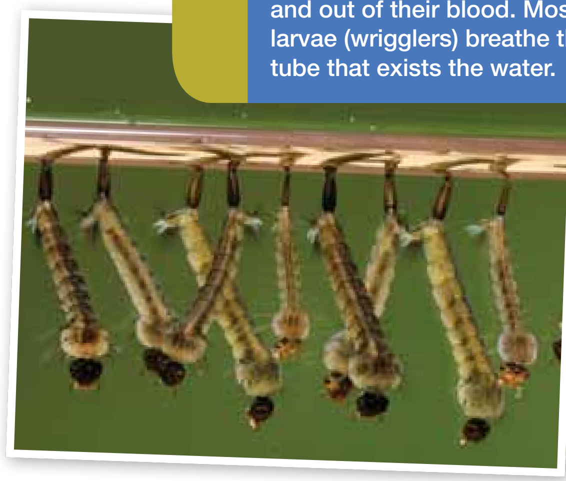
Figure 3.3.9

The lungs supply the bloodstream with oxygen so that aerobic respiration can occur in the cells. They also provide an exit for waste carbon dioxide and some water vapour.

SciFile

How do mozzies breathe?

Mammals, birds, reptiles and amphibians such as frogs have lungs to draw in oxygen and expel carbon dioxide. Amphibians also exchange gases via their skin. Insects don't have lungs. Instead they have small tubes from the outside of their bodies feeding the gases directly into and out of their blood. Mosquito larvae (wrigglers) breathe through a tube that exists the water.



3.7

Comparing photosynthesis and respiration

The chemical equations for photosynthesis and respiration suggest that the two processes are exact opposites of each other. For example, photosynthesis makes glucose, and respiration uses it. Both processes also use an 'energy-storage' molecule called ATP (adenosine triphosphate). However, the two processes differ. Table 3.3.1 lists the similarities and differences between photosynthesis and respiration.

Table 3.3.1 Comparison of photosynthesis and aerobic respiration

Photosynthesis	Aerobic respiration
Makes glucose	Uses glucose
Uses carbon dioxide	Makes carbon dioxide
Makes oxygen gas	Uses oxygen gas
Uses ATP	Uses ATP
Has two steps: light reaction and dark reaction	—
Enzymes speed up the reaction	Enzymes speed up and control the reaction
Occurs only in the chloroplasts of cells of green plants	Occurs in the mitochondria of cells of all living things
Shuts down at night	Happens continuously (day and night)

3.3 Unit review

Remembering

1 **Name** the following chemicals.
  a CO_2
  b O_2
  c $C_6H_{12}O_6$

2 **Name** the green pigment found in plants.

3 **Name** the opening in the leaf that allows gases to move in and out.

Understanding

4 **Describe** what an enzyme is.

5 **Explain** why having a large number of air spaces in the spongy mesophyll is an advantage for a plant.

6 **Explain** how aerobic respiration releases energy from glucose.

7 Sucrose (table sugar) comes from the stems of sugar cane. **Outline** how it got there.

8 Environmentalists sometimes talk about a *carbon sink*. **Explain** what this term means.

9 a **Describe** what a diatom is.
  b **Explain** why diatoms are important in an era of climate change.

Applying

10 Equipment was set up as shown in Figure 3.3.10 to gather information about photosynthesis.

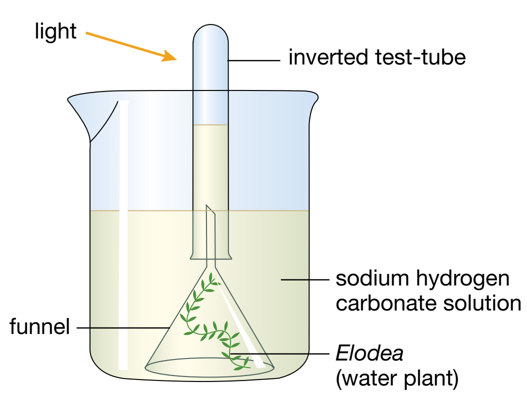


Figure 3.3.10

  a **Identify** the gas that would be collected in the test-tube.
  b **Demonstrate** how the rate of photosynthesis could be determined using this equipment.

Analysing

11 **Contrast** the ways in which plants and animals get their glucose.

12 **Compare** photosynthesis and aerobic respiration by:
  a writing their word equations
  b writing their balanced formula equations
  c listing the ways in which they are similar
  d listing the ways in which they are different.

Evaluating

13 The cells in the leaf epidermis are clear and colourless. **Propose** the advantages of this.

14 Climate change may lead to increased ocean temperatures. **Propose** reasons why some environmentalists are very worried about this possibility.

15 It has been suggested that humans will need to take green plants along with them if they are ever to travel far into space. **Propose** reasons why.

Inquiring

1 Design an experiment to demonstrate that light is necessary for photosynthesis. Show your plan to your teacher. If you get their approval, carry out your experiment.

2 a Research how our understanding of photosynthesis developed.
  b Identify the main people involved in the discovery.

3 Use the key words *respiration games* to find interactive games on the internet.

4 Use the key words *respiration videos* to find clips on the internet to watch.

5 Research the life of Antoine Lavoisier and Pierre La Place and their work in proving that animals use respiration to release the energy they need from food.

6 a Research what anaerobic respiration is and when it is most likely to occur in humans.
  b List organisms that use anaerobic instead of aerobic respiration for their energy.

3.3 Practical activities

1 Looking at stomata

Purpose

To compare the number of stomata on different leaf surfaces.

Materials

- leaf cut from a plant
- clear nail varnish
- paintbrush or brush from a bottle of nail varnish
- forceps
- microscope
- slide and coverslip
- small container of water
- dropper

Procedure

1. With the brush, apply a thin coat of nail varnish to a small area on the underside of the leaf.
2. Allow the varnish to dry and then use the forceps to gently peel the layer of varnish from the leaf.

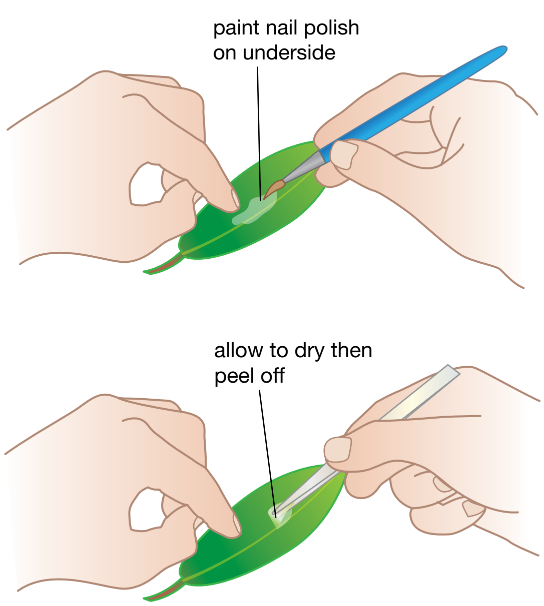


Figure 3.3.11

3. The nail varnish will have made an exact copy of the leaf surface.
4. Place the film of varnish in a drop of water on the microscope slide and place the coverslip on top, making sure that no air bubbles are trapped.
5. Examine the slide using low power on the microscope.
6. Count the number of stomata in a field of view.
7. Change the microscope to high power and focus on one stoma. Identify the guard cells.
8. Repeat steps 1 to 7 using the upper surface of the leaf.

Results

1. Record the number of stomata you counted in one field of view for both the upper and lower surfaces.
2. Construct a diagram of the stoma and guard cells. Label the parts.

Discussion

1. **Describe** the orientation of the leaf you studied when it was on the plant. Did it lie horizontally or hang vertically?
2. a **State** whether the stoma you drew was open or closed.
   b **Justify** your answer.
3. **Compare** the number of stomata found on the two surfaces.
4. **Explain** any advantage to the plant of having the observed distribution of stomata.
5. **Predict** how the number and distribution of stomata could change if:
   a leaves hung vertically rather than horizontally
   b the leaves came from a plant living in a very moist environment
   c the leaves floated on water, like a water lily.

2 Testing leaves for starch

Purpose

To test leaves for the presence of starch.

Materials

- 1 variegated leaf that has been in sunlight for several hours
- beaker
- hotplate
- methylated spirits
- hotplate
- test-tube
- test-tube rack
- Petri dish
- tongs
- iodine solution
- dropping pipette
- tweezers

SAFETY

Methylated spirits is flammable, so keep it well away from flames and the hotplate.

Wear safety glasses at all times.

Procedure

1 Sketch the leaf, showing where there is a lot of chlorophyll (the green parts) and where there is little (the paler or cream parts). Keep this sketch for later.

2 Place around 100 mL of water in the beaker and heat on the hotplate until it boils. Drop the leaf in the water and heat it for about 30 seconds.

3 Use the tweezers to carefully remove the leaf from the water and place it in a test-tube. Keep the water in the beaker boiling.

4 Keeping well away from the hot plate, add methylated spirits to the test-tube so that the leaf is covered.

5 Place the test-tube into the beaker of boiling water and heat until the green chlorophyll is removed from the leaf.

6 Using tongs, carefully remove the test-tube from the beaker of boiling water and remove the leaf from the test-tube.

7 Place the leaf back into the beaker of boiling water for a few minutes to soften it.

8 When the leaf is soft, remove it from the water and place it in a Petri dish.

9 Add 4 drops of iodine solution to the leaf.

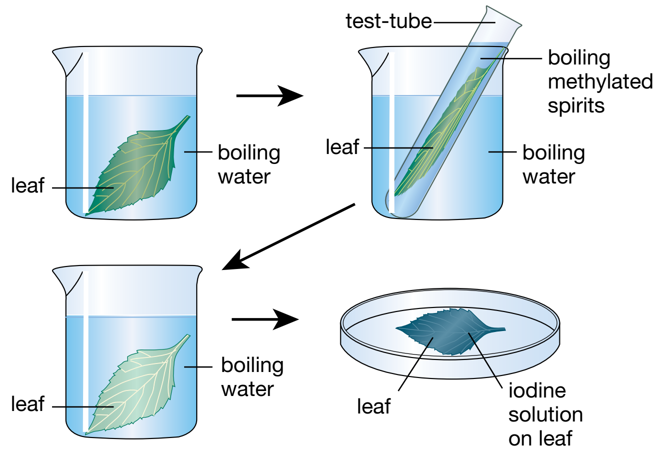


Figure 3.3.12

Extension

10 Tape black paper or aluminium foil onto another leaf that is still attached to the plant. Cut a 'window' in the paper/foil to expose part of the leaf.

11 After a few days, pick the leaf and test as above for the presence of starch.

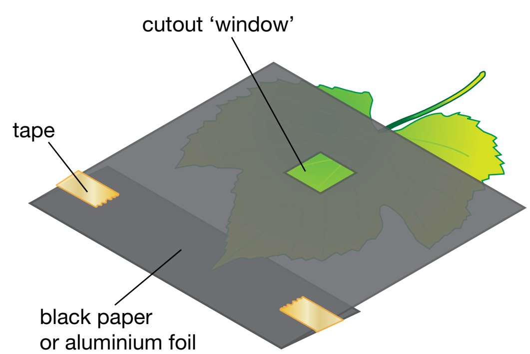


Figure 3.3.13

Results

Sketch the leaf, showing where starch is present and where it is absent.

Discussion

1. **Name** the substance in the leaves with which iodine reacts.
2. If you carried out the extension, **compare** the two diagrams you have made of the leaf.
3. **Explain** what the diagrams tell you about starch production in the leaf.
4. a **Predict** the results you would have obtained if you had tested a leaf picked from the plant at dawn.
   b **Justify** your prediction.
5. If you carried out the extension, **construct** an annotated diagram that explains what you observed.

3 Respiring plants

Purpose

To investigate respiration in plants.

Materials

- 9 test-tubes
- 3 test-tube racks
- 9 pieces of water plant such as *Elodea*
- bromothymol blue indicator
- drinking straw
- 50 mL beaker

Procedure

1. Two-thirds fill each test-tube and the 50 mL beaker with water. Add a few drops of bromothymol blue to give the solution an obvious blue colour.
2. Using the drinking straw, bubble exhaled air through the water in the 50 mL beaker.
3. Observe and record the colour change in the indicator.
4. Label the test-tube racks: dark, low light, bright light.
5. Add the same amount of water weed to each test-tube.
6. Place three test-tubes into each of the test-tube racks.
7. Place the test-tube racks in an appropriate place, like those suggested below:
   - dark—could be placed in a cupboard
   - low light—could be placed in a corner of the classroom away from the windows
   - bright light—could be placed on a window sill, but make sure the water in the test-tubes does not get hot.
8. Leave the test-tubes for 24 to 48 hours.
9. Observe and record any changes in the colour of the indicator.

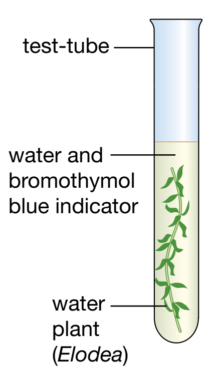


Figure 3.3.14

Results

1. Describe what happened when you bubbled exhaled air through the water containing bromothymol blue.
2. Record your observations in a table like the one below.

Treatment	Indicator colour	
	Start	After 24 hours
Dark		
Low light		
Bright light		

3. Bromothymol blue is an indicator that is blue in an alkaline or a neutral solution. It turns green and then yellow in an acidic solution. Carbon dioxide dissolved in water produces a weak acid.

   Use this information to identify whether the solution in each test-tube was alkaline, neutral or acidic.

Discussion

1. **Explain** the colour change that occurred when you bubbled exhaled air through the water with bromothymol blue.
2. **Describe** what happened in each of the test-tubes.
3. **Explain** why this happened.

3 Chapter review

Remembering

1 **Name** the following chemicals.
  a $Fe_2O_3{\cdot}H_2O$
  b HCl
  c $C_6H_{12}O_6$

2 **List** two types of reactions that are classified as oxidation reactions.

3 **Name** the poisonous gas produced by incomplete combustion.

4 **Recall** the following reactions by writing their word equations and/or balanced formula equations.
  a tarnishing of silver
  b combustion of octane
  c neutralisation of potassium oxide with nitric acid
  d photosynthesis

5 **Recall** the following reactions by completing their equations.
  a acid + base → ..... + ...
  b methane + oxygen → ..... + ...
  c $CaCO_3 + 2HCl \rightarrow$ ..... + ... + ...
  d $C_6H_{12}O_6 + 6O_2 \rightarrow$ ..... + ...

6 **List** three substances required for iron to rust.

7 **Name** the reactant that is always needed for combustion to occur.

Understanding

8 Burning fossil fuels causes problems for our atmosphere. **Describe** these problems.

9 a **Outline** where the raw materials for photosynthesis come from.
  b **Outline** how the raw materials get into the cells of the leaf.

10 **Explain** the outcome of breathing faster and deeper when you excercise.

Applying

11 A small fire will be extinguished if covered by something that doesn't burn. **Use** the concept of combustion to **explain** why.

12 **Identify** the missing number that would balance each of the following equations.
  a $\ldots KOH + H_2SO_4 \rightarrow K_2SO_4 + H_2O$
  b $2Al + \ldots HCl \rightarrow 2AlCl_3 + 3H_2$

Analysing

13 **Contrast** the ways in which plants and animals get the oxygen needed for aerobic respiration.

14 **Classify** the following reactions as exothermic or endothermic.
  a gas burning in a Bunsen burner
  b vinegar and sodium carbonate suddenly get cold when mixed
  c photosynthesis
  d respiration

15 **Analyse** the following chemical equations and balance them.
  a $Cu + SO_2 \longrightarrow Cu_2S + O_2$
  b $CH_4 + O_2 \longrightarrow CO_2 + H_2O$
  c $Ag + H_2S \longrightarrow Ag_2S + H_2$

Evaluating

16 Huge areas of rainforest in the Amazon and in Borneo are being chopped down each year.
  a **Propose** reasons why the forests are being destroyed.
  b **Propose** reasons why this destruction should be stopped.

Creating

17 **Construct** a word equation for the reaction:

$Ca + 2HCl \rightarrow CaCl_2 + H_2$

18 **Construct** a table comparing photosynthesis and respiration.

19 **Use** the following ten key terms to **construct** a visual summary of the information presented in this chapter.

chemical reaction
exothermic
endothermic
photosynthesis
combustion
oxidation
glucose
oxygen gas
carbon dioxide
respiration

3.8

Thinking scientifically

Q1 This chemical equation is unbalanced because it has different numbers of atoms of a particular element on each side of the arrow.

$Li + H_2O \rightarrow LiOH + H_2$

Identify the element/s that is/are unbalanced in this equation.

A Li
B H
C O
D Li, H and O

Q2 Four different students attempted to balance the equation in question 1.

Identify which student (A, B, C or D) has balanced it correctly.

A $Li + H_2O \rightarrow LiOH + H$
B $Li_2 + H_4O_2 \rightarrow Li_2O_2H_2 + H_2$
C $Li_2 + (H_2O)_2 \rightarrow (LiOH)_2 + H_2$
D $2Li + 2H_2O \rightarrow 2LiOH + H_2$

Q3 Fiona dropped a stick of chalk (containing calcium carbonate, $CaCO_3$) into hydrochloric acid (HCl). It fizzed as the reaction produced carbon dioxide gas (CO_2), water (H_2O) and calcium chloride ($CaCl_2$).

Identify the equation for this reaction.

A $CaCl_2 + H_2O + CO_2 \rightarrow CaCO_3 + 2HCl$
B $CaCO_3 + H_2O + CO_2 \rightarrow CaCl_2 + 2HCl$
C $CaCO_3 + 2HCl + H_2O \rightarrow CaCl_2 + CO_2$
D $CaCO_3 + 2HCl \rightarrow CaCl_2 + H_2O + CO_2$

Q4 Fiona measured the amount of carbon dioxide gas generated as the chalk dissolved in question 3. She repeated the experiment, but this time she crushed the stick of chalk into a powder. Her results are shown in the table below.

Time (s)	Volume of CO_2 generated (cm^3)	
	Stick of chalk	Crushed chalk
0	0	0
15	50	100
30	100	200
45	150	200
60	200	200
105	200	200

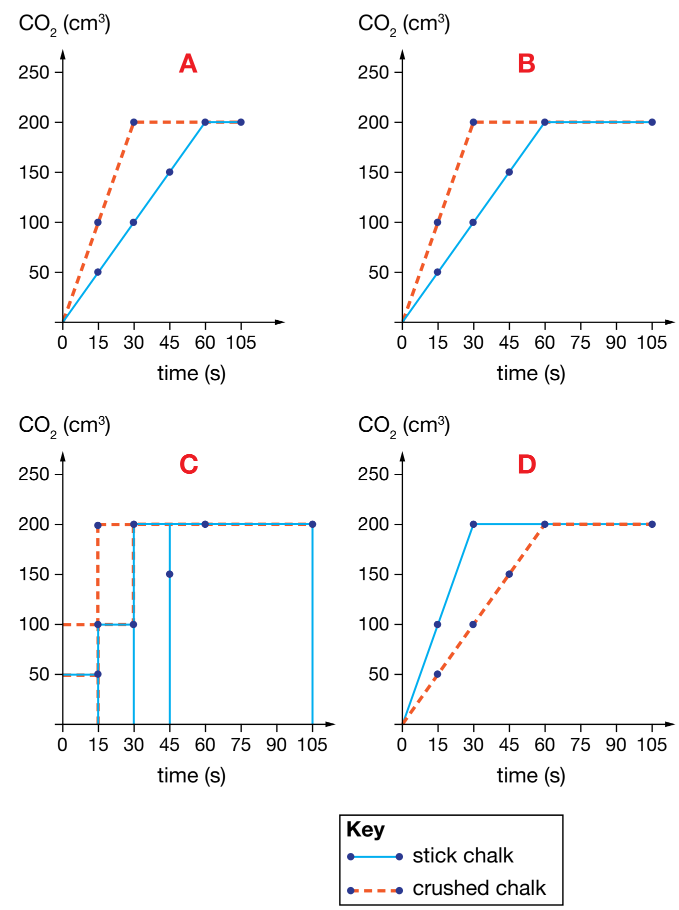
From these results, identify the best conclusion.

A Chalk and hydrochloric acid react together.
B Chalk always produces 200 cm^3 of carbon dioxide.
C Crushed chalk reacts faster than a stick of chalk.
D Hydrochloric acid burns.

Q5 From the results in the table in question 4, identify the inference most likely to be correct.

A All the chalk had dissolved by the end of the experiment.
B Carbon dioxide always takes up 200 cm^3.
C Chalk always takes at least one minute to react.
D The formula for carbon dioxide is CO_2.

Q6 Which of the following graphs best displays the results of question 4?



Glossary

Unit 3.1

Aerobic respiration: a reaction that uses oxygen to release energy stored in glucose

Anodising: a way of protecting aluminium from corrosion, by deliberately creating a layer of aluminium oxide over it

Balanced formula equation: a chemical equation that has the same numbers of each atom on both sides of the arrow

Combustion: a rapid reaction with oxygen that releases energy in the form of heat and/or light

Combustion

Complete combustion: combustion that occurs when there is plenty of oxygen. It produces carbon dioxide and water vapour.

Corrosion: the breakdown of metals due to their reaction with other chemicals

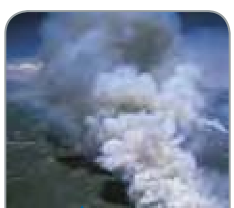
Endothermic: a chemical reaction that absorbs energy

Exothermic: a chemical reaction that releases energy

Glucose: a type of sugar produced by photosynthesis, with chemical formula $C_6H_{12}O_6$

Hydrocarbons: highly combustible chemicals; petrol is a mixture of hydrocarbons

Incomplete combustion: combustion that occurs when oxygen is limited. It produces carbon (soot, smoke) and carbon monoxide. It does not release as much heat or light as complete combustion.



Incomplete combustion

Law of conservation of mass: atoms are not created or destroyed in a chemical reaction. They can only be rearranged.

Photosynthesis: endothermic reaction that takes place in green plants. Uses energy from sunlight to combine water and carbon dioxide and produce glucose and oxygen gas.

Products: chemicals produced in a chemical reaction. They are written on the right-hand side of the arrow.

Reactants: chemicals that take part in a chemical reaction. They are written on the left-hand side of the arrow.

Rust: hydrated iron(III) oxide, $Fe_2O_3{\cdot}H_2O$

Tarnish: a black coating of silver sulfide that is produced when silver reacts with sulfur in the atmosphere; chemical formula Ag_2S

Verdigris: a green coating of copper hydroxide that is produced when copper reacts with moisture, carbon dioxide and oxygen in the atmosphere; chemical formula $Cu(OH)_2$

Word equation: simple written description of what is happening in a reaction

Unit 3.2

Acid rain: rain that has acids such as nitric acid and sulfuric acid dissolved in it

Neutralisation: a reaction of an acid with a base, forming a salt and water

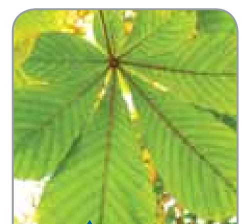
Neutralisation

Salt: the term commonly used for sodium chloride, but covers any compound formed by a metal taking the place of the hydrogen atom in an acid

Unit 3.3

Carbon sink: a term used to describe materials that store carbon in their structures. Plants and animals can be thought of as carbon sinks.

Chlorophyll: a green chemical found in the chloroplasts of green plants, needed to carry out photosynthesis



Chlorophyll

Diatoms: single-celled organisms that live in water. They are an important store of carbon or carbon sink.

Diatoms

Diffusion: a process in which chemicals move, caused by different concentrations of the chemical

Enzyme: a biological catalyst that speeds up a reaction

Glucose: a simple sugar formed by photosynthesis and used in respiration; chemical formula $C_6H_{12}O_6$

Respiration: a chemical reaction in which glucose is broken down, releasing energy for use by the plant or animal. Carbon dioxide and water are also produced. It occurs in the mitochondria.

Look who is using science

PHOTOGRAPHER

My name is Rod Ash and I am a photographer. My interest in photography first evolved when I was living and working in the Middle East and Europe. By documenting my travel adventures through photography, I developed a keen interest in the creative and practical processes involved with this art form.

In its very basic form, photography is very much about understanding light. My diverse background in a variety of service-based industries reflected my interest in working with people, and photography was a great medium to continue this. My work is both studio and location based and allows me to travel. I love the interaction with my clients and being involved in what is often some of the most important events of their lives. I am always challenged by the science and technology associated with photography, and how I can apply this to creating an enjoyable photographic experience for my clients as well as the photographic art that reflects this experience.

PROJECTIONIST

My name is Ben Charter and I work as a technical supervisor at Village cinemas. I prepare films and project them onto a movie screen.

Most of my day is spent threading film into projectors, checking that sessions start on time and that everything runs smoothly. New-release movies arrive in boxes, on three 610-metre spools. I splice cues onto the film where the credits start, and these cues trigger the cinema lights to come up. I then splice the three reels together onto one 1800-metre spool and thread this onto a platter so the film is ready to run from start to finish.

I started working in the cinema as an usher and worked my way up in the business. I have moved around and worked in five Village cinemas across Australia. I enjoy my job and, best of all, I get free tickets to any movie I'd like to see!

RADIOGRAPHER

My name is Brendon Hansen and I am a radiographer. I work in a hospital and capture different types of images using specialised equipment. These images include general X-rays (including mammography and dental imaging), ultrasound and CT scans.

The image is recorded on an imaging plate, which is housed within a cassette. A CR (computed radiography) reader converts this recording into a digital image. The image is sent through a PACs (Picture Archive Communication system) to a radiologist, for analysis.

The radiologist prepares and submits a report to the patient's doctor about the information revealed in the image.

I was employed as a trainee radiographer in a hospital and attended night school to become qualified. Today, radiography is offered as a three-year full-time university course. It is a job I enjoy because I am working with and helping other people.