

5

Chemical reactions

Engineers developing polymers for spacesuits or the next generation of passenger aircraft need knowledge and understanding of chemical reactions to produce new materials that are strong,

light and capable of resisting high temperatures. Other useful substances and materials such as fuels, metals and pharmaceuticals are also products of chemical reactions.



OVERARCHING IDEAS

- Patterns, order and organisation
- Form and function
- Stability and change
- Scale and measurement
- Matter and energy

SCIENCE UNDERSTANDING

Different types of chemical reactions are used to produce a range of products and can occur at different rates.

Elaborations

Investigating how chemistry can be used to produce a range of useful substances such as fuels, metals and pharmaceuticals

Predicting the products of different types of simple chemical reactions

Using word or symbol equations to represent chemical reactions

Investigating the effect of a range of factors, such as temperature and catalysts, on the rate of chemical reactions

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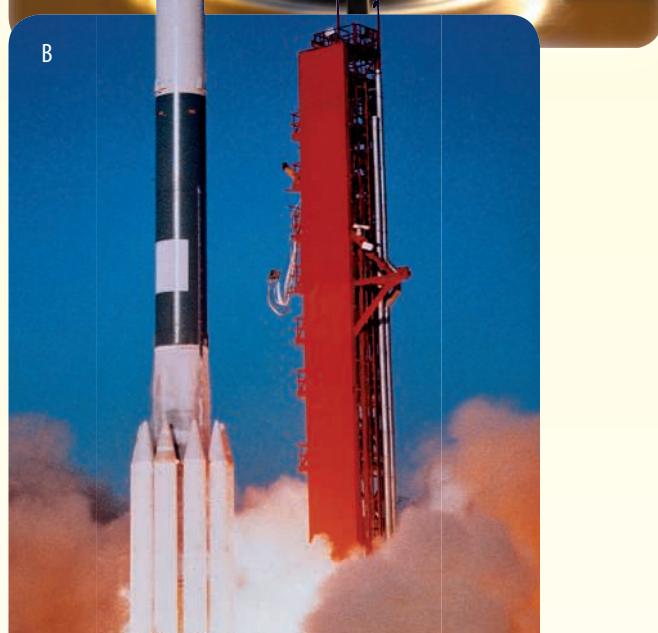
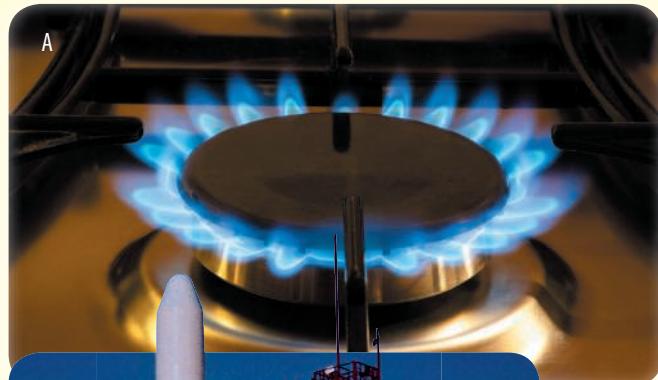
Spacesuits worn by astronauts when they are walking in space contain many layers of synthetic materials. They are all products of chemical reactions.

THINK ABOUT CHEMICAL REACTIONS

- What do plastic fruit juice containers, a toilet seat and a \$100 note have in common?
- Why are some plastics harder than others?
- How does zinc slow down the rusting of iron?
- Spectacles that turn into sunglasses — how do they do it?
- Bottled gas, candle wax and petrol all come from one substance. What is it?
- Cow manure to replace petrol? How is that possible?
- In what part of your body do you find catalytic catalase?
- How do light sticks produce light?

Chemical reactions

You should already know quite a lot about chemical reactions. Answer the questions at right to review your knowledge.

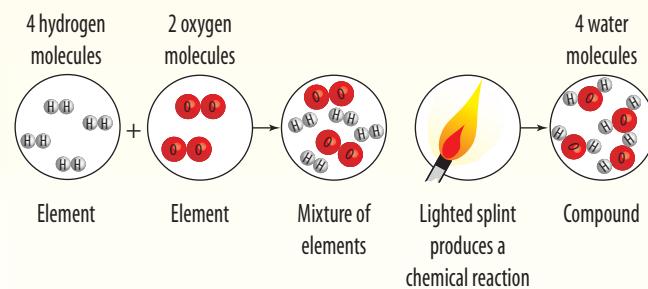


REMEMBER AND EXPLAIN

- Each of the photos at left depicts an energy transformation that occurs as a result of a chemical reaction.
 - What one-word name is given to all three chemical reactions?
 - Which one or more of the chemical reactions is or are exothermic?
 - Name the one reactant that participates in all three chemical reactions.
 - Identify the fuel in each of the three chemical reactions.
 - Identify one chemical product of the reactions depicted in photos A and C.
 - Name one chemical product that results from the reaction in photo B.
- Chemical reactions take place in all living things to keep them alive.
 - Which chemical reaction takes place in all green plants in the presence of sunlight?
 - Identify the only solid product of the chemical reaction referred to in part (a).
 - Name the chemical reaction that takes place in every cell of all animals to transform stored energy to other forms of energy.

Inside chemical reactions

Chemical reactions take place when the bonds between atoms are broken and new bonds are formed, creating a new arrangement of atoms and therefore at least one new substance.



- Explain what happens to the chemical bonds during the chemical reaction between oxygen and hydrogen as illustrated in the diagram above.

Form and function: Plastic facts

Which material is strong, light in weight and cheap to make, comes in a huge range of colours and can be moulded into any shape?

It could only be one of the **synthetic** (manufactured) materials we know as **plastics**. All plastics are products of chemical reactions. They are used to manufacture food containers and packaging, ballpoint pens, plumbing materials, car parts, rubbish bins, cling films like GLAD®Wrap and a multitude of other items.



WHAT DOES IT MEAN?

The word *plastic* comes from the Greek word *plastikos*, meaning 'able to be moulded'.

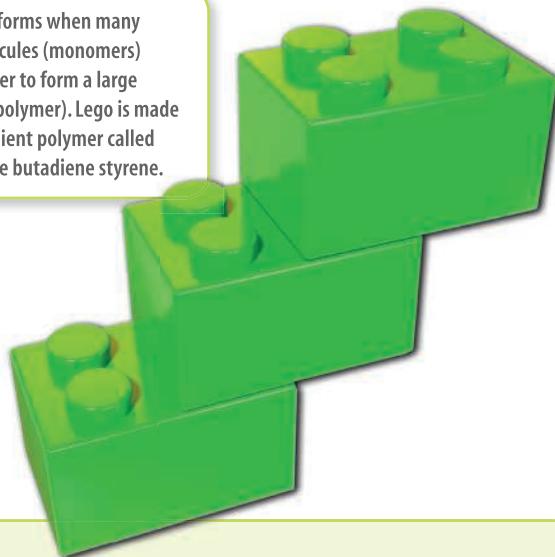
Monomers and polymers

All of the synthetic materials we call plastics are **polymers**. Polymers are very large molecules that consist of many repeating units called **monomers**. Monomers are small molecules. Most monomers contain the element carbon. Polymer molecules may, therefore, contain thousands of carbon atoms. The other elements found in monomers and polymers include hydrogen, oxygen, chlorine, fluorine and nitrogen.

The chemical reactions that occur when polymers form can be modelled using plastic beads or blocks that click together to form a long chain. Each plastic bead or block represents a single monomer molecule. The long chain, which may contain thousands of monomers, represents a polymer molecule.

Casein is a polymer made up of many small molecules called amino acids. Amino acids are the monomers from which the casein polymer is made. The prefix *poly* (meaning 'many') is often used when naming polymers. For example, polyvinyl acetate (PVA) is a polymer made from the monomer known as vinyl acetate.

A polymer forms when many small molecules (monomers) link together to form a large molecule (polymer). Lego is made from a resilient polymer called acrylonitrile butadiene styrene.



INQUIRY: INVESTIGATION 5.1

Making casein plastic

KEY INQUIRY SKILL:

- planning and conducting

Equipment:

safety glasses	100 mL of milk
white vinegar	250 mL beaker
glass rod	250 mL conical flask
thermometer	filter paper and funnel
Bunsen burner, heatproof mat and matches	
tripod and gauze mat	

- Pour the milk into the 250 mL beaker and warm it slowly to 50 °C.

- Remove from the heat and add about 5 mL of vinegar drop by drop, stirring carefully with the glass rod. The milk will separate into curds (solid) and whey (liquid).
- Filter the curds and whey. Discard the liquid (filtrate) and mould the solid curds into a shape with your fingers.
- Place the solid material on a piece of paper towelling and allow it to dry for a few days.

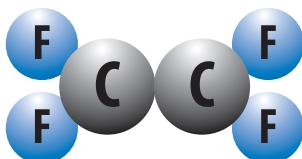
The plastic you have made consists mainly of a protein called casein. Casein is used to make medicines, glues and cosmetics.

DISCUSS AND EXPLAIN

- Describe the properties of this plastic.
- Devise a simple test to find out whether casein is soluble in water.

Co-polymers

Some polymers form when identical monomer units link together. Teflon, which is used as a non-stick coating on pans and baking trays, is a polymer of this type. Others, such as nylon and synthetic rubber, are formed when two different monomers alternate in the chain, creating a **co-polymer**. The chemical reactions that join monomers together are known as **polymerisation** (polymer-forming) reactions.



A tetrafluoroethene molecule. Tetrafluoroethene is the monomer from which teflon is formed.

HOW ABOUT THAT!

In 1992, scientists in the USA found a way to grow plastic. The plastic was produced in small amounts by mustard plants after genetic engineers added the genes of a type of soil bacteria to the plants. These bacteria were able to produce granules of a natural polymer called polyhydroxybutyrate (PHB). This polymer is very similar to the one called PET (polyethylene terephthalate) that is used to make soft-drink bottles. Unlike synthetic plastics, PHB is biodegradable; that is, it can be broken down by microbes after it is thrown away.

VERSATILE POLYMERS

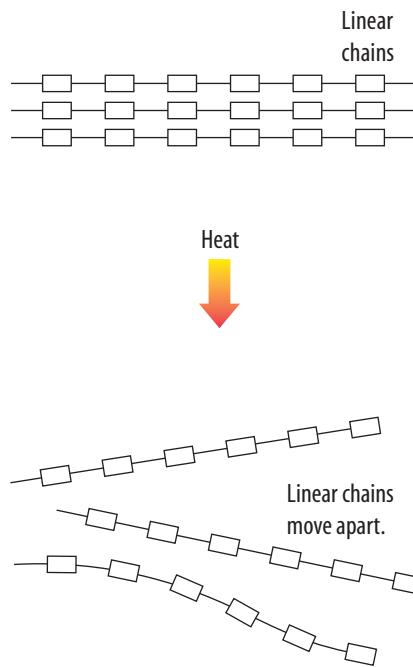
A plastic fruit juice container and a toilet seat are both made from polymers, or plastics. Some plastics are flexible and soften when they are heated. They can be moulded easily into a variety of useful products such as milk and fruit juice containers, rubbish bins, spectacle lenses, electrical insulation and laundry baskets. Other plastics are quite rigid and do not soften when heated. These plastics are used to make items such as toilet seats, electrical switches, bench tops, outdoor furniture, lampholders and other products that require strength and rigidity.

HOW ABOUT THAT!

Australia was the first country in the world to use only plastic notes. The notes are more difficult to counterfeit and last much longer than the old paper notes. They can also be recycled into other products.

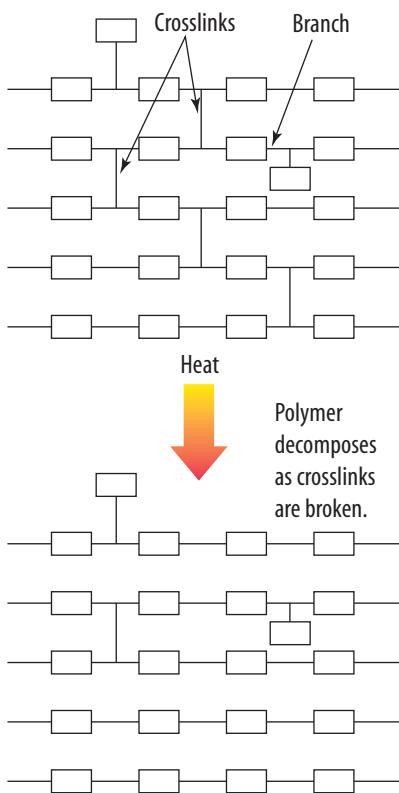
Two of a kind

Thermoplastic polymers soften when they are heated. They melt easily and can be moulded into useful products when hot. Polythene and PVC are examples of thermoplastic or thermosoftening polymers. Polythene (also called polyethylene or, more correctly, polyethene) is a soft plastic that is used to make cling film, squeeze bottles, milk crates and many other useful items. PVC has many different uses, for example as shoe soles, mouthguards, drainpipes, floor tiles and packaging. The chains of monomer molecules in a thermoplastic polymer are able to slide past each other when the polymer is heated, allowing the plastic to soften and melt.

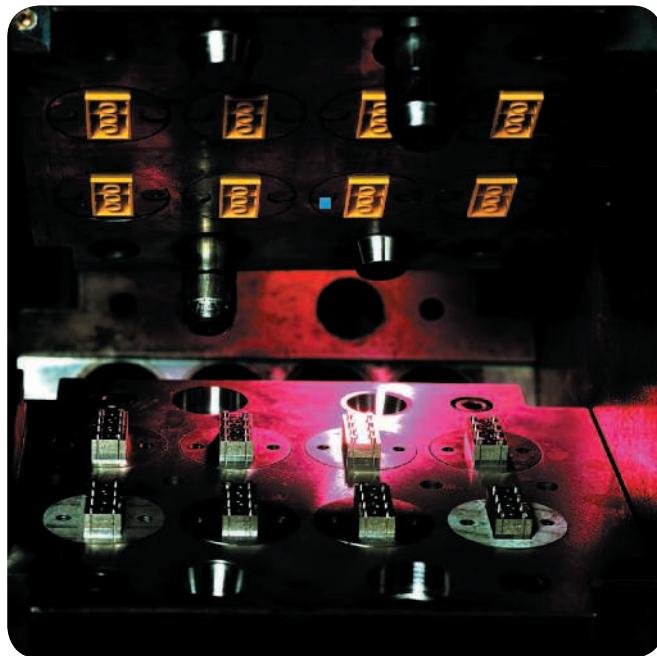


Structure of a thermoplastic polymer. The chains of monomer molecules are able to slide past one another when the polymer is heated.

Thermosetting polymers do not soften when they are heated, but **char** (blacken) instead. They are hard, rigid and sometimes brittle. Bakelite, which is used to make electrical switches, door handles and lampholders, is a thermosetting polymer. Other thermosetting polymers such as melamine are used to make laminates for bench tops. In these polymers, the chains of monomer molecules are locked together firmly by chemical bonds between the chains, known as **crosslinks**. Strong heating can break down their structure, leaving the black element carbon.



Structure of a thermosetting polymer. The chains of monomer molecules are locked firmly together. When the polymer is heated it does not melt, but eventually breaks down (decomposes).



Lego blocks are produced using a thermopolymer that is kept molten at 235 °C and then moulded under pressure. It cools to form a solid in about 15 minutes.

UNDERSTANDING AND INQUIRING

REMEMBER

- 1 What is the meaning of the word *plastic*?
- 2 What is a polymer?
- 3 Which element is contained in most monomers and polymers?
- 4 What do thermosetting and thermoplastic polymers have in common? In what ways are they different?
- 5 Classify the following polymers as thermosetting or thermoplastic: bakelite, PVC, polyethene, melamine, polythene.
- 6 What is a crosslink?
- 7 What is another word that means the same as thermoplastic?

THINK

- 8 Name the polymers formed from the following monomers.
 - (a) Ethene
 - (b) Vinyl chloride
 - (c) Styrene
 - (d) Propene
- 9 Explain why thermosetting polymers do not melt as easily as thermoplastic polymers.

- 10 Would you use a thermosetting or thermoplastic polymer to make the following? Give a reason for your choice in each case.

- | | |
|----------------|---------------------|
| (a) Bucket | (c) Saucepan handle |
| (b) Doorhandle | (d) Toothbrush |

IMAGINE

- 11 Imagine if all the objects made from plastics suddenly disappeared. How would your life be changed? Write an imaginative piece describing this. You may wish to talk to someone over the age of 70 about life before plastics.

INVESTIGATE

- 12 Design an experiment to compare the strength of plastic supermarket bags with the strength of other types of bags. Ensure your tests are fair tests.
- 13 Thermosoftening plastics are usually sold to manufacturers in the form of powders or small granules. Find out about the following ways of moulding the granules into useful products.
 - (a) Vacuum forming
 - (b) Calendering
 - (c) Blow moulding
- 14 Most plastics undergo photodegradation. What does this mean?

A game of balance

The symbols of the elements in the periodic table are the chemists' alphabet. Just as we can create millions of words from the 26 letters of the English alphabet, formulae for millions of chemicals can be written using the approximately 118 symbols of the elements (see chapter 4). These formulae can be used to write chemical **equations** that show how the atoms in the reactants are rearranged to form the products in a chemical reaction. The same formulae are used worldwide so they can be understood in every language.

Chemical equations

Writing equations involves some simple mathematics and a knowledge of chemical formulae. Chemical equations are set out in the same way as word equations, with the reactants to the left of the arrow and products to the right of the arrow. However, they are different from word equations in three ways:

- formulae are used to represent the chemicals involved
- the physical states of the chemicals are often included
- numbers are written in front of the formulae in order to balance the numbers of atoms on each side of the equation.

The rules of the 'game' of balancing equations are described below. Read through the rules very carefully before you play the game.

GAME RULES

GAME RULE 1. Know your products

The products of a reaction must be known from either **observation** or reliable sources (such as chemists) to tell us the products. For example, it is well known that the product of the reaction between hydrogen gas and oxygen gas is water vapour (gas).

GAME RULE 2. Know your formulae

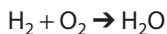
You need to know the formulae of all the reactants and products. For example:

- formula of hydrogen gas H₂
- formula of oxygen gas O₂
- formula of water vapour H₂O.

Remember! Because each substance has only one correct chemical formula, it **cannot** be changed by altering the subscript numbers.

GAME RULE 3. Write down the formulae

The formulae must be written according to the word equation, with reactants on the left-hand side of the arrow and products on the right-hand side.

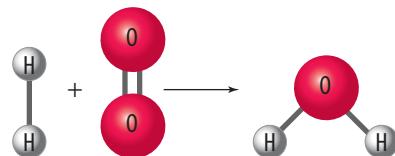


GAME RULE 4. Balance the numbers of atoms

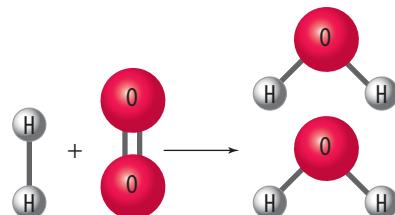
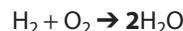
First, make a list of the elements present in the formulae under the heading 'Element', as shown above right. Then count up how many atoms are represented by the formula

of each element under the headings 'Reactants' and 'Products'.

Element	Reactants	Products
H	2	2
O	2	1



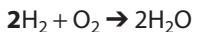
You can see that there are not enough oxygen atoms on the product side of the equation. The only way this can be adjusted is by writing numbers in front of the chemical formulae. When we write a number **in front** of a formula, it **multiples all the atoms** in that formula. Let's increase the number of oxygen atoms on the product side by placing a 2 in front of the formula for water.



Recounting the atoms we find:

Element	Reactants	Products
H	2	4
O	2	2

The oxygen atoms are now balanced, but the hydrogen atoms are not. Let's try writing a 2 in front of hydrogen's formula on the reactant side to increase the number of hydrogen atoms.



Counting the atoms again we find:

Element	Reactants	Products
H	4	4
O	2	2

The numbers of each of the elements are the same on both sides of the equation. The equation is balanced!

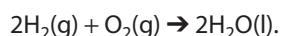
GAME RULE 5. Include the states

To indicate the physical state of each chemical involved in the reaction, the following symbols are used.

- Solid (s)
- Liquid (l)
- Gas (g)

The symbol (aq) is used to represent an **aqueous solution** of a substance. An aqueous solution is obtained when a substance is dissolved in water.

Write the correct symbol representing the physical state of each reactant and product:



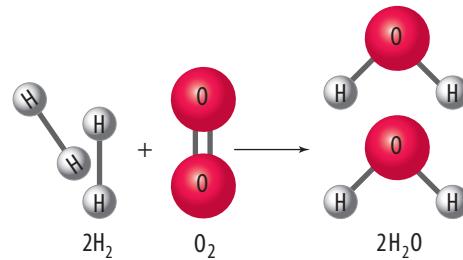
Formulae correct!

Number of atoms balanced!

States correct!

Formula equation complete!

Game over!



The reaction between hydrogen and oxygen

PLAY THE GAME

- Write a word equation and an equation using formulae for each of the six reactions listed. An example is provided on the next page. See the tables below for the correct formulae.
- 1 Carbon monoxide gas and oxygen gas react to form carbon dioxide gas.
- 2 Sodium hydroxide solution and hydrochloric acid solution react to form sodium chloride solution and water.

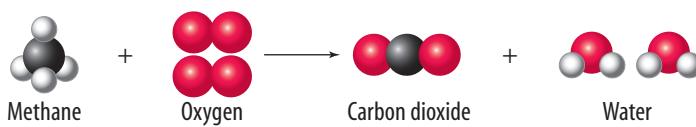
The formulae of some common ionic compounds

Compound	Formula
Sodium hydroxide	NaOH
Sodium chloride	NaCl
Magnesium chloride	MgCl ₂
Copper hydroxide	Cu(OH) ₂
Sodium sulfate	Na ₂ SO ₄
Copper sulfate	CuSO ₄
Sodium hydrogen carbonate	NaHCO ₃
Mercury(II) oxide	HgO
Sodium citrate	C ₆ H ₅ O ₇ Na ₃

- 3 Mercury metal and oxygen gas react to form solid mercury(II) oxide.
- 4 Magnesium metal and hydrochloric acid solution react to form hydrogen gas and magnesium chloride solution.
- 5 Sodium metal and water react to form hydrogen gas and sodium hydroxide solution.
- 6 Copper sulfate solution and sodium hydroxide solution react to form solid copper hydroxide and sodium sulfate solution.

The formulae of some common covalent substances

Compound	Formula
Water	H ₂ O
Citric acid	C ₆ H ₈ O ₇
Carbon dioxide	CO ₂
Oxygen	O ₂
Hydrochloric acid	HCl
Carbon monoxide	CO
Hydrogen	H ₂

Balancing a chemical equation	Example (Methane gas will burn in air. This is an example of a combustion reaction. This type of reaction produces CO₂ and H₂O.)												
Step 1: Start with the word equation and name all of the reactants and products.	Methane gas + oxygen gas → carbon dioxide + water												
Step 2: Replace the words in the word equation with formulae and rewrite the equation.	Methane gas = CH ₄ Oxygen gas = O ₂ (reactants) Carbon dioxide = CO ₂ Water vapour = H ₂ O (products) CH ₄ + O ₂ → CO ₂ + H ₂ O												
Step 3: Count the number of atoms of each element (represented by the formulae of the reactants and products).	<table border="1"> <thead> <tr> <th>Element</th> <th>Reactants</th> <th>Products</th> </tr> </thead> <tbody> <tr> <td>C</td> <td>1</td> <td>1</td> </tr> <tr> <td>H</td> <td>4</td> <td>2</td> </tr> <tr> <td>O</td> <td>2</td> <td>3</td> </tr> </tbody> </table>	Element	Reactants	Products	C	1	1	H	4	2	O	2	3
Element	Reactants	Products											
C	1	1											
H	4	2											
O	2	3											
Step 4: If the number of atoms of each element is the same on both sides of the equation, the equation is already balanced. If not, numbers need to be placed in front of one or more of the formulae to balance the equation. These numbers are called coefficients and they multiply all of the atoms in the formula.	To balance the hydrogen atoms, put a 2 in front of H ₂ O: CH ₄ + O ₂ → CO ₂ + 2H ₂ O. The oxygen atoms can be balanced by putting a 2 in front of the O ₂ on the left: CH ₄ + 2O ₂ → CO ₂ + 2H ₂ O. The equation is now balanced. It can be checked by counting the number of atoms of each element on both sides of the new equation. <table border="1"> <thead> <tr> <th>Element</th> <th>Reactants</th> <th>Products</th> </tr> </thead> <tbody> <tr> <td>C</td> <td>1</td> <td>1</td> </tr> <tr> <td>H</td> <td>4</td> <td>4</td> </tr> <tr> <td>O</td> <td>4</td> <td>4</td> </tr> </tbody> </table>	Element	Reactants	Products	C	1	1	H	4	4	O	4	4
Element	Reactants	Products											
C	1	1											
H	4	4											
O	4	4											
Step 5: Add physical state symbols.	CH ₄ (g) + 2O ₂ (g) → CO ₂ (g) + 2H ₂ O(g) 												

UNDERSTANDING AND INQUIRING

REMEMBER

- Describe three differences between word equations and equations in which formulae are used.
- How are the states (solid, liquid and gas) indicated in a chemical equation?
- What is an aqueous solution and how is it represented in a chemical equation?

THINK

- Which symbols would you use in a chemical equation to represent the metals iron, mercury, zinc and aluminium?
- Try writing a balanced equation using formulae for the reaction that occurs when you eat a sherbet lolly. These sweets commonly contain citric acid and sodium

hydrogen carbonate. In the mouth, these chemicals dissolve in your saliva and then react together to form sodium citrate solution, carbon dioxide gas and water.

- Explain why it is necessary to balance chemical equations.
- Test your ability to balance chemical equations by completing the **Checking for balance** interactivity. **int-0677**
- Use the **Balancing equations** weblink in your eBookPLUS to learn more about balancing chemical equations.

eBookplus



- 5.1 Chemical equations
- 5.2 Balancing chemical equations
- 5.3 A world of reactions

Precipitation reactions

When table salt (sodium chloride) is dissolved in water to form an **aqueous solution**, it seems to disappear. The ions in the salt no longer bond together as a large array of positive and negative ions like they do as a solid. The sodium ions and the chloride ions separate when they dissolve in water.

The dissolving of sodium chloride in water can be represented by the equation:



Ions in aqueous solutions are therefore separate entities and are able to react independently.

Ionic compounds dissolve in water to varying degrees. Some are soluble, others slightly soluble and others insoluble. The box below right outlines some handy rules for predicting whether or not a compound is soluble.

Suddenly it appeared!

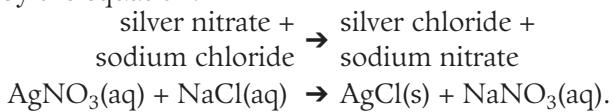


The formation of the brilliant yellow precipitate, lead iodide, from the colourless solutions lead nitrate and potassium iodide

are added together, a brilliant yellow precipitate is formed.

CHANGING PARTNERS

Another example of a precipitation reaction is the one between silver nitrate solution and sodium chloride solution. When these two colourless solutions are added together in a test tube the contents become cloudy, indicating that a precipitate has formed. If the tube is allowed to stand for a while, the solid settles to the bottom and we can see that a clear solution is also present. The products of the reaction are insoluble solid silver chloride (the precipitate) and sodium nitrate (not visible because it is soluble in water). This reaction can be represented by the equation:



Silver nitrate, sodium chloride and sodium nitrate all dissolve in water. Therefore, they have the symbol

SOLUBLE OR NOT?

1 All compounds containing either the Na^+ , NH_4^+ , K^+ , or NO_3^- ion will dissolve in water. Compounds containing these ions never form precipitates.

Example: This rule tells us that NaCl , NH_4Cl , K_2SO_4 and AgNO_3 are all soluble in water and therefore do not form precipitates.

2 Compounds containing the Cl^- , Br^- and I^- ions are soluble, except when they contain the Ag^+ , Pb^{2+} or Hg^{2+} ions.

Example: This rule tells us that FeCl_3 , ZnBr_2 and AlI_3 are soluble, but that AgCl , HgBr_2 and PbI_2 are not soluble.

3 Compounds containing the SO_4^{2-} ion are soluble, except for BaSO_4 , PbSO_4 and CaSO_4 .

Example: This rule tells us that ZnSO_4 will dissolve, but BaSO_4 will form a precipitate.

4 Compounds containing CO_3^{2-} and PO_4^{3-} are insoluble except when they contain the ions Na^+ , NH_4^+ or K^+ .

Example: This rule tells us that BaCO_3 will form an insoluble precipitate, but Na_2CO_3 will not.

5 Compounds containing OH^- are insoluble, unless they contain the ions Na^+ , NH_4^+ or K^+ .

Example: This rule tells us that $\text{Zn}(\text{OH})_2$ will form a precipitate, but NaOH will not.

6 Some compounds are slightly soluble. These include $\text{Ca}(\text{OH})_2$, PbCl_2 , PbBr_2 , CaSO_4 and Ag_2SO_4 .

(aq). Silver chloride does not dissolve in water, so it has the symbol (s) to indicate that it is solid.

The equation shows that the ions in the reactants have changed partners. The silver ion is paired with the chloride ion on the product side of the reaction and the sodium ion is paired with the nitrate ion. The opposite

is the case on the reactant side of the equation. A positive ion can pair up only with a negative ion because oppositely charged ions are attracted to each other. When writing the formula of any new compound, the positive ion is always written first.

INQUIRY: INVESTIGATION 5.2

Will it precipitate?

KEY INQUIRY SKILLS:

- questioning and predicting
- planning and conducting
- communicating

Equipment:

5 semi-micro test tubes and a test-tube rack

a white tile

a black tile

safety glasses

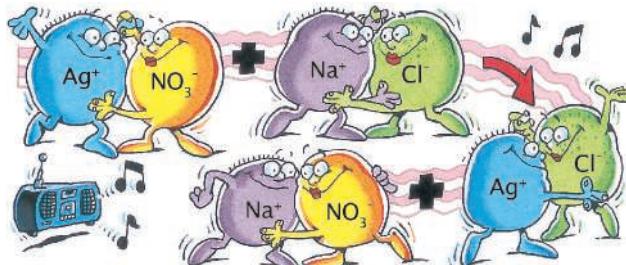
dropping bottles of the following solutions: copper sulfate, sodium chloride, silver nitrate, cobalt chloride, sodium hydroxide, potassium iodide

CAUTION: Wear safety glasses.

- Place 10 drops of copper sulfate solution in each test tube.
- Add 10 drops of sodium chloride to the first test tube, 10 drops of silver nitrate to the second, and so on until each tube contains copper sulfate solution and one other solution. Hold a black or white tile behind the test tube if necessary to detect the presence of a precipitate.
- If there is a reaction, record your observations in a table.
- Tip the residues into a waste bottle. Wash out the test tubes thoroughly and this time place 10 drops of sodium chloride in each of the test tubes. Again add one of the other solutions to each of the test tubes (but not copper sulfate as this combination has already been tested). Record your observations in your table.
- Repeat until all possible pairs of solutions have been tested.

DISCUSS AND EXPLAIN

- Write word equations for each of the pairs that reacted to form a precipitate.
- Use formulae to write equations for each of the pairs that reacted to form a precipitate.
- You could have predicted which pairs of solutions would form a precipitate using the box of solubility rules under the heading *Soluble or not* in this section. Check to see if the rules match your results.



Ions sometimes change partners when a chemical reaction takes place.

UNDERSTANDING AND INQUIRING

REMEMBER

- What is a precipitate?

THINK

- Write an equation for the reaction that occurs when the salt copper sulfate dissolves in water.
- Which two of the following compounds will be soluble in water?
(a) NaNO_3 (c) PbI_2
(b) KI (d) $\text{Zn}(\text{OH})_2$
- Which of the following compounds will be insoluble in water?
(a) CuCO_3 (c) NaCl
(b) Agl (d) $\text{Mg}(\text{OH})_2$
- Write down the possible combinations of ions when the following solutions are mixed together.
(a) Sodium chloride and copper sulfate
(b) Sodium hydroxide and copper sulfate
(c) Lead nitrate and sodium hydroxide
(d) potassium iodide and sodium carbonate
- For each of the reactions listed in question 5, name the precipitate that would form. If you believe that no precipitate would form, write 'no precipitate'.
- Use the **Introduction to reactions** weblink in your eBookPLUS to find out more about precipitation and other reactions.
- Create a table with three columns headed 'Soluble', 'Insoluble' and 'Slightly soluble'. Use the information in the box headed *Soluble or not* to fill the table.

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work
sheet

→ 5.4 Precipitation

Chemicals can be a health hazard

Many of the chemicals used in industry, medicine, schools, universities and homes can be hazardous to your health. The hazards come about because these chemicals can react with parts of your body — inside or out. Apart from the dangers to your own health, chemicals can, as a result of their properties or their reactions with common substances such as water and air, cause great damage to property and the environment.

Laws exist, at both national and state level, to ensure that people using harmful chemicals are informed about how to handle and use them safely. For this purpose, harmful chemicals are placed within one or both of the groups known as **dangerous goods** or **hazardous substances**.

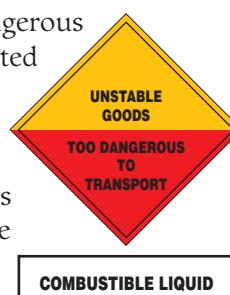
Dangerous goods

Chemicals in the dangerous goods group are those that could be dangerous to people, property or the environment. Most dangerous goods are grouped into one of nine classes, according to the greatest immediate risk they present. Some of the classes are divided into subclasses. Dangerous goods must be identified with the appropriate dangerous goods sign on their labels. The table on the opposite page lists

the classes and subclasses, along with their respective label signs.

Outside these nine classes, there are two other groups of dangerous goods:

1. goods too dangerous to be transported (GTDTBT)
2. combustible liquids (C1), which includes liquids that are not as easily ignited as flammable liquids, but which will ignite at temperatures below their boiling point.



HAZARDOUS SUBSTANCES

Chemicals in the hazardous substances group are those that have an effect on human health. The effect may be immediate, such as poisoning and burning, or long term, such as causing

liver disease or cancer. Hazardous substances can enter the body in a number of ways. They can be inhaled, absorbed through the skin, ingested (swallowed) or injected.

Hazardous substances are identified on their labels by a signal word providing a warning about the substance, or the word 'Hazardous' printed in red. Signal words include 'dangerous poison', 'poison', 'warning' and 'caution'. Labels of hazardous substances also include:

- information about the risks of the substance
- directions for use
- safety information
- first aid instructions and emergency procedures.

If the substance is also in the dangerous goods group, the label will also include the appropriate diamond sign showing its class.



Classes and subclasses of dangerous goods

Class	Description	Sign
Class 1	Explosive substances or articles used to produce explosions	
Class 2.1	Flammable gases: gases that ignite in air if in contact with a source of ignition such as a spark or flame	
Class 2.2	Non-flammable, non-toxic gases: these gases may cause suffocation	
Class 2.3	Toxic gases: gases likely to cause death, serious illness or injury if inhaled	
Class 3	Flammable liquids: liquids with vapours that can ignite on contact with air at temperatures below 60.5 °C	
Class 4.1	Flammable solids: solids that are easily ignited by a source of ignition such as a spark or flame	
Class 4.2	Substances liable to spontaneous combustion: solids that can ignite without an external source of ignition	
Class 4.3	Substances that emit flammable or toxic gases on contact with water	
Class 5.1	Oxidising agents: substances that may contribute to the combustion of other substances, increasing the risk of fire	
Class 5.2	Organic peroxides: substances that undergo exothermic decomposition reactions	
Class 6.1	Toxic substances: chemicals likely to cause death, serious illness or injury if swallowed, inhaled or brought into contact with skin	
Class 6.2	Infectious substances: substances containing micro-organisms likely to cause diseases in humans or animals	
Class 7	Radioactive material	
Class 8	Corrosive substances: substances that corrode metals or cause injury by reacting on contact with living tissue	
Class 9	Miscellaneous dangerous goods and articles: dangerous substances and objects that do not belong to the other classes	

Keeping you informed

All employers are required by law to make sure that their employees are fully informed about the chemicals in the workplace that are classified as dangerous goods and/or hazardous substances. A list of such chemicals stored or used in the workplace must be kept, along with a copy of the chemical's **material safety data sheet (MSDS)**.

Chemical suppliers are required to provide an MSDS for each of the hazardous substances or dangerous goods that they supply. In turn, employers are required to make the MSDS accessible to employees that are exposed to the chemicals.

An MSDS is likely to consist of several A4 pages. Many can be downloaded directly from the internet. The information on an MSDS should include:

- the ingredients of the product

- the date of issue — an up-to-date MSDS should be no more than five years old
- information about health hazards and first aid instructions
- precautions that need to be taken when using the product
- information about storage and safe handling of the product.

Assessing risk

A **risk assessment** identifies the potential hazards of an experiment and gives protective measures to minimise the risk. Before any experiment involving chemicals is conducted in your school laboratory, a risk assessment is carried out. The form of a risk assessment varies from school to school, but will always contain:

- a summary of the experiment
- a list of the risks and safety precautions for each chemical
- information about whether the chemical is classified as

a hazardous substance or dangerous good

- a list of protective measures to be taken. These might include the use of a fume hood and/or the wearing of safety glasses or other protective items.

- first aid information.

Most of the information used in a risk assessment is obtained from the MSDS for each of the chemicals used. The date on the MSDS used for each chemical must be stated to ensure that the risk assessment is up to date.

Part of a risk assessment sheet is shown on the following page. Risk assessment sheets in schools are usually completed and signed by a qualified science teacher or laboratory technician. Your science teacher is required to carefully read the risk assessment sheet before allowing an experiment involving chemicals to commence.

UNDERSTANDING AND INQUIRING

REMEMBER

- 1 What do chemicals listed as dangerous goods have in common?
- 2 If a chemical in the dangerous goods group is explosive, toxic and corrosive, how is the decision about which class it is placed in made?
- 3 What do chemicals listed as hazardous substances have in common?
- 4 List four signal words used on the labels of hazardous substances.
- 5 What is an MSDS and what should it include?
- 6 From where do employers obtain an MSDS for hazardous substances and dangerous goods?
- 7 Whose responsibility is it to make sure that people have access to an MSDS for each of the hazardous chemicals and dangerous goods that they store or use?

THINK

- 8 What characteristics do chemicals listed as both dangerous goods and hazardous substances have in common?

- 9 Explain the difference between flammable liquids (Dangerous goods, Class 3) and combustible liquids (Dangerous goods, C1).

- 10 Explain the difference between the purposes of an MSDS and a risk assessment sheet.
- 11 Why should every chemical used in a laboratory (including water) be considered to be a health hazard?

INVESTIGATE

- 12 Many chemical suppliers provide access to MSDSs online. Use the internet to search for an MSDS on hydrochloric acid and use it to answer the following questions.
 - List some alternative names for hydrochloric acid.
 - What are the health hazards of hydrochloric acid?
 - Describe the first aid treatment recommended if hydrochloric acid:
 - is ingested (swallowed)
 - is inhaled
 - makes contact with an eye
 - makes contact with the skin.
 - What recommendations are made for the storage of hydrochloric acid?

RISK ASSESSMENT SHEET

ACTIVITY	Investigating reactivity		
REFERENCE	Science Quest 10		
CHAPTER 4	Chemical patterns		

INVESTIGATION 4.4

SUMMARY OF EXPERIMENT

REACTIVITY OF METALS

- 1 Placing pieces of magnesium, copper, zinc, aluminium and iron in test tubes
- 2 Adding 1M hydrochloric acid to the test tubes and observing the reaction

PROTECTIVE MEASURES

Glasses	Gloves	Dust mask	Lab coat	Fume hood
x			x	x

SAFETY INFORMATION

Reactant	HS	DG	CLASS	MSDS	UN	HAZCHEM
Hydrochloric acid 1M	N	Y	8			
		<ul style="list-style-type: none"> • Do not breathe gas/fumes/vapour/spray. • Wear suitable protective clothing. • Avoid contact with skin. 				

FIRST AID

SWALLOWED Contact doctor or poisons centre. Give glass of water.

EYE Wash with running water for 15 minutes. Medical attention.

SKIN Remove contaminated clothing. Wash with soap and water.

INHALED Fresh air. Rest. Keep warm.

REACTANT	HS	DG	CLASS	MSDS	UN	HAZCHEM
Magnesium	N	Y	4.1		1869	4(Y)
• Flammable	<ul style="list-style-type: none"> • Wear suitable clothing and eye protection. • Do not breathe dust. • Never add water to this product. • Keep locked up. • Avoid contact with skin. 					

FIRST AID

SWALLOWED Rinse mouth with water.

EYE Wash with running water.

SKIN Wash with soap and water.

For burns: Immerse in cold running water. Bandage lightly. Medical attention.

INHALED Blow nose. Rinse mouth with water.

REACTANT	HS	DG	CLASS	MSDS	UN	HAZCHEM

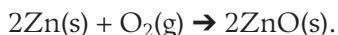
Part of a risk assessment sheet for Investigation 4.4

A world of reactions

In a world where countless chemical reactions take place, it is helpful to classify the reactions. They can be classified according to whether they release or absorb energy and can also be grouped together according to the nature of the reactants, the nature of the products, the way in which charged particles in atoms rearrange themselves, or even the number of reactants. Because there are different ways of classifying chemical reactions, any one reaction can fall into several different groups.

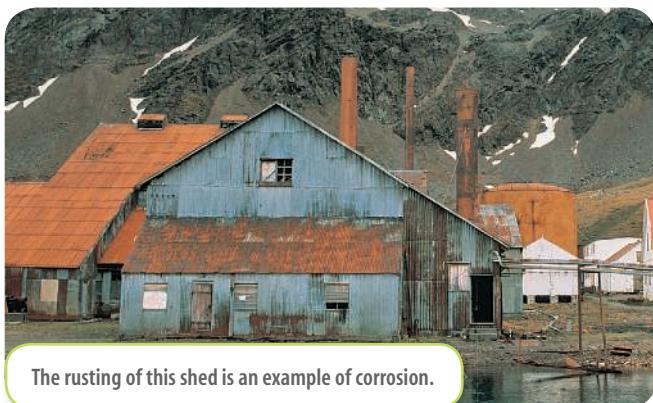
Corroding away

Corrosion reactions are those in which a metal is ‘eaten away’ by substances in the air or water. If you look at a sheet of **galvanised** iron, you will notice that it does not have a shiny metallic surface. Galvanised iron has been coated with a layer of zinc metal. The zinc prevents the iron underneath from reacting with the oxygen and water in the air and rusting. Instead, zinc reacts with oxygen and a dull layer of zinc oxide forms on the surface. The equation for this reaction is:

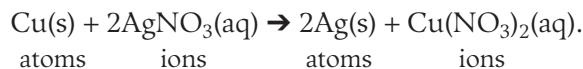


Displaced metals

In the classroom laboratory, waste solutions containing silver ions are never poured down the sink. They are collected and sent to commercial laboratories where the valuable silver is recovered



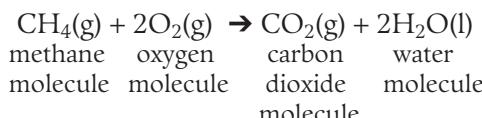
from the solutions. Silver metal can be recovered from silver nitrate solution simply by adding a piece of copper wire. This happens according to the equation:



Reactions of this type, where an element displaces another element from a compound, are called **displacement reactions**. In this example, copper has displaced the silver from the silver nitrate solution. The reactions of metals with acids are examples of displacement reactions.

Combustion — a burning question

Combustion reactions are those in which a substance reacts with oxygen and heat is released. Examples of combustion reactions include the burning of petrol in a motorcycle engine, wax vapour in a candle flame and natural gas in a kitchen stove. In each of these cases **hydrocarbons** (compounds containing only the elements carbon and hydrogen) combine with oxygen in the air to form carbon dioxide gas and water vapour. This is shown in the following equation for the burning of methane (natural gas) in a gas jet.



Breaking down

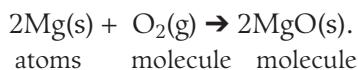
In **decomposition reactions** one single compound breaks down into two or more simpler chemicals. An example of this is the decomposition of zinc carbonate. This is represented by the equation:



Getting together

Often two elements combine in chemical reactions to form a compound. Such reactions are

called **combination reactions**. The reaction of magnesium with oxygen is a spectacular example. Magnesium burns in air, producing a brilliant flash of white light. The equation for this combination reaction is:



Notice that this combination reaction is also a combustion reaction. It is also an exothermic reaction because it transfers energy to the surroundings. (Endothermic reactions are chemical reactions that absorb energy from the surroundings.)

Transferring electrons

In many chemical reactions, electrons are either completely or partially moved from one atom, ion or molecule to another. This process is known as **electron transfer**. Chemical reactions that involve electron transfer are called **redox reactions**. Redox reactions are extremely important in industry and in our everyday lives.

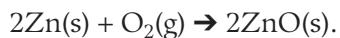
A redox reaction is really two reactions occurring simultaneously. In the electron transfer process, one reactant loses electrons and another gains electrons. Loss of electrons is known as **oxidation**. Gain of electrons is called **reduction**. Oxidation and reduction always occur together, thus the two words are combined to form the word *redox*, which is used to describe reactions where electrons are transferred.

The mnemonic **OIL RIG** may help you to remember these processes: oxidation is loss, reduction is gain.

Each of the corrosion, displacement, combustion and combination reactions described so far in this section are examples of redox reactions. Oxidation and reduction can be clearly seen in the reaction that occurs when zinc corrodes.

CORROSION OF ZINC

The chemical equation for the corrosion of zinc is:



In the corrosion of zinc, a transfer of electrons from the zinc atoms to the oxygen molecules occurs, causing the formation of positive zinc ions and negative oxide ions. These oppositely charged ions attract and bond together to form the ionic compound zinc oxide.

Zinc atoms + oxygen molecule \rightarrow Zn^{2+} ions + O^{2-} ions

In this reaction, zinc atoms lose electrons; thus zinc is oxidised. Oxygen molecules gain electrons; thus oxygen is reduced. Remember that oxidation and reduction always occur together.

INQUIRY: INVESTIGATION 5.3

Decomposing powder

KEY INQUIRY SKILLS:

- planning and conducting
- processing and analysing data and information
- communicating

Equipment:

laboratory coat and safety glasses

zinc carbonate powder

spatula

Bunsen burner, heatproof mat and matches

large Pyrex test tube and test-tube rack

test-tube holder

electronic balance

marking pen

stereo microscope

Petri dish

CAUTION: Wear safety glasses and laboratory coat.

- Place two spatulas of zinc carbonate powder in the test tube. Weigh the test tube and record the mass.
- Mark the level of the powder in the test tube with the marking pen.
- Heat the test tube gently in a blue Bunsen burner flame for 5 to 10 minutes.

CAUTION: Make sure the test tube is not pointing at anyone.

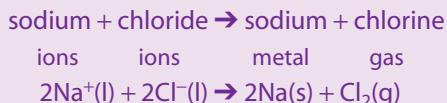
- While heating the test tube, hold a lit match at the mouth of the tube. Record your observations.
- Allow the test tube to cool down. Note any change in the level of powder and then reweigh the test tube. Record the mass.
- Place small amounts of zinc carbonate and the powder from the test tube in the Petri dish. Examine them using a stereo microscope. Record your observations.

DISCUSS AND EXPLAIN

- 1 Which gas was given off during the reaction?
- 2 Explain any change that occurred in the mass.
- 3 Write word and formula equations for the reaction.

HOW ABOUT THAT!

In the early days of chemistry, oxidation was defined as the combination of a chemical with oxygen or as the removal of hydrogen from a compound. Reduction was defined as the opposite of oxidation; that is, the removal of oxygen or the combination of hydrogen with a chemical. Today we know that oxygen and hydrogen may not be involved at all in a redox reaction. An example is when sodium metal and chlorine gas are produced by passing an electric current through molten sodium chloride.

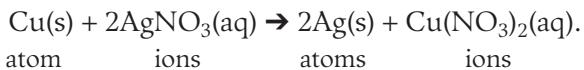


In this redox reaction, sodium is reduced and chlorine is oxidised.

Oxidation is now defined as the transfer of electrons from a reactant. In the above redox reaction, chlorine is oxidised and sodium is reduced.

DISPLACEMENT OF SILVER

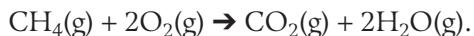
The chemical equation for the displacement of the silver ion from silver nitrate by copper is:



In this reaction, electrons are transferred from the copper atoms to the silver ions. Silver ions (Ag^+) in the solution gain electrons to form atoms of solid silver. Thus, silver ions are reduced. Copper atoms ($\text{Cu}(\text{s})$) lose electrons, forming copper ions ($\text{Cu}^{2+}(\text{aq})$), which dissolve into a solution. The formation of copper ions changes the colour of the solution from colourless to blue. The copper atoms are oxidised. The nitrate ion is not involved in the electron transfer.

COMBUSTION OF METHANE

The chemical equation for the burning of methane in a gas jet is:

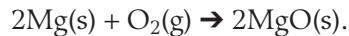


In this redox reaction, electron transfer is not complete. The reactants are molecules and the products are also molecules. In each molecule, electrons are shared by the atoms. However, the oxygen atoms in the products attract the electrons more strongly than the carbon and hydrogen atoms.

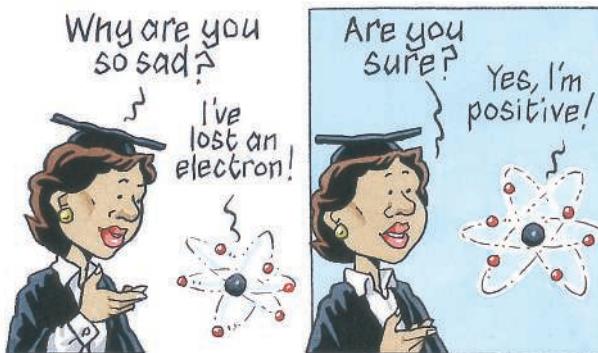
Therefore, the shared electrons spend more time close to the oxygen atoms. The electrons have been partially transferred to the oxygen atom. Thus, oxygen is reduced and the carbon in methane is oxidised.

COMBINATION OF MAGNESIUM AND OXYGEN

The chemical equation describing the combination of magnesium and oxygen as a result of burning is:



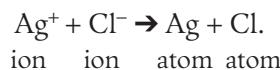
In this reaction, electrons are transferred from the atoms in the magnesium metal to the oxygen atoms in the oxygen molecule. This forms positive metal ions and negative oxide ions. These ions are attracted to each other because of their opposite charges and form the white ionic solid magnesium oxide. Magnesium, which loses electrons, is oxidised, and oxygen is reduced.



Light and shade

People who wear glasses often don't want to bother with swapping over to sunglasses when they go outside. **Photochromic** glasses solve the problem by darkening as the wearer moves from indoors into bright sunshine. They lighten again when the wearer moves back into an area of low light. Plastic photochromic glasses use organic material that darkens the lenses when exposed to ultraviolet light.

Glass photochromic glasses work due to the presence of silver chloride (AgCl) crystals in the glass. When a wearer is in the sunshine, ultraviolet light is absorbed by the silver chloride crystals and a redox reaction occurs. Electrons are transferred from the chloride ions to the silver ions according to the equation:



Silver particles then form in the glass, darkening the lens so that visible light is absorbed and reflected.

The fading of the dark glass is more complicated. The chlorine atoms are very reactive. To stop them reacting with the silver atoms and reversing the process too quickly, singly charged copper ions are dissolved in the molten glass during the manufacturing process. These ions react with the chlorine atoms to form chloride ions and doubly charged copper ions in the reaction:



When the glasses are no longer in the sunlight, the doubly charged copper ions accept an electron from the silver atom. The silver ion re-forms and the dark lens becomes light again:



Reactions with a zap!

The chemical reactions that produce electrical energy in electric cells (more commonly known as batteries) are redox reactions. In electric cells,

electrons are transferred from one reactant to another through the wires that make up the electric circuit. This is very useful because the moving electrons can provide the energy to operate our appliances. Thus, chemical energy from the redox reaction is converted to electrical energy. The reactants in the cells are not in direct contact with each other. In an ordinary carbon battery or dry cell, the reactants are separated by a paste that allows the movement of electric charge. The electrons flow from one reactant at the negative electrode, through the electric circuit to the other reactant at the positive electrode. Chemical products are formed at both electrodes.

WHAT DOES IT MEAN?



The word *photochromic* comes from the Greek words *photo*, meaning 'light', and *khroma*, meaning 'colour'.

UNDERSTANDING AND INQUIRING

REMEMBER

- 1 Construct a table like the one below and use it to summarise each of the groups of reactions discussed in this section. List one example of a reaction for each group.

Reaction type	Description	Example

- 2 What do all redox reactions have in common?
 3 What is oxidation?
 4 What is reduction?
 5 Where does the word *redox* come from?
 6 Consider the reaction:

$$2\text{Zn(s)} + \text{O}_2\text{(g)} \rightarrow 2\text{ZnO(s)}.$$
 (a) From which reactant are the electrons being transferred?
 (b) Which reactant are they transferred to?
 7 Give an example of a redox reaction where electron transfer is not complete.

THINK

- 8 (a) Refer to the tables in section 5.2. Write a balanced equation using formulae for the following reactions:
 (i) copper metal + zinc sulfate solution → zinc metal + copper sulfate solution
 (ii) sodium metal + oxygen gas → solid sodium oxide
 (iii) carbon monoxide gas + oxygen gas → carbon dioxide gas
 (iv) hydrogen peroxide (H_2O_2) solution decomposes to form hydrogen gas and oxygen gas.
 (b) State the type of each of the reactions in part (a).
 9 Explain how it can be said that the reaction between magnesium and oxygen is four reactions in one: a combustion reaction, a combination reaction, a redox reaction and an exothermic reaction.

eBook plus

- 10 Test your ability to identify different types of reactions by completing the **Time Out: 'Reactions'** interactivity. **int-0759**
 11 Use the **Chemical reactions** weblink in your eBookPLUS to learn more about the different types of chemical reactions.



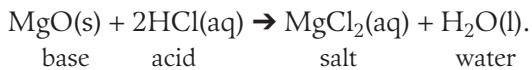
5.5 Metal displacement
5.6 Corrosion and combustion

Producing salts

One very important reaction involving acids and bases is **neutralisation**.

Neutralisation is the name given to the chemical reaction in which an acid and a base react with each other to produce water. The other substance produced in a neutralisation reaction is called a **salt**.

Your stomach contains hydrochloric acid, which helps to break up food for digestion. Too much acid, however, can be a problem. If your stomach produces too much acid, you may need to take an antacid such as milk of magnesia. This medicine has the solid base magnesium oxide (MgO) suspended in it. This base reacts with the hydrochloric acid in your stomach according to the equation:



Base	Acid	Negative ion present in salt	Salt
Sodium hydroxide	Sulfuric acid	Sulfate SO_4^{2-}	Sodium sulfate
Magnesium oxide	Hydro chloric acid	Chloride Cl^-	Magnesium chloride
Sodium oxide	Acetic acid	Acetate CH_3COO^-	Sodium acetate
Copper(II) oxide	Nitric acid	Nitrate NO_3^-	Copper(II) nitrate

UNDERSTANDING AND INQUIRING

REMEMBER

- 1 What is a salt?
 - 2 What are the products of the reaction between an acid and a base that contains the hydrogen carbonate ion?

THINK

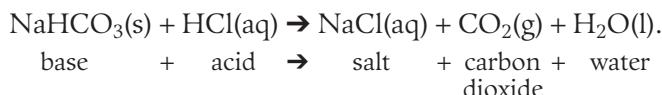
Use the tables in section 5.2 and the table at right to answer the following questions.

- 3 Using formulae, write equations for the following reactions.

 - Solid sodium hydrogen carbonate and sulfuric acid react to form a sodium sulfate solution, carbon dioxide and water
 - Solid potassium hydroxide and hydrochloric acid react to form a solution of potassium chloride and water
 - Solid copper oxide reacts with sulfuric acid to form a solution of copper sulfate and water

The products are the salt magnesium chloride, and water. The salt contains the positive metal ion from the base and the negative non-metal ion from the acid.

The base sodium hydrogen carbonate, commonly known as bi-carb, is a component of baking powder. It has the formula NaHCO_3 and contains the hydrogen carbonate ion HCO_3^- . When bases containing this ion react with acids, the gas carbon dioxide is produced as well as salt and water. When hydrochloric acid and bi-carb are mixed together, the following reaction takes place:



In both of the above reactions, the salts formed were metal chlorides, because they contained the chloride ion (Cl^-) from the hydrochloric acid. Neutralisation reactions between many different acids and bases are possible; therefore, it is possible to produce many different salts. Some of these reactions are summarised in the table below.

- 4 Name the salts that would form from the reaction between:

 - (a) magnesium hydroxide and hydrochloric acid
 - (b) potassium hydroxide and acetic acid
 - (c) sodium carbonate and sulfuric acid.

Some common laboratory bases

Base	Formula
Sodium hydroxide	NaOH
Copper hydroxide	Cu(OH) ₂
Potassium hydroxide	KOH
Magnesium hydroxide	Mg(OH) ₂
Sodium carbonate	Na ₂ CO ₃
Sodium bicarbonate	NaHCO ₃

INQUIRY: INVESTIGATION 5.4

Pass the salt!

KEY INQUIRY SKILLS:

- planning and conducting
- processing and analysing data and information
- communicating

Equipment:

safety glasses and laboratory coat
50 mL burette
retort stand, bosshead and clamp
tripod and gauze mat
Bunsen burner, heatproof mat and matches
20 mL pipette
100 mL conical flask
pipette bulb
white tile
dropping bottle of phenolphthalein indicator
wire shaped into a loop with a handle
small funnel
1 mol/L hydrochloric acid solution
1 mol/L sodium hydroxide solution
evaporating dish
silver nitrate solution in a dropping bottle
sample of sodium chloride
test tube

CAUTION: Wear safety glasses and a laboratory coat.

- Rinse the burette with the hydrochloric acid solution and then, using the funnel, fill the burette with the hydrochloric acid solution.
- Rinse the pipette with sodium hydroxide solution using the pipette bulb.

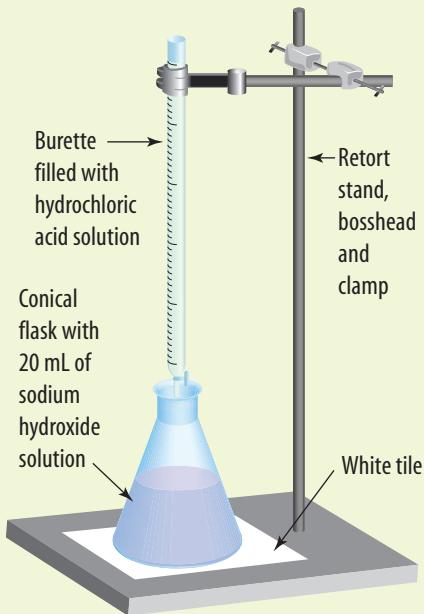
CAUTION: Never pipette using your mouth.

- Set up the equipment as shown in the diagram at right. Use the pipette and bulb to transfer 20 mL of the sodium hydroxide solution into the conical flask.
- Add a few drops of phenolphthalein indicator to the sodium hydroxide.

- Add the acid from the burette carefully until the pink colour of the indicator disappears. The colour change indicates that the neutralisation reaction is complete.
- Pour the contents of the flask into an evaporating dish. Heat the dish with the Bunsen burner and gently evaporate the water. Be careful — spattering may occur.
- When the water has nearly evaporated, turn off the Bunsen burner and allow the dish to cool and the remaining water to evaporate without further heating.
- Test the white crystals for the presence of sodium ions by placing a few crystals on a wire loop and heating in a Bunsen burner flame. Compare this flame colour with a known sample of sodium chloride. Record your observations.
- Test for the presence of chloride ions by dissolving a few crystals in half a test tube of water and adding a few drops of silver nitrate. A white cloudiness indicates that chloride ions are present. Record your observations.

DISCUSS AND EXPLAIN

- 1 Comment on the information that the flame and silver nitrate tests provided. What conclusion can you draw?
- 2 Write a word equation for the neutralisation reaction.
- 3 Write a balanced equation, using formulae, for the neutralisation reaction.
- 4 Design a test to show that water was the other product of the reaction.



HOW ABOUT THAT!

Many salts are brightly coloured and many are highly poisonous and not at all suitable for sprinkling on your fish and chips! Salts containing copper ions are

usually blue, those containing nickel are pale green, those containing iron can be green or orange, and cobalt salts are pink.

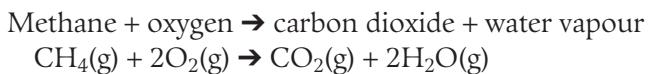
Fuelling our lifestyle

No cars, no streetlights, no heating in cold weather, no television ... We would not have these 'necessities' if we didn't have access to the chemical energy stored in **fossil fuels**. The expression *fossil fuel* refers to coal, natural gas and oil, all of which were formed from decaying plants and animals over tens or hundreds of millions of years.

Plants transform energy from the sun into chemical energy by **photosynthesis**. During the formation of fossil fuels, the plant and animal matter decays but the chemical energy remains stored in the fossil fuels. When we burn fossil fuels, the chemical energy is converted to other forms of energy in combustion reactions (see section 5.5).

Gas fuel

The flame you see on a gas stove results from the burning of natural gas. This gas was formed millions of years ago, when the remains of tiny marine and freshwater plants and animals were transformed into the natural gas that became trapped in rock. When natural gas is burned to heat water or your home and to cook food, methane reacts with oxygen to produce carbon dioxide and water vapour. During the reaction, the chemical energy stored in the methane molecules is transformed, heating the surrounding air, water or food.



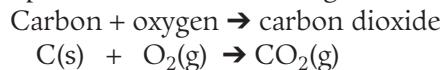
Solid fuel

Another fuel that is formed over a period of millions of years is **coal**. Coal is formed from the remains



The flame burning on a gas stove marks the end of a long journey for a chemical called methane.

of plants that were buried in sediments between 20 million and 300 million years ago. As coal (which consists mainly of carbon) is burned, it reacts with oxygen to produce carbon dioxide gas.



In Australia, coal is used mainly in the generation of electricity. In power stations, the energy released in the chemical reaction is used to change water into steam. The rapidly moving steam turns the turbines that generate electricity.

Coal is also used to make other fuels such as coal gas and to make methanol and coke. Coke is used in the refining of steel.

Liquid fuel

Crude oil is a sticky, dark, smelly liquid. Most of the chemicals in it are hydrocarbons, compounds of hydrogen and carbon atoms. Crude oil was formed from the remains of marine plants and animals that died over 200 million years ago.

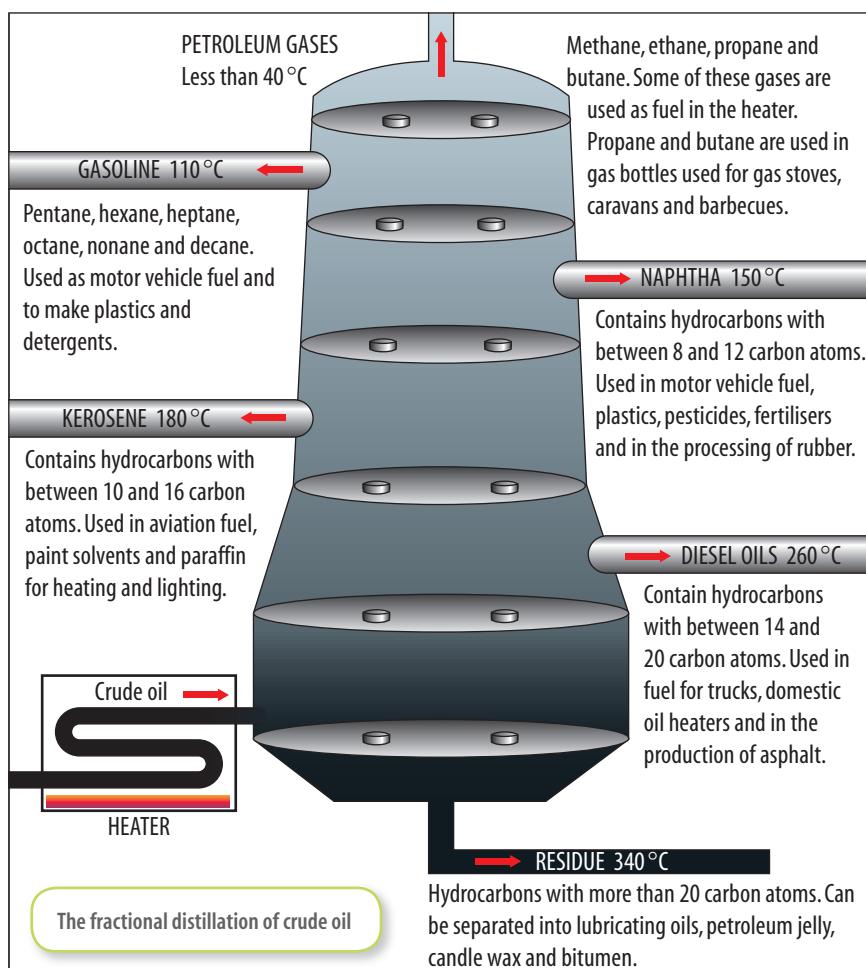
Crude oil is a mixture of chemicals that includes diesel fuel, petrol, aviation fuel, tar, kerosene and many more hydrocarbons. So many chemicals make up crude oil that it has to be separated into the different hydrocarbons before it can be useful.

The table of hydrocarbons on the next page shows that the longer the molecule becomes, the higher its boiling point is. Chemists use this property to separate the components of crude oil in a process called **fractional distillation**.

When crude oil is heated to 370 °C, most of its components are changed into a gaseous state. In fractional distillation, this gaseous crude oil is passed into the bottom of a fractionating tower, which becomes cooler further up the tower. The hot vapours cool as they rise up the fractionating tower. The heaviest hydrocarbons condense back to a liquid near the base of the tower. The other hydrocarbons, still gases, rise through the tower until they cool off enough to condense back to a liquid (at a temperature just below their boiling point). The different hydrocarbons are separated at different places up the tower according to their different boiling points. Each **fraction** is piped away for processing.

Hydrocarbons

Hydrocarbon	No. of carbon atoms	Structure	Boiling point (°C)
Methane	1	CH_4	-164
Ethane	2	$\text{CH}_3\text{--CH}_3$	-89
Propane	3	$\text{CH}_3\text{--CH}_2\text{--CH}_3$	-42
Butane	4	$\text{CH}_3\text{--CH}_2\text{--CH}_2\text{--CH}_3$	-0.5
Pentane	5	$\text{CH}_3\text{--CH}_2\text{--CH}_2\text{--CH}_2\text{--CH}_3$	36
Hexane	6	$\text{CH}_3\text{--CH}_2\text{--CH}_2\text{--CH}_2\text{--CH}_2\text{--CH}_3$	69
Heptane	7	$\text{CH}_3\text{--CH}_2\text{--CH}_2\text{--CH}_2\text{--CH}_2\text{--CH}_2\text{--CH}_3$	98
Octane	8	$\text{CH}_3\text{--CH}_2\text{--CH}_2\text{--CH}_2\text{--CH}_2\text{--CH}_2\text{--CH}_2\text{--CH}_3$	126
Nonane	9	$\text{CH}_3\text{--CH}_2\text{--CH}_2\text{--CH}_2\text{--CH}_2\text{--CH}_2\text{--CH}_2\text{--CH}_2\text{--CH}_3$	151
Decane	10	$\text{CH}_3\text{--CH}_2\text{--CH}_2\text{--CH}_2\text{--CH}_2\text{--CH}_2\text{--CH}_2\text{--CH}_2\text{--CH}_2\text{--CH}_3$	174



Alternatives to fossil fuels

The world's reserves of fossil fuels are limited, and eventually they will run out. At present, in Australia, we obtain 95 per cent

of our energy needs from fossil fuels. It is important that as well as conserving energy, we search for alternatives to fossil fuels.

BIOFUELS

Biofuels are fuels made from **biomass**. Biomass is the name

given to plant and animal tissue. Living things, including bacteria, animals and plants, are all energy converters. When they convert energy, some waste is produced. The chemical energy in waste from living things and other chemicals made by living things can be converted into more useful forms of energy.

IT'S NOT REALLY WASTE

Imagine producing fuel from human sewage! It would not only help solve the problem of disposing of human waste in big cities, but also reduce the demand on fossil fuels. You might be surprised to know that sewage is already being used to make fuel.

The fuel produced from biomass can be a solid (like the wood burned in an open fireplace or barbecue), a liquid (like ethanol) or a gas. The gas produced from biomass is known as **biogas**.

Plant and animal wastes can be converted to biogas in a biogas digester. Biogas is mainly methane and carbon dioxide. The methane produced can then be used for heating and to power homes and farms.

Biogas is the product of the chemical reaction that takes place when wastes rot in the absence



This biogas facility at Melbourne Water's Western Treatment Plant at Werribee is used to generate electricity.

of oxygen. The solids left over from the production of biogas can be used as fertiliser or combined with compost and sand to make organic soils.

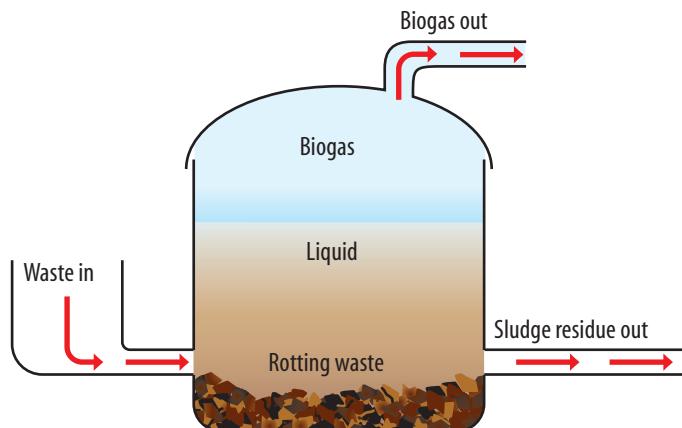
Sewage treatment plants, and farms on which animals graze, are ideal locations for biogas digesters because of the availability of animal waste. Farms also provide a use for the leftover solids from biogas digesters.



These bubbles of methane are trapped in a frozen pond. The methane gas is produced by rotting organic matter that has sunk to the bottom of the pond.

CHINA LEADS THE WAY

In China, where about 70 per cent of the population lives on farms or in villages, more than 12 million households use biogas digesters to provide energy for lighting and cooking. Human and animal waste is fed into the digester. Many digesters are directly connected to toilets and pigsties. The waste is allowed



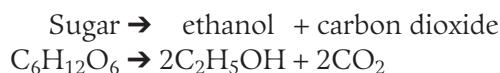
A simple household biogas digester

to rot, producing a gas that is about 60 per cent methane, which bubbles to the top of the digester. The dark and surprisingly odourless sludge residue is drained from the digester and used as fertiliser.

China also has more than 1500 larger biogas plants that produce gas for heating and the generation of electricity.

ALCOHOL — A PETROL ALTERNATIVE

Alcohol produced from fermented sugar or corn is a biofuel that can be used to fuel motor vehicles. The alcohol produced from the fermentation of sugar is ethyl alcohol, commonly called **ethanol**.



Ethanol as a fuel source has been most successfully adopted in Brazil, where there is a large source of sugar cane and conditions are suitable for fermenting and distilling the sugar cane. In Brazil, all passenger and light commercial vehicles are powered by ethanol or a blend of petrol and ethanol. New cars

manufactured in Brazil are now designed to run on fuels that are made up of anything between 20 per cent and 100 per cent ethanol. They are known as 'flexible-fuel' or 'flex' vehicles.

Motor vehicles account for about two-thirds of the petroleum used in Australia. As reserves of petroleum become more scarce and expensive, ethanol is becoming a more desirable alternative. The use of biofuels like ethanol also helps to improve air quality and reduces the production of greenhouse gases.

A blend of ethanol and petrol is now available in Australia as E10, which is 10 per cent ethanol and 90 per cent unleaded petrol. Most new cars manufactured in Australia are able to run on E10.

HOW ABOUT THAT!

When cows burp or pass wind, they release methane gas. In fact, cows are responsible for up to about 20 per cent of the methane in the atmosphere. Imagine if the methane could be used as fuel!

UNDERSTANDING AND INQUIRING

ANALYSE AND EVALUATE

- 1 Use the information in the table of hydrocarbons to draw a graph showing the relationship between the number of carbon atoms in a hydrocarbon and the boiling point of the hydrocarbon. Explain how this relationship is useful in the refining of crude oil.

REMEMBER

- 2 Explain how all fossil fuels are formed.
- 3 Identify the type of chemical reaction in which fossil fuels are converted to other forms of energy.
- 4 Write a word equation for the burning of methane.
- 5 What is a hydrocarbon?
- 6 Which property of the different hydrocarbons in crude oil allowed chemists to develop the process of fractional distillation?
- 7 List the six components of crude oil and state one use for each component.
- 8 Distinguish between *biomass* and *biogas*.
- 9 Describe the process of producing biogas.
- 10 Which two gases are the main components of biogas?

THINK

- 11 Fossil fuels can be referred to as stores of solar energy. Explain the meaning of this statement.
- 12 Which has the higher boiling point, diesel oil or kerosene?

- 13 Which type of chemical reaction is the one used to produce ethanol by fermentation?

CREATE

- 14 Write an article for *Farmers Weekly* to convince farmers, who usually put cow manure from their milking sheds onto their farms as fertiliser, to use cow manure to make biogas.

DISCUSS AND REPORT

- 15 In a group, discuss and produce a report on each of the following questions.
 - (a) Why should the use of biogas as a fuel for heating be encouraged?
 - (b) Wood is an example of a biofuel. What are the disadvantages in the use of wood as a fuel?
 - (c) Suggest a range of alternatives to fossil fuels that could be used to supply our energy needs in Australia. List the advantages and disadvantages of each alternative.

INVESTIGATE

- 16 Carbon capture is the process of separating carbon dioxide from the emission of fossil-fuel-fired plants and biogas digesters so that it can be stored in a suitable location instead of adding to the carbon dioxide already in the atmosphere. Research and report on current methods of:
 - (a) capturing carbon dioxide
 - (b) storing carbon dioxide.

The need for speed

The speed at which chemical reactions occur varies. Some reactions occur within a fraction of a second, while others may take days or even years. Sometimes it is necessary or convenient to speed up a chemical reaction.

Reaction rate

The speed, or **rate**, of a reaction can be very important. We need to know how long food will take to cook, or how long it will take for a medicine such as an antacid to make us feel better. Controlling the rate at which reactions occur is therefore of great interest to scientists. Increasing the temperature, the surface area of solid reactants, the concentration of the reactants or, in some cases, the exposure to light can increase the rate of chemical reactions.

CHANGE THE AMOUNT

The burning of wood is a combustion reaction. The chemical word equation for this reaction is:



When you're out camping you might want to boil your billy quickly, or maybe just get warm by the fire. You could speed up the rate of burning by fanning the flames of the fire. This increases the amount of oxygen reaching the wood. This is an example of changing the amount, or concentration, of a reactant.

CHANGE THE TEMPERATURE

Many types of organism are found in food. Chemical reactions that spoil food take place in microbes. Refrigeration cools the food and the microbes. This makes the chemical reactions inside the microbes also slow down and the food keeps for longer.

Heating things up can make a reaction happen more quickly. Think of frying an egg. If you do it on a low flame, it will take longer than if you use a high flame. Heating makes the particles in the

reactants move faster and collide more often. This helps to speed up the reaction.

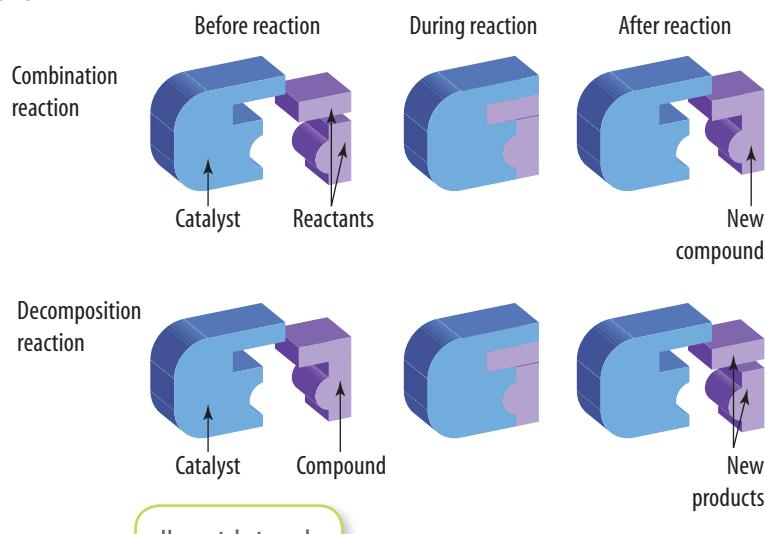
CHANGE THE SURFACE AREA

Bath bombs are sold as solid balls. When they are added to water, the chemicals inside them begin to dissolve. The ball slowly disappears.

But what if the same bath bomb is crushed into smaller pieces? A much larger surface area comes in contact with the water, and the bath bomb dissolves much more quickly.

Catalysed reactions

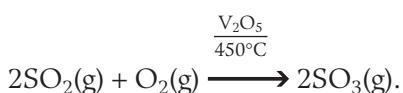
Another way to increase the rate of a reaction is to use a **catalyst**. Catalysts are not changed by the reaction. There is always as much catalyst present at the end of a reaction as there was at the start. Catalysts work by helping bonds to break more easily; therefore, the reactants need less energy to react and the reaction is faster. A catalyst can be recovered and used again and again. We all make use of catalysts every day. Cars have catalytic converters. Contact lenses are cleaned using a catalysed chemical reaction, and there are catalysts in the food you eat every day. There are also thousands of catalysts in your body without which you could not live. These biological catalysts are called **enzymes**.



CATALYSTS IN INDUSTRY

Industry makes use of many catalysts. For example:

- iron and iron oxide are used to catalyse the production of ammonia gas. Ammonia is used to make fertilisers and explosives.
- vanadium oxide (V_2O_5) is used in the production of sulfuric acid. One important reaction in this process, between sulfur dioxide gas and oxygen, has a very slow rate at room temperature. However, it proceeds rapidly at 450°C in the presence of a vanadium oxide catalyst according to the equation:

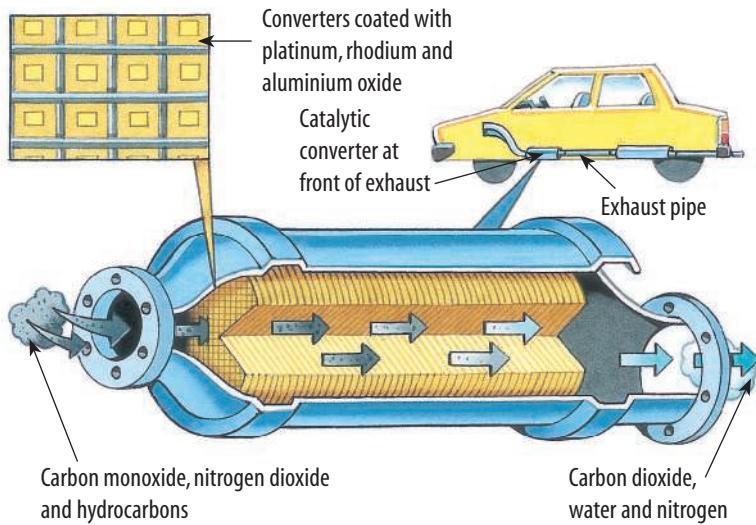


Note that the catalyst is written above the arrow and not on the side of the reactants. It is not changed as the reaction takes place.

- crystalline substances made of aluminium, silicon and oxygen called **zeolites** are used to 'crack' (break up) the large molecules in crude oil to form the smaller molecules, such as octane, found in petrol.

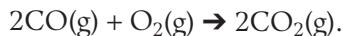
EVERYDAY CATALYSTS

In the confined space of the internal combustion engine, the fuel does not completely react with oxygen. As a result, carbon monoxide (CO), a highly poisonous gas, is produced. Nitrogen oxides are other harmful gases produced by car engines. In order to reduce the amount of pollution from these gases, cars are fitted with catalytic converters as part of the exhaust system. These converters have a

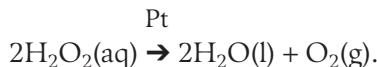


Catalytic converters have a large surface area and are coated with a metal catalyst.

honeycombed surface that is coated with the metals platinum and rhodium and with aluminium oxide. At the catalyst surface, the nitrogen oxides are converted to less harmful gases and the carbon monoxide is reacted with more oxygen to form carbon dioxide according to the equation:



Catalysts can also help clean your contact lenses. One cleaning product makes use of a platinum catalyst. A solution of hydrogen peroxide (H_2O_2) is poured into a small container that contains a platinum-coated disc. The platinum causes the peroxide to decompose according to the reaction:



Any microbes not tolerant to oxygen on the contact lenses are killed by the oxygen released.



Catalysts are used to clean contact lenses.

CATALYSTS IN LIVING THINGS

Almost every one of the chemical reactions that take place in your body is controlled by an enzyme. Enzymes are large protein molecules. They are essential for digesting food, breaking down toxic waste products, and numerous other chemical processes that keep you alive and healthy. The enzyme **amylase**, which is present in your saliva, is involved in the breakdown of starch into sugar.

Your liver contains an enzyme called **catalase**. Catalase speeds up the breakdown of hydrogen peroxide, a toxic waste product produced in your cells.

Enzymes are also used to make bread, cheese, vinegar and many other food products.



Bubbles of oxygen form on the platinum-coated disc. As they rise up past the contact lenses in the white plastic cage, they disinfect them.

INQUIRY: INVESTIGATION 5.5

A liver catalyst

KEY INQUIRY SKILLS:

- planning and conducting
- processing and analysing data and information
- evaluating

Equipment:

heatproof mat

2 test tubes and test-tube rack

20% hydrogen peroxide solution

spatula

fresh liver

safety glasses

mortar and pestle

- Pour hydrogen peroxide to a depth of 3 cm into the test tubes. Label the test tubes 1 and 2.
- Grind a small piece of liver in the mortar and pestle. Add liver to test tube 1 only.
- Record your observations.

DISCUSS AND EXPLAIN

- 1 What effect did the liver have on the breakdown of hydrogen peroxide?
- 2 What evidence is there to suggest that a chemical reaction has taken place?
- 3 Suggest a reason why the liver was ground up before it was placed in the hydrogen peroxide solution.
- 4 What is the function of test tube 2?

UNDERSTANDING AND INQUIRING

REMEMBER

- 1 Explain what a catalyst does and give three examples.
- 2 Why are catalysts important to industry?
- 3 What are enzymes?

THINK

- 4 Why do catalytic converters have a honeycombed surface?
- 5 Give one reason why the enzyme amylase is added to bread.

INVESTIGATE

- 6 Find out why leaded petrol must not be used in cars fitted with catalytic converters.
- 7 Research the production of cheese. Find out the enzymes used to produce a range of cheeses. Present your findings as a poster or wall chart.
- 8 Several diseases are caused by the body's failure to produce a particular enzyme. Phenylketonuria (PKU) and galactosemia are two such diseases. Research one of these diseases and present a report about their causes and treatment.

work
sheet

→ 5.7 Speeding up reactions.

A cool light

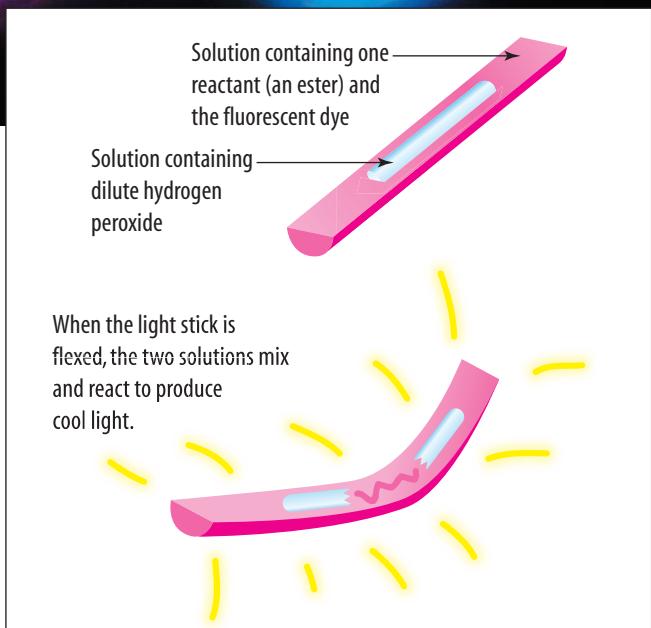


Night golf can be played using golf balls that glow in the dark. Glow necklaces and light sticks are glowing plastic tubes that are popular in the evening at outdoor events and amusement parks. Light sticks can also be included in survival kits as a light source. Where does the light come from in these glowing devices? The answer lies in **chemiluminescence** — the production of light from a chemical reaction.

Light from a chemical reaction

A light stick consists of two distinct parts: an outer plastic tube and an inner glass vial. The outer plastic tube is sealed and contains a solution of a chemical called an ester and a fluorescent dye. The inner glass vial is thin and breakable. It contains a solution of hydrogen peroxide. When the light stick is bent, the inner glass vial breaks, causing the two solutions to mix. The chemical reaction (a redox reaction) between the two solutions produces the light.

The chemical reaction between the hydrogen peroxide solution and the ester solution releases energy that is transferred to the **fluorescent** dye molecules. The excited dye molecules give off their excess energy as light without any noticeable heat. That is why the light is referred to as cool light.



The combination of the ester, the hydrogen peroxide and the fluorescent dye produces a cool light.

Light from living things

Some living things can produce light in a process called **bioluminescence**. One of the most common examples of bioluminescence is seen in **fireflies**, insects of the family *Lampyridae*. The abdomens of fireflies glow during the mating season to attract potential mates. This type of light is also a form of cool light, produced by chemical reactions in the cells of the firefly. During these chemical reactions energy is transferred to luminescent molecules. Like the molecules of dye in the light stick, these luminescent molecules become excited and emit

energy as light. In the firefly, the chemical reactions are controlled by special enzymes called **luciferases**. The luciferase enzymes are produced in the cells of the firefly's abdomen and allow the light-producing chemical reactions to occur.

There are many living things that use bioluminescence to light their dark surroundings, to attract their prey and to camouflage themselves. Organisms such as bacteria, protozoa, fungi, sponges, crustaceans, insects, fish, squid, jellyfish and simple plants have been found to be bioluminescent.



Bioluminescent fungi during the day (left) and at night (right). Some scientists believe that bioluminescent fungi use their light to attract insects.



Some jellyfish use bioluminescence to startle predators or to attract a mate.

Mimicking bioluminescence

The production of cool light by fireflies has been used as a model for the development of chemiluminescent materials. Although the production of light by chemiluminescence has been possible for some time, commercial applications

were often not developed because the reactions were relatively inefficient. The firefly is able to produce light very efficiently by the chemical reactions in the cells of its abdomen. However, in recent years chemical research has uncovered new chemiluminescent reactions and more efficient reactions have been developed. This has enabled the commercial production of chemiluminescent items and the use of chemiluminescence techniques in scientific research.

Using chemiluminescence and bioluminescence

The reactions that occur in chemiluminescence and bioluminescence have been adapted for use in scientific research, medicine, ecology, hygiene and food quality control. Bioluminescence is used when testing for tuberculosis to determine the most suitable antibiotic to be given to the patient. Scientists have used gene transfer technology to insert the firefly's gene for making luciferase enzymes into bacteria from the tuberculosis patient. These bioluminescent bacteria are then tested for their resistance to different antibiotics. The effectiveness of the antibiotics can be easily determined by the amount of bioluminescence remaining. Bioluminescent bacteria have also been used to test for mercury pollution in water. No doubt in the future many more uses will be found for chemiluminescence and bioluminescence.

UNDERSTANDING AND INQUIRING

THINK

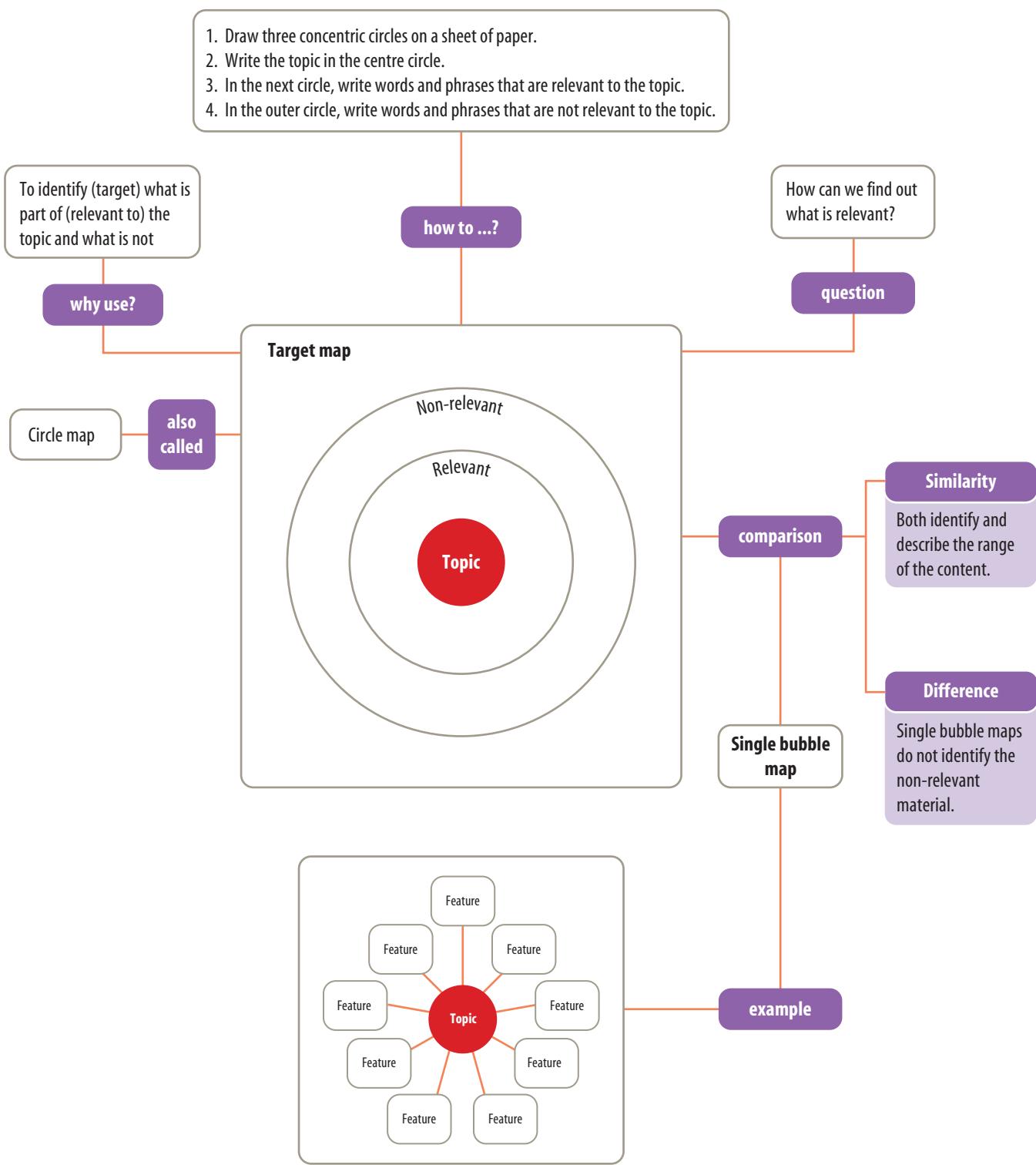
- 1 In what ways are chemiluminescence and bioluminescence similar?
- 2 Draw a diagram to explain how light is produced in a chemiluminescent light stick.

INVESTIGATE

- 3 Use the library and the internet to find out how chemiluminescence and bioluminescence are used by scientists. Produce a web page of your findings, including links to some of the websites that you used for your investigation.
- 4 Bioluminescence can be used by organisms to light their dark surroundings, to attract a mate, to attract their prey and to camouflage themselves. Find examples of plants or animals that use bioluminescence for each of these reasons.

Target maps and single bubble maps

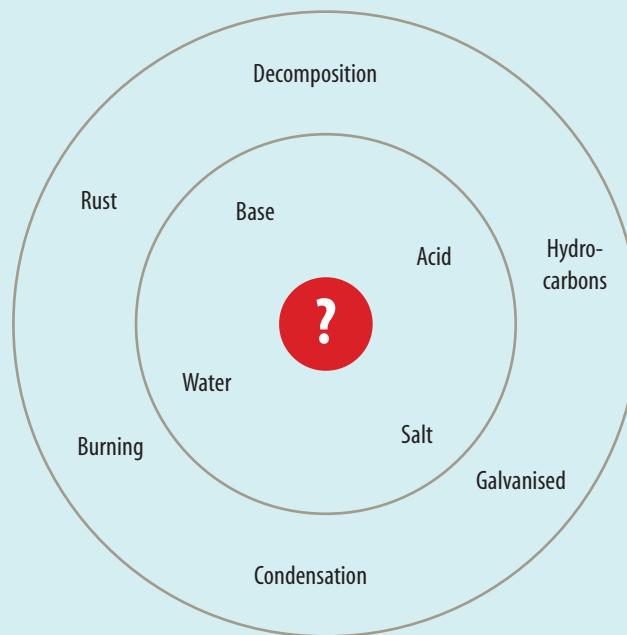
1. Draw three concentric circles on a sheet of paper.
2. Write the topic in the centre circle.
3. In the next circle, write words and phrases that are relevant to the topic.
4. In the outer circle, write words and phrases that are not relevant to the topic.



UNDERSTANDING AND INQUIRING

THINK AND CREATE

- 1 The target map below separates the content that is relevant to a particular group of chemical reactions. Which group of chemical reactions is represented?



- 2 Use the terms in the target map in question 1 and the box below to construct target maps that are relevant to:
- all chemical reactions
 - combustion reactions
 - corrosion reactions.

precipitate	melting	reactants
oxygen	energy absorbed	products
evaporation	broken bonds	

- 3 (a) Work in a small group to write down as many ideas associated with chemical reactions as you can.



- (b) Once your group has completed a list, work on your own to create a single bubble map that represents what you believe to be the ten most important ideas related to chemical reactions.

- 4 Create single bubble maps to represent the important ideas associated with:
- precipitation reactions
 - redox reactions
 - dangerous goods
 - hazardous substances.
- 5 Create a single bubble map on the topic 'Plastics'.



- 6 Sort the following substances into three groups to create single bubble maps relevant to the topics:
- salts
 - fuels
 - catalysts.

biogas	methane
sodium chloride	platinum
enzymes	propane
magnesium chloride	sodium acetate
coal	ethanol
zeolites	copper nitrate
hydrocarbons	vanadium oxide
amylase	sodium sulfate

MAKING AND USING PLASTICS

- describe the molecular structure of polymers
- explain how polymers are derived from monomers
- relate the uses of polymers to their properties

WRITING CHEMICAL EQUATIONS

- describe chemical reactions using chemical formulae
- write correctly balanced chemical equations

TYPES OF CHEMICAL REACTIONS

- describe and compare the characteristics of precipitation, corrosion, displacement, combustion, decomposition, combination and neutralisation reactions
- describe the transfer of electrons to and from different atoms in redox reactions
- distinguish between oxidation and reduction in redox reactions
- describe examples of a range of redox reactions
- describe the use of fractional distillation in the refining of crude oil for use in combustion reactions
- outline some examples of the use of biofuels as an alternative to fossil fuels

CHEMICAL REACTION RATES

- describe the effect of temperature, surface area of solid reactants and concentration of reactants on the rate of chemical reactions
- describe the role of catalysts in chemical reactions
- investigate the examples of the use of naturally occurring catalysts in the human body

SCIENCE AS A HUMAN ENDEAVOUR

- appreciate the role of plastics in everyday life
- recognise the need to use laboratory chemicals safely and responsibly
- describe the dangers associated with each of the classes and subclasses of substances classified as dangerous goods
- recognise and interpret an MSDS and a risk assessment sheet
- investigate the technologies associated with carbon capture and storage
- discuss and debate the advantages and disadvantages of the use of fossil fuels and their alternatives for the supply of energy
- investigate the use of catalysts in motor vehicles and food production
- investigate the causes and treatment of diseases caused by enzyme deficiencies

eBookplus

Summary

eLESSON

Saving acid wetlands

Watch a video from the ABC's *Catalyst* program to discover whether an acid site near Cairns can be saved.

Searchlight ID: eles-1072

INTERACTIVITIES

Checking for balance

Use this interactivity to test your ability to balance chemical equations.

The equations below describe some chemical reactions. Enter the appropriate numbers in the correct place to balance the equations.

Mg(OH)₂ + HCl -> MgCl₂ + H₂O

Searchlight ID: int-0677

Time Out: 'Reactions'

Use this exciting interactivity to test your ability to classify different types of reactions before time runs out.

Time Out

What type of reaction is this?

Displacement

Combustion

Neutralisation

Cu + 2AgNO₃ → 2Ag + Cu(NO₃)₂

Searchlight ID: int-0759

INDIVIDUAL PATHWAYS

eBookplus

Activity 5.1

Revising chemical reactions

Activity 5.2

Investigating chemical reactions

Activity 5.3

Investigating chemical reactions further

LOOKING BACK

- 1** What is the only reliable evidence indicating that a chemical reaction has taken place?
- A change in temperature
 - A change in state
 - Formation of a new substance
 - Disappearance of one or more reactants
- 2** Describe one characteristic that is common to all materials that we call plastics.
- 3** Explain how polymers are made, using the terms *monomers* and *chemical bonds* in your explanation.
- 4** Two types of plastics are thermoplastic polymers and thermosetting polymers.
- Describe the differences in the properties of these two types of plastics.
 - Explain the differences in their properties in terms of bonding between the chains of monomers of which they are made.
 - List two examples of each type of plastic.
- 5** In an experiment to test the effect of the amount of liver on the breakdown of hydrogen peroxide, the following results were obtained.

Mass of liver (g)	Volume of oxygen released (cm ³)
0.5	2.5
1.0	5.1
2.0	9.8
2.5	11.5

- Write a word equation for the reaction occurring in this experiment.
- Use formulae to write an equation for this chemical reaction.
- Graph these results on graph paper.
- What does the graph show about the effect of the liver on the rate of this reaction?
- Why does the liver affect this reaction?

- 6** Complete the following table, then write the final balanced equation and show physical state symbols.

Balancing a chemical equation

Example: Ethene gas will burn in air. This is an example of a combustion reaction. This type of reaction produces CO₂ and H₂O.

Step 1: Start with the word equation and name all of the reactants and products.

_____ gas + _____ gas → carbon dioxide + water

Step 2: Replace the words in the word equation with formulae and rewrite the equation.

Ethene gas = C₂H₄ Oxygen gas = _____ (reactants)
 _____ = CO₂ Water vapour = _____ (products)

Element	Reactants	Products
C		
H		
O		

- 7** When an aqueous solution of barium hydroxide reacts with an aqueous solution of ammonium hydroxide, the temperature of the products becomes low enough to freeze water.

- What is an aqueous solution?
- Is this an example of an exothermic or endothermic chemical reaction? Explain your answer.
- Where does the energy transferred to or from the reactants go?

- 8** The two reactants in the chemical reaction taking place in the test tube shown at right are aqueous solutions. There is enough evidence in the photograph to identify the type of chemical reaction taking place.

- What type of chemical reaction is it?
- What evidence in the photograph identifies the type of reaction?

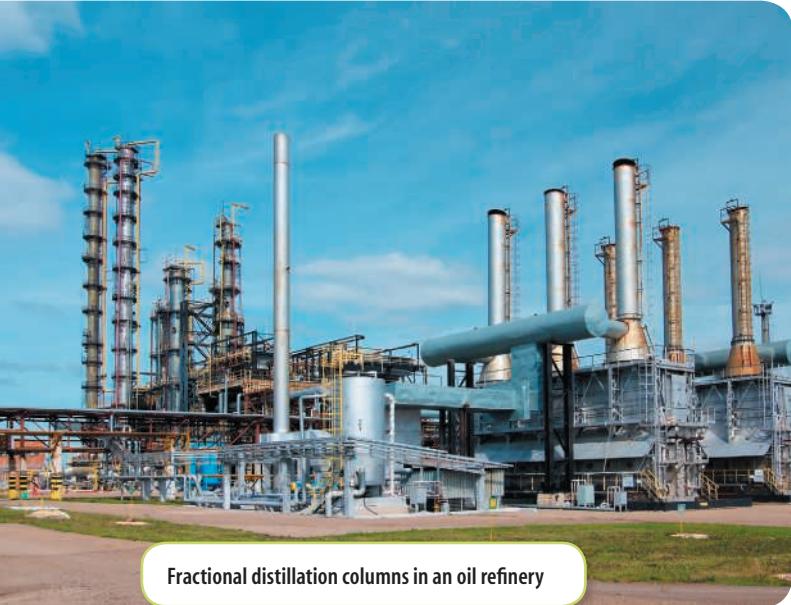


- 9** Which of the following is a balanced equation?

- Na + 2Cl → 2NaCl
- MgO + 2HCl → MgCl + H₂
- MgO + 2HCl → MgCl₂ + H₂O
- 2Na + Cl → 2NaCl

- 10** Which of the following are products of the reaction between silver nitrate and sodium chloride?

- Silver nitrate and sodium chloride
- Nitrogen chloride and silver sodium
- Do not react so there will be no products
- Silver chloride and sodium nitrate



- 11 Many chemicals are classified as dangerous goods and/or hazardous substances.
 - (a) Describe the differences between these two categories of chemicals.
 - (b) What do these two categories of chemicals have in common?
- 12 What is an MSDS and what is it used for?
- 13 Write balanced equations using formulae for the following reactions.
 - (a) Aluminium metal + oxygen gas → solid aluminium oxide
 - (b) Potassium metal + oxygen gas → solid potassium oxide
 - (c) Solid carbon + oxygen gas → carbon dioxide gas
 - (d) Solid copper carbonate → solid copper oxide + carbon dioxide gas
 - (e) Iron metal + sulfur powder (S_8) → solid iron sulfide (FeS_2)
 - (f) Copper sulfate solution + zinc metal → copper metal + zinc sulfate solution
 - (g) Copper(II) sulfate solution + sodium hydroxide solution → solid copper(II) hydroxide + sodium sulfate solution
 - (h) Solid magnesium hydroxide + hydrochloric acid → magnesium chloride + water
- 14 State the reaction type (displacement, combination, decomposition, precipitation, combustion or neutralisation) for each of the reactions in question 13.
- 15 Which of the reactions in question 13 are redox reactions?
- 16 The chemical reaction between acids and metals is a displacement reaction. An experiment was carried out to measure how long it took for equivalent amounts of different metals to dissolve in 100 mL of hydrochloric acid. The results shown in the table above right were obtained.

Unfortunately, the person recording the data on the computer accidentally changed the order of the metals recorded in the table.

Metal	Time taken for the metal to dissolve (min)
Iron	1.0
Magnesium	3.0
Tin	2.5
Aluminium	3.5
Nickel	2.0
Zinc	1.5

- (a) Using the table of the known activity series in section 5.3, redraw the table so that the correct metal is matched with the correct time.
 - (b) Explain why all of these reactions are called displacement reactions.
 - (c) Which element is displaced in the reactions?
 - 17 Predict the salts that would result from the neutralisation reaction between:
 - (a) magnesium oxide and hydrochloric acid
 - (b) copper(II) oxide and sulfuric acid
 - (c) sodium hydroxide and acetic acid
 - (d) sodium oxide and nitric acid.
 - 18 During fractional distillation, what differing observable property of hydrocarbons is used to separate them from crude oil?
 - 19 How is the molecular structure of methane different from that of octane?
 - 20 Which hydrocarbons used in fuel production are separated from crude oil at the highest temperature?
 - 21 Identify four gases that are separated from crude oil at the very top of the distillation tower.
 - 22 Describe (in words) the chemical transformation that takes in a biogas digester.
 - 23 Write the chemical word equation that describes the fermentation process used to produce ethanol.
 - 24 One of the chemical reactions used during the production of sulfuric acid makes use of the catalyst vanadium oxide (V_2O_5). The chemical equation for this reaction is:
- $$V_2O_5 \\ 2SO_2(g) + O_2 \longrightarrow 2SO_3(g).$$
- (a) What is a catalyst?
 - (b) Why doesn't the V_2O_5 appear as one of the reactants?
 - (c) What name is given to the catalysts in living things?
 - 25 (a) Describe at least one chemical reaction that is caused by light and how the reaction is useful.
 - (b) What is chemiluminescence?
 - (c) How is bioluminescence different from other types of chemiluminescence?

Flavour fountain

SEARCHLIGHT ID: PRO-0114

Scenario

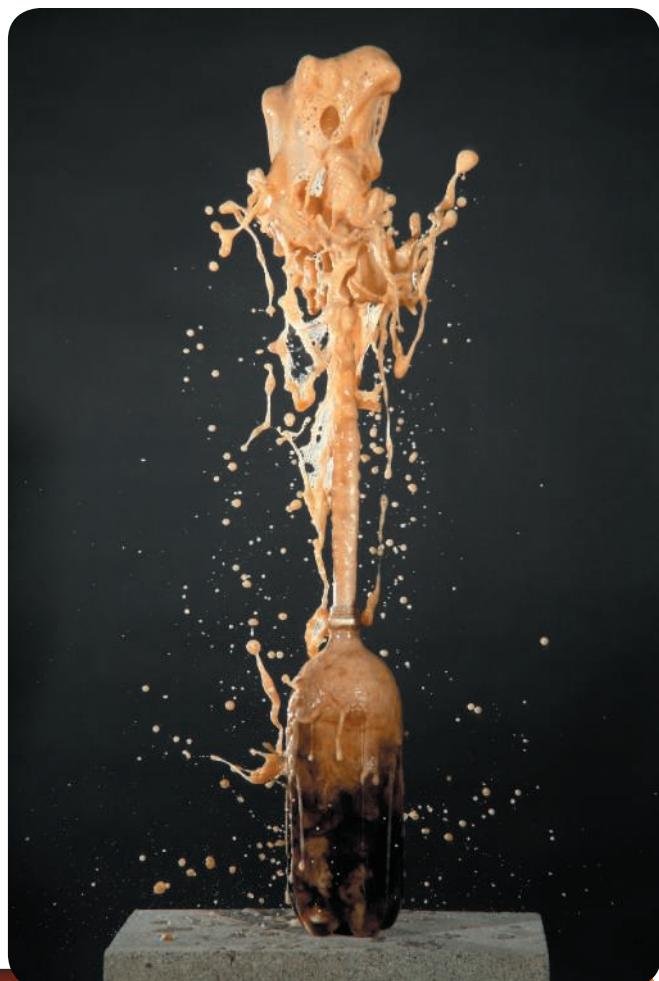
The Sparky Cola Corporation has a series of advertisements for which they are famous that always involve a Mentos lolly being dropped by various means into a bottle of Sparky Cola, causing a huge foaming jet to burst out of the bottle. As a good science student, you know that the jet is the result of the carbon dioxide dissolved in the cola being able to form sizable gas bubbles very quickly on the rough surface of the lolly. You may well have even done this trick yourself.

Sparky Cola have decided that they want bigger jets than ever before and they pride themselves on using real video footage rather than CGI. They are providing a special prize at the next Science Fair for the project that determines how the biggest jet can be produced from a single Mentos lolly and 600 mL of cola. You are to provide not only a scientific report, but also video footage of your highest fountain that they can use in their next ad. You and your friends are determined to win the cash prize at the Science Fair and the TV fame for your Flavour Fountain footage!

Your task

You will design and carry out an investigation that will test a number of different factors (for example, whether regular cola or diet cola is used) to determine which will produce the highest cola fountain from a 600 mL

bottle of cola and a Mentos lolly. Your findings will be presented in the form of a scientific report. You will also produce video footage of the highest fountain that you can make using what you have discovered.



Process

- Open the ProjectsPLUS application for this chapter located in your eBookPLUS. Watch the introductory video lesson and then click the 'Start Project' button to set up your project group. You can complete this project individually or invite other members of your class to form a group. Save your settings and the project will be launched.
- Navigate to your Research Forum. Here you will find a number of topic headings that you can use to start your research. As you find more information and different research topics suggest themselves, you may add new topic headings.



- Start your research. Make notes of information that you gather that will provide background for your investigation and direct its design. Enter your findings as articles under your topic headings in the Research Forum. You should each find at least three sources (other than the textbook, and at least one offline such as a book or encyclopaedia) to help you discover extra information about factors that may influence the rate at which the carbon dioxide is produced and the force with which the foam is ejected upwards. You can view and comment on other group members' articles and rate the information they have entered. When your research is complete, print out your Research Report to hand in to your teacher.

- Design your investigation by determining what will be the dependent, independent and controlled variables; the number of times you will repeat measurements; what factors you will test; and how you will measure the height of the fountains produced.
- Perform your investigation. Take photographs during your investigation for inclusion in your report.

- Visit your Media Centre and download the report template to help you build your experimental report. In each section of the template, you will find directions as to what information should be included. Delete these directions as you complete each section. You will also find an Excel spreadsheet that you may use to enter the data from your investigation as you go, and which will allow you to produce a line graph of your results. The table and the graph can then be copied and pasted into your report. Your Media Centre also includes a selection of images that you may like to use in your report as well as links to websites that you might find useful.
- Once you have determined how to produce the tallest possible flavour fountain, you will need to put it into practice and video the result.

SUGGESTED SOFTWARE

- ProjectsPLUS
- Word or other word-processing software
- Excel
- Movie Maker (PC) or iMovie (Mac) or other video-editing software
- Internet access



MEDIA CENTRE

Your Media Centre contains:

- a report template in Word
- a selection of useful weblinks
- a selection of images
- an assessment rubric.



Your ProjectsPLUS application is available in this chapter's Student Resources tab inside your eBookPLUS. Visit www.jacplus.com.au to locate your digital resources.