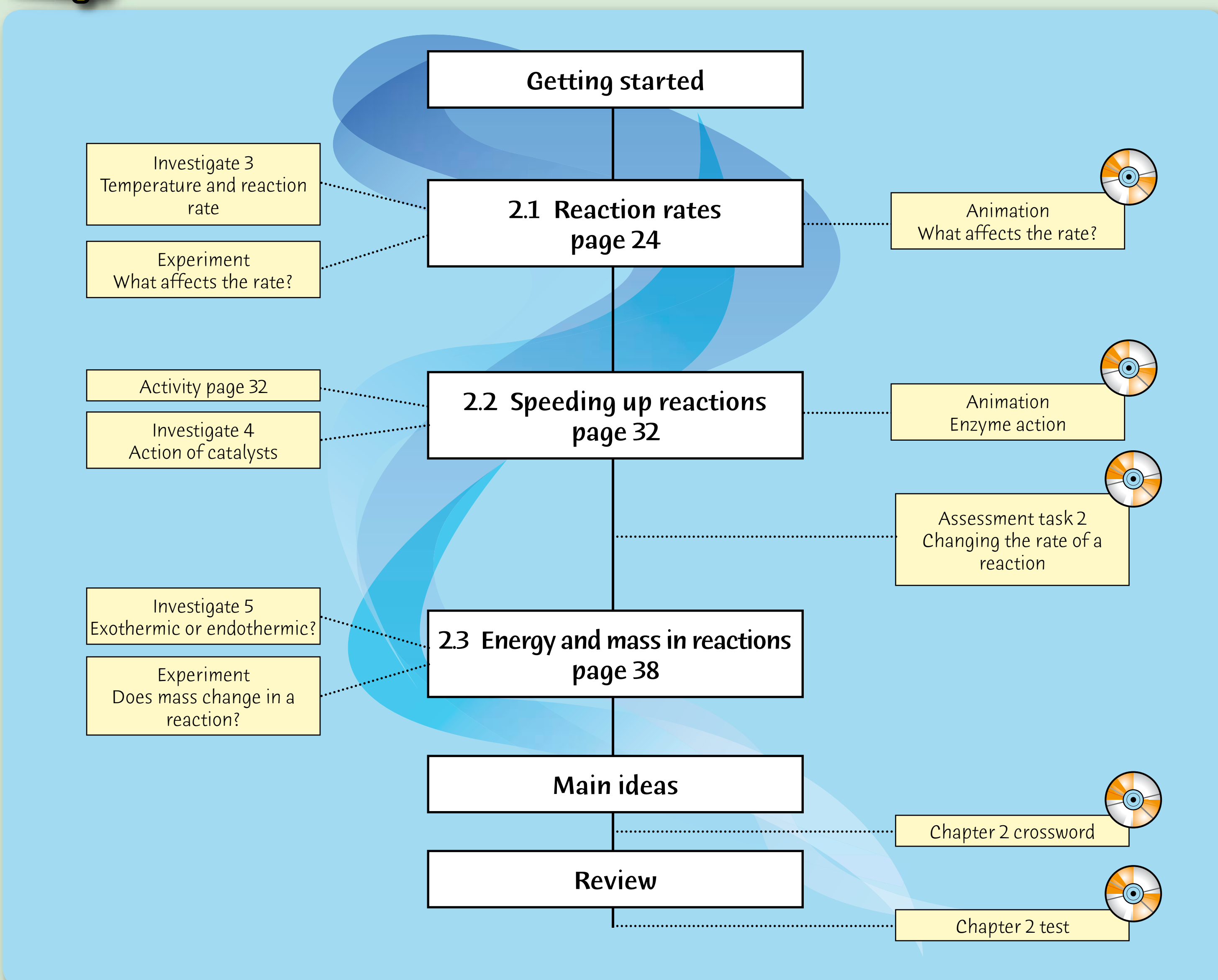
2 Investigating reactions

Planning page



Essential Learnings for Chapter 2

Essential Learnings	References		
	Student book (page number)	***Workbook (page number)***	***Teacher Edition CD (Assessment task)***
Knowledge and understanding ***Natural and processed materials*** Changes in physical properties of substances can be explained using the particle model	pp. 27–28		
Reaction rate is affected by various factors, including temperature, concentration and surface area	pp. 24–36	p. 15 Exercise 5 p. 17	Assessment task 2 Changing the rate of a reaction
Chemical reactions can be described using word and balanced equations	p. 42	Exercise 10 p. 19	
Ways of working Draw conclusions that summarise and explain patterns, and that are consistent with the data and respond to the question	Investigate 3 pp. 25–26 Investigate 4 pp. 33–34 Experiments pp. 29, 41	Exercise 4 p. 16	Assessment task 2 Changing the rate of a reaction
Plan investigations guided by scientific concepts and design and carry out fair tests	Investigate 3 pp. 25–26 Experiment p. 29		Assessment task 2 Changing the rate of a reaction
Evaluate data, information and evidence to identify connections, construct arguments and link results to theory	Investigate 3 pp. 25–26 Investigate 4 pp. 33–34 Experiment p. 41		

QSA Science Essential Learnings by the end of Year 9

Vocabulary

catalase
catalyst
combustion
concentration
conservation
decomposition
endothermic
enzyme
exothermic
hydrochloric
hydrogen peroxide
inhibitor
photosynthesis
reactants
reaction
reliable
respiration
theory

Focus for learning

Make silly putty and investigate its properties (page 23).

Equipment and chemicals (per group)

Getting started page 23	PVA glue, 2 small containers, teaspoon, food colouring in dropping bottle, borax, stirrer, paper towel
Investigate 3 page 25	dilute hydrochloric acid (1M), sodium thiosulfate (hypo) solution (0.2M), 10 mL and 50 mL measuring cylinders, 100 mL flask, stopwatch, sheet of white paper, thermometer, 500 mL beaker, ice
Experiment page 29*	same as for Investigate 3 plus magnesium ribbon, marble chips, hammer
Investigate 4 page 33	beaker (eg 250 mL), fresh hydrogen peroxide solution (3%), 6 test tubes and test tube rack, iron filings, sand or dust, piece of fresh potato, piece of liver (or other red meat), short piece of string (jute) or taper, spatula, manganese dioxide, iron(III) chloride, various plant and animal materials (Try this)
Investigate 5 page 39	**Part A:** 2 test tubes, thermometer, datalogger and temperature probe (optional), zinc, sodium thiosulfate (hypo), dilute hydrochloric acid (1M) **Part B:** a range of compounds (eg ammonium chloride, anhydrous calcium chloride, potassium chloride, potassium hydroxide, potassium nitrate, sodium chloride), balance (Try this)
Experiment page 41	large plastic soft drink or sports drink bottle with lid, 2 small test tubes, piece of string, sodium hydrogen carbonate, acetic acid, teaspoon, measuring cylinder, balance (accurate to 0.01 g)
Activity page 42	cardboard, glue, scissors

* Students to list equipment they will need, which may be different from what is listed here.

2 Investigating reactions

Getting Started

Silly putty

Try making silly putty using the instructions below. You may be able to do it at home.

1 Measure out about 6 teaspoons of PVA glue into a small container, and add two or three drops of food colouring.
2 In another container dissolve about a quarter of a teaspoon of borax in 20 mL of water. (Wash your hands after using the borax.) Slowly add this solution to the glue, stirring constantly.
3 When the mixture has turned to a thick slime, wash it thoroughly in running water and dry it with a paper towel.

- Experiment with the slime to see what its properties are. For example, can you stretch it? Does it bounce? . . .
- Was there a chemical reaction when you mixed the glue and the borax solution? How do you know?
- Did the food colouring take part in the chemical reaction? How could you find out?

You can store your slime in a sealable plastic bag or container.

Are you sure you didn't add any extra ingredients?

Starting point

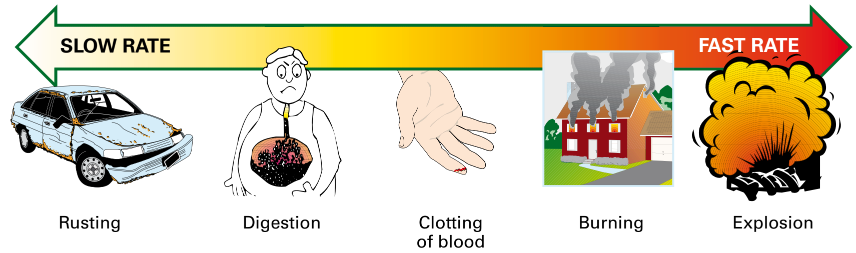
1 Borax is *disodium tetraborate* and is a white soluble crystalline salt used as a disinfectant. It is very important to fill out a risk assessment form if doing this activity in class, and to stress to the students not to handle food after touching their slime unless they have washed their hands.
2 If making the silly putty in class, to prevent congested working areas set up several workstations around the room for the materials. Measure out the PVA beforehand into small plastic disposable cups. Ice-cream sticks are ideal for stirring the mixture.
3 If you allow students to take the mixture home:
   - Consider doing the activity at the end of the day.
   - Ensure students keep the mixture in a plastic bag.
   - Remind students to keep the mixture away from young children, and that consuming the mixture may cause illness.
   - Remind students that the mixture can stain carpets and furnishings.
4 You may like to set a series of short experiments, one per workstation, and have a worksheet with simple questions for the students to answer about each activity. Where possible, use non-toxic materials. Try the following, by adding:
   - water to anionic polyacrylamide polymer powder/crystals (also known as SAP or super absorbent polymer, commonly used as water-saving crystals)
   - vinegar to sodium hydrogen carbonate (bicarbonate of soda)
   - a small piece of calcium metal to water (the calcium needs to be kept dry as it is very reactive)
   - a tiny amount of potassium permanganate crystals to water
   - a drop of iodine solution to starch suspension.

   Place a set of clear instructions at each workstation. (Put the instructions in plastic pockets to protect them.) For each chemical used, students should write down its chemical name as well as its common name. Students will like this because they will feel they are doing some 'real chemistry'.

Hints and tips

- A rate is considered to be a quantity divided by time. How *fast* or how *slow* is a measure of speed, not time. If one reaction took a shorter time to react than another, then we can say that the reaction was faster. The *rate* of a chemical reaction refers to the rate at which a *reactant* disappears or at which a *product* appears. Reaction rate is influenced by the temperature, concentration of reactants, surface area and if a catalyst is used.
- You should also ensure students understand what a *chemical reaction* is. One standard definition for a chemical reaction is 'the interaction of two or more substances, resulting in chemical changes in the substances'. However, under certain conditions only one reactant is needed for a chemical change. Consider toasting a piece of bread; heat is applied causing a chemical change. Electricity can also cause a chemical reaction, such as in a battery, but of course heat and electricity are not substances. You also need to be careful to distinguish between physical and chemical changes. Most chemical reactions are not easily reversible.
- Explain *colloids* to students. A colloid is a substance present in a solution in the colloidal state, meaning the particles have not dissolved to form a true solution and are bigger in size. When the sodium thiosulfate reacts with the hydrochloric acid, the colloid formed is sulfur. A colloid is different from a suspension in that the particles in a suspension settle, whereas in a colloid they don't.

2.1 Reaction rates



When you toast a piece of bread, the toast looks and tastes different from the bread you started with. The toasting of the bread is a chemical reaction. Reactions occur whenever new substances with different properties are formed.

Some reactions occur very slowly. For example, the chemical weathering of rocks can take thousands of years. The rusting of iron and the decay of dead plants and animals both involve slow reactions. The digestion of food is faster, but it still takes 3–5 hours to digest a meal. If you cut yourself, it takes a few minutes for the blood to clot.

At the other end of the scale are very rapid reactions. Burning is a fast reaction, the borax and glue in Getting Started reacted instantly, and the reactions in an explosion occur in less than a thousandth of a second!

The speed of a reaction is called its **reaction rate**. A slow rate means the reaction takes a long time. A fast rate means it takes only a short time.

Temperature and rate

Belinda often fixes things around the house using Araldite, where you mix two tubes to make a glue. She has noticed that the glue sets more quickly on warm days than on colder days. She wonders whether the glue-setting reaction is faster at higher temperatures. When she asks her teacher about this, he suggests that she does an experiment to find out.

Belinda's teacher discusses with her how to measure the rate of the reaction. He talks about reactants and products, and tells Belinda she could measure the rate at which the product is formed. In other reactions, such as when acids react with metals, it is easier to measure the rate at which the reactants are used up.

Part A (liquid) + Part B (liquid) → epoxy glue (solid)
REACTANTS — PRODUCT

The teacher tells Belinda about a reaction where it is easy to measure the effect of temperature on reaction rate by measuring the rate at which the product is formed. When hydrochloric acid is added to hypo (sodium thiosulfate), the solution turns cloudy after a while. The cloudiness is due to a reaction in which the element sulfur forms a colloid.

sodium thiosulfate + hydrochloric acid → sulfur + other products

In Investigate 3 you can try this reaction yourself. The aim of the investigation is to find an answer to the research question.

Learning experience

Perform some simple experiments as a teacher demonstration and ask the students to observe whether any new substances were formed. Get them to explain why (or why not) a new substance may have been produced. Reinforce the concept that chemical reactions occur whenever new substances with *different* properties are formed. It would be worth generating a list of what is meant by 'different properties'.

Demonstrating some reactions helps in consolidating for the student which substances are the reactants and which are the products. Placing calcium metal in water is particularly impressive as it not only clearly demonstrates the speed of a reaction (how quickly the reactants are used up) but how there must be a release of energy during the reaction as the beaker of water gets hot. Dramatise the demonstration by dropping in a tiny handful of calcium. The students will really enjoy the 'sizzling' noise and will be able to feel how hot the beaker has become. The water also becomes cloudy due to the formation of limewater (calcium hydroxide solution).

This demonstration can be used at various points throughout this topic to show how reaction rate can vary. Change the reactant concentration (add more: what happens?), the temperature (use iced water and hot water: what happens?) and discuss the exothermic reaction (feel the beaker get hotter: why?).

Investigate
3 TEMPERATURE AND REACTION RATE

Research question

How does temperature affect the rate of reaction between hypo and dilute hydrochloric acid?

Materials

Corrosive

- dilute **hydrochloric acid** (1M)
- sodium thiosulfate (hypo) solution (0.2M)
- 10 mL and 50 mL measuring cylinders
- 100 mL flask
- stopwatch
- sheet of white paper
- thermometer
- 500 mL beaker
- ice

Working with technology

Teacher note: You can obtain more reliable results if you use a light intensity probe and datalogger to measure when the mixture goes cloudy.

Planning and Safety Check

- Discuss with your partners what you will be doing in each part. Sort out who will do what.
- Which variables will you need to control (keep the same) in this investigation?
- What safety precautions will be necessary?
- Design a data table for Part B.

PART A
The hypothesis

1 In your science notebook, write an answer to the research question. In other words, write a hypothesis about how temperature affects reaction rate.
(A hypothesis is a generalisation which can be tested.) You can write your hypothesis in several different ways. You could say ***If*** *the temperature is* ______, ***then*** *the reaction rate will be* _____. Alternatively, you could say *The* ______ *the temperature, the* ______ *the reaction rate.*

2 Will hypo and hydrochloric acid react faster at 10°C or at 40°C? Use your hypothesis to write a prediction.

PART B
Testing the hypothesis

Method

1 Measure out 50 mL of hypo solution into the small flask. Use a thermometer to measure the temperature of the solution.
Record this as room temperature in your data table.

2 Mark a cross in pen on a sheet of white paper. Stand the flask on top of the cross.
When hydrochloric acid is added to the hypo solution it goes cloudy due to a sulfur colloid. The cross will seem to disappear when you look down through the neck of the flask.

3 Add 5 mL of acid to the flask and start timing. Swirl the flask twice and note the time when the cross disappears.
Record the time for the reaction. This is called the reaction time.

4 Wash out the flask. Measure out another 50 mL of hypo and add it to the flask.

Wear safety glasses.

Hints and tips

- Familiarise yourself with the MSDS for the chemicals involved, particularly sodium thiosulfate.
- It is a good idea for the students to partly write their practical report before starting the investigation, so they are ready to write down the results.
- It is worth checking to see if students know how to tell which are the dependent and independent variables, and which variables are controlled.

Lab notes

- This investigation is quite complex and is best done over two or three lessons. Perhaps set aside one lesson to prepare (ie Part A and demonstration), one lesson to conduct the investigation and another to write it up fully, answer the Discussion questions and write a conclusion.
- Remind students not to use the thermometer for stirring.

Learning experience

What are some everyday chemical reactions? Ask the students to brainstorm and generate a class list. Discuss when some everyday reactions are beneficial and when they are not. What preventative measures are put in place to slow down or stop some reactions? Consider rusting, photosynthesis, water pipes blocked due to scale caused by hard water, chemical processes taking place in our bodies, milk going off if not refrigerated. A PMI chart could be used as a tool to help in this process—divide the board into three sections (Positive, Minus, Interesting/Implications) and fill it in accordingly.

Hints and tips

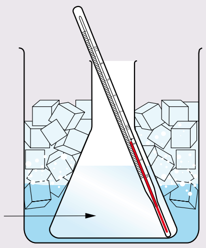
Remind students how to draw line graphs (page 9), especially emphasising smooth lines of best fit. The animation *Drawing a line graph* could be shown here. Students should use graph paper or similar for Discussion question 5.

Homework

Pose the question, 'Why are refrigerators used for storing foods?' Students could design an experiment to find out how temperature affects the rate of milk going off or a banana ripening. The students might like to carry out their experiment.

A fun activity could be to bake a cake or make some biscuits and write up a practical report explaining the chemistry of cake-baking. Students could discuss how temperature affects the reaction and explain how the product (baked cake) has different properties from the reactants (raw ingredients).

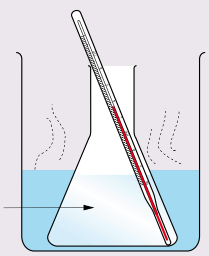
5 Put some water in a 500 mL beaker, and add some ice. Put the flask in the beaker of ice and let the hypo cool to about 10°C.



6 When the hypo has cooled, quickly take the flask out of the ice, wipe the water from the outside, and put the flask over the cross. Add 5 mL of acid immediately, start timing, and swirl the flask twice.
Record the reaction time and the temperature of the hypo.

7 Wash out the flask again. Measure out another 50 mL of hypo, and add it to the flask.

8 Put some hot water (out of the hot tap, or water heated to about 60°C) in the beaker. Sit the flask in the beaker and let the hypo warm to about 30°C.



9 Repeat Step 6.

10 Repeat for 40°C, and again record your results.

Discussion

1 At which temperature was the reaction fastest? Was your prediction in Part A Question 2 correct?

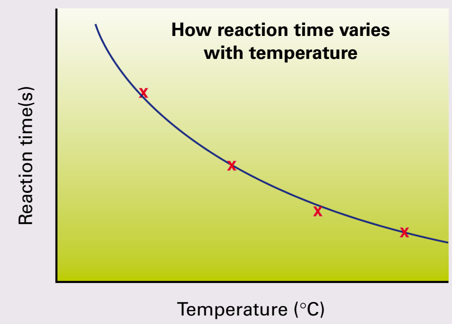
2 Use your results to decide whether your original hypothesis was correct. If necessary, rewrite it.

3 Which was the *independent* variable in this experiment—the variable you purposely changed? Which was the *dependent* variable—the variable you measured?

4 Which were the *controlled* variables in this investigation?

5 To give you a better idea of how the reaction rate changes with temperature, draw a graph of reaction time against temperature, as shown below.

First decide on a suitable scale for the reaction time and the temperature axes. Mark each point on the graph with a cross. Then join up the crosses with a *smooth* curve. Remember, the curve does not have to go through each point—so long as it shows the general trend of the results.



6 Explain the shape of the graph. Does the graph support your hypothesis?

7 Why did you swirl the flask twice for each reaction?

8 Do you think the investigation could be improved? If so, give details.

PART C
Predicting

1 Using your graph from Part B, what do you predict for the reaction time at 35°C? At 50°C?

2 Repeat the reaction at 35°C and 50°C.
How accurate were your predictions?

Everyday reactions

In her science project Belinda studied many different reactions. She found the same thing for each reaction—*the reaction rate increases as the temperature increases*. An everyday example of this occurs in cooking, where you need heat to make reactions go. As you increase the temperature these reactions go faster.

Many reactions that depend on temperature also occur inside living things. Plants usually grow more rapidly in summer than they do in winter. The body temperature of all animals except birds and mammals changes with that of their surroundings, and this is why snakes and lizards are inactive in winter and become much more active in warmer weather.

In some cases it is important to slow down reactions by decreasing the temperature. For example, the spoiling of food is caused by chemical reactions that can be slowed down by keeping the food cold in a refrigerator.

Fig 8 Dead bodies are kept refrigerated to slow down decomposition reactions.

Explaining reaction rates

Chemical reactions can be explained in terms of the particle theory of matter, which you have learnt about in previous studies.

The particle theory of matter

1. All matter is made up of tiny particles too small to see.
2. There are spaces between the particles.
3. There are attractive forces between particles. The weaker these forces are, the further apart the particles are.
4. The particles are always moving.
5. At high temperatures the particles move faster than they do at low temperatures.

A reaction can occur only when the particles of the reacting substances come into contact with each other. According to the particle theory, as the temperature increases the particles move faster and collide more often. They also collide more violently (more energetically) than they do at lower temperatures. For these two reasons, reaction rate increases with temperature.

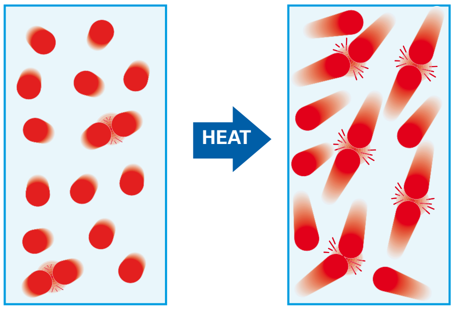


Fig 9 At higher temperatures the particles have more energy and collide more often and more violently. This is why chemical reactions are more likely to occur.

Hints and tips

Revisit the particle theory of matter to explain the difference between heat and temperature (*ScienceWorld 1* page 215 or *ScienceWorld 2* page 47). Heat (energy) is transferred from one object to another as a result of a temperature difference. Temperature is a measure of the kinetic (moving) energy of the atoms. This means that as the substance gets warmer, particles collide more often. Chemical reactions occur when the particles of the reacting substances come in contact with each other, so the higher the temperature the more energetic the collisions are, and a chemical reaction is more likely to take place. We can generalise and say *as the temperature increases, the reaction rate increases*.

Learning experience

Try constructing a chart on the board with positives and negatives. Under Positives, give examples of when fast reaction rates are good. Under Negatives, give examples of when they are not desired. Encourage the students to give examples of reactions. They should be able to come up with many biological reactions affected by temperature.

Learning experience

Ask students to write an explanation of the word *decompose* in relation to chemistry, and give an example to illustrate the process. How does heat affect decomposition?

Hints and tips

New words and concepts such as *rate*, *chemical reaction* and *concentration* should be reinforced frequently. At appropriate random times choose a student to give a definition or example of one of the new words or concepts. Doing this frequently allows you to identify any section which needs to be revisited, and any students who may require further learning assistance.

Homework

Ask students to compile a dot-point summary of the chapter so far. This can be added to later and used as a revision tool for tests or examinations.

Animation

Students should view the animation *What affects the rate?* on the CD.

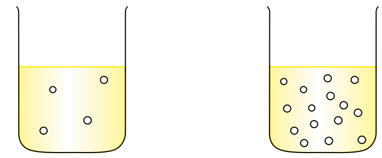
Learning experience

A demonstration of making cordial works well to show concentrated and dilute solutions. Keep halving the diluted cordial with water until it is only faintly coloured. Alternatively you could use coloured water, but students tend to remember things they are familiar with, so dilute and concentrated cordial is more likely to be remembered by association.

At this point it is advisable to establish if the students can recall the difference between a *solute*, *solvent* and *solution*. A quick demonstration using salt and water is adequate; salt is the solute, water the solvent and salty water is the solution. You may choose to demonstrate how a more concentrated solution can be formed. Ask the students to tell you how to achieve this. A quick extension exercise may be to model a saturated solution and ask why no more salt is dissolving in the water. Students who have well-developed higher-order thinking skills will readily answer the challenge.

Concentration

There are other variables besides temperature that affect reaction rate. **Concentration** is a measure of how much solute is dissolved in a certain volume of solution.



A **dilute** solution contains only a small amount of dissolved solute in a certain volume of solvent.

A **concentrated** solution contains a large amount of solute dissolved in the same volume of solvent.

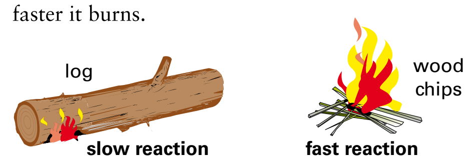
A higher concentration of a reactant usually increases the reaction rate. This is because the reacting particles are closer together and collide more often. For example, household bleach can be used to remove stains on clothing. If the stains are particularly bad, you need to put more bleach into the wash to increase its concentration. Similarly, concentrated acids 'eat away' cloth more rapidly than dilute acids.

Fig 12 Sawdust has a large surface area and burns so rapidly it can explode.

Surface area

The rate of a reaction is also affected by whether the reactants are in big pieces or are finely powdered, or somewhere in between. For example, a wooden log burns fairly slowly, but chips of wood burn almost instantly. The reason for this is that only the wood on the outside of the log can burn (react with the oxygen in the air). Once the outside layer has burnt, the next layer can burn, but the process is slow.

When the log is broken up into chips, there is much more wood that can burn. In other words, the chips have a greater *surface area* than the log. So the greater the surface area of the wood, the faster it burns.



Another good example to show the effect of surface area is the reaction of zinc with dilute hydrochloric acid. Pieces of zinc react slowly, whereas zinc foil reacts more rapidly, and zinc powder reacts very rapidly. This is why powdered metals like zinc are dangerous. They react so quickly with some substances that an explosion may occur.

To see an explanation of reaction rates, open the **What affects the rate?** animation on the CD.

Working with technology

Learning experience

A stunning but potentially dangerous teacher demonstration can be done to show how surface area affects reaction rate. This needs to be done in a fume cabinet—you should stress to the students not to try it at home!

1 Obtain a large, dry, empty tin (a Milo tin works well) and drill a hole in the side of the tin close to its bottom.
2 Connect a long piece of rubber tubing to the tin via the hole and place it in the fume cabinet.
3 Put some custard powder into the tin.
4 Light a tealight candle and carefully place it in the tin so as not to disturb the powder.
5 Gently place the lid on the tin (do not press firmly) and close the fume cabinet.
6 Take the end of the rubber tubing and give it a good blow.

The air should disperse the powder in the tin, exposing more surface area and igniting the powder. The lid will blow off and a dramatic ball of fire will delight the students. (It may be an idea to have a bucket of water near you just in case!)

Experiment
WHAT AFFECTS THE RATE?

Research question

How is the rate of a reaction affected by:

1 the concentration of the reactants?

2 the surface area of the reactants?

3 the mixing of the reactants, eg by shaking or stirring?

Design an experiment (or experiments) to answer one or more of the questions above.

Planning and reporting hints

1 Decide which question you are going to investigate. Then plan your experiment carefully, keeping safety in mind. Read the hints below.

- To answer Question 1 you could use the reaction between hypo and hydrochloric acid (Investigate 3). You could vary the concentration of either the hypo solution or the hydrochloric acid. To make a solution less concentrated you need to add a measured volume of water.
- You could try the reactions of hydrochloric acid with magnesium ribbon or marble chips (calcium carbonate). For Question 2 magnesium ribbon could be cut into smaller pieces, and marble chips could be crushed.
- Try to make quantitative observations by working out a way of measuring the rate of reaction. Display your results in a data table and in a graph.
- Make sure you control all variables except the one you are purposely varying.
- If possible, repeat your experiment to see if you get the same results. If you do, then you can be more confident your conclusions are correct. If someone else repeats your experiment and gets the same results, you can be even more confident. Results like this are said to be **reliable**.

2 Discuss your design and safety precautions with your teacher before you start the experiment.

3 Write a report of your experiment (or experiments) using these five headings:

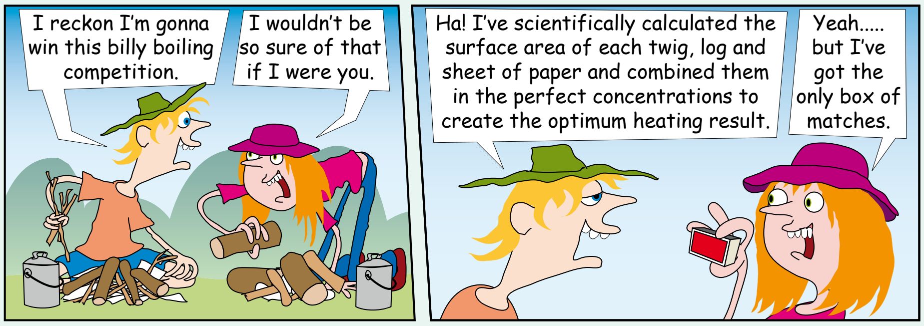
a In the *Aim* make sure you state the hypothesis you plan to test.

b In the *Method* list the materials you used and what you actually did, including how you controlled variables.

c Under *Results* include your observations. Use data tables and graphs where appropriate.

d In the *Discussion* suggest where you might have made an error or how the experiment could be improved.

e In the *Conclusion* state whether or not the results support (agree with) your hypothesis.



Hints and tips

- Ask a set of quick questions at the start of the lesson on the material already covered. Students only need to record answers. Spend no more than 5–10 minutes.
- It is useful to direct students back to pages 3 and 14–15 on how to prepare a written experiment report, and the steps in investigating scientific problems.

Lab notes

- To do this experiment properly it will probably take three lessons:
  - —the first lesson for students to prepare their experiment, have it checked by the teacher and order their equipment
  - —the second lesson to conduct the experiment and accurately record data
  - —the third lesson to discuss the experiment and the report, and write it up.
- Try to avoid students taking the report home to 'finish it off'. A good idea is to sign the students' work at the end of the lesson at the point they are up to if homework time is given. This way, you can gauge how effectively they have used their class time.

Check! solutions

1 The observations which are to do with the rate of reaction are C and D, because some mention is made of the time taken.

2 Three variables that can affect the rate of a reaction are the temperature, concentration and surface area of the reactants.

3 The ripening of fruit is a chemical reaction which becomes slower at lower temperatures. This explains why tomatoes will not ripen as quickly in a refrigerator.

4 The conditions which will give the fastest reaction will be the iron filings with the concentrated acid at 60°C. The conditions which will give the slowest reaction will be the iron bolt with dilute acid at 0°C.

5 a Antacid powder has a greater surface area than antacid tablets and will enable a much faster reaction to occur in the stomach.
 b Concentrated acids will react more quickly with other chemicals including clothes and skin. This explains why they are more dangerous than dilute acids.
 c Car exhausts are hot when the motor is running and they also often contain water which is produced when the fuel burns. This is why they rust faster than other parts of the car.
 d Milk will go sour if left in a warm place because microbes will grow in it more quickly at higher temperatures. This is why milk lasts longer in a refrigerator.
 e Cutting potatoes into smaller pieces provides a larger surface area to be in contact with the boiling water. This means that they will cook more quickly.

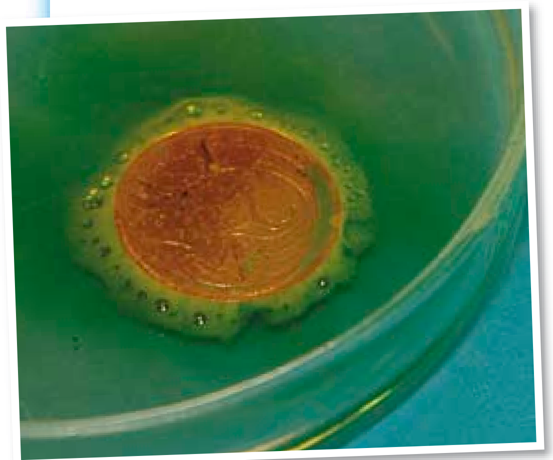
6 Corrosion is a chemical reaction. The reason why the pipe carrying hot water corrodes more quickly is that chemical reactions occur faster at higher temperatures.

7 a The volume of gas produced at 30°C is 11 mL.
 b If the rate of the reaction increases steadily the amount of gas produced at 60°C will be 20 mL.
 c The temperature at which 15 mL of gas will be produced is 43°C.

8 The rate of bubbling could be slowed down by cooling the test tube or diluting the reactants by adding water to the test tube.

Check!

1 The teacher added acid to a copper coin in a petri dish. The students made the following observations. Which one of these observations is to do with the *rate* of the reaction?
 A A brown gas was produced.
 B The solution turned a greenish-blue.
 C The coin was partly eaten away.
 D The bubbling stopped after about 5 minutes.



2 List *three* variables that can affect the rate of a reaction.

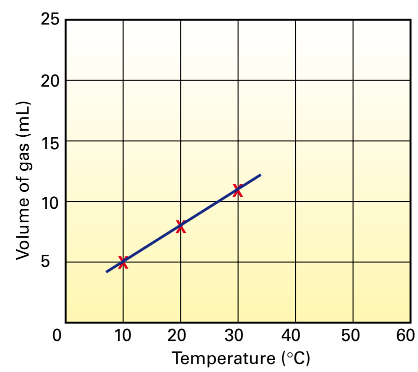
3 Green tomatoes can be picked and left in a warm place to ripen. However if they are put in a refrigerator, they ripen much more slowly. Why is this?

4 Suppose you want to react iron with hydrochloric acid. You can use an iron bolt or iron filings. The acid can be dilute or concentrated. And you can do the reaction at 0°C, room temperature (about 20°C) or 60°C.
Which conditions would give you the fastest reaction? Which conditions would give the slowest reaction?

5 Write a complete sentence to explain each of the following statements.
 a Antacid powders work faster than antacid tablets.
 b Concentrated acids are more hazardous than dilute acids.
 c Car exhausts rust much faster than other parts of a car.
 d Milk needs to be kept in a refrigerator.
 e Potatoes cook more quickly if you cut them into small pieces.

6 Which will corrode more quickly—a pipe that carries hot water or one that carries cold water? Explain.

7 The graph below shows the volume of gas produced in a minute during a chemical reaction at three different temperatures. Use the graph to answer these questions.
 a What was the volume of gas produced during the reaction when the temperature was 30°C?
 b Predict the volume of gas that would be produced if the temperature was 60°C.
 c Predict the temperature of the reaction that would produce approximately 15 mL of gas in one minute.



8 A reaction which is producing bubbles of gas is occurring in a test tube. What *two* things could you do to slow down the amount of bubbling?

challenge

1 Which would rust more quickly—an iron nail or iron filings? Design an experiment to find out.

2 Aluminium frypans can be used in cooking, yet the label on a container of very fine aluminium powder warns that the contents are *highly flammable*. Explain the difference.

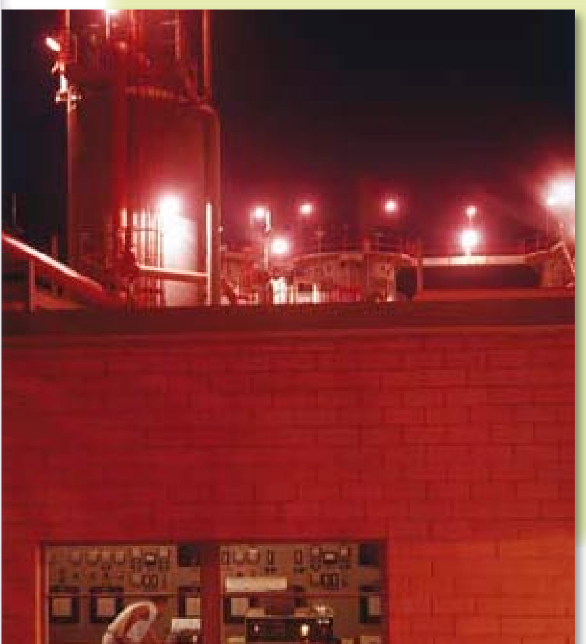
3 Use the particle theory on page 27 to explain the following.

- **a** Why does increasing the concentration of the reactants usually increase the reaction rate?
- **b** Why does increasing the surface area of the reactants usually increase the reaction rate?

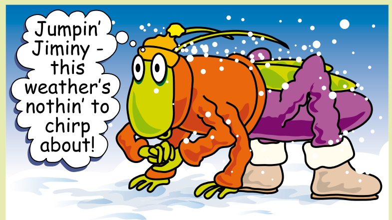
4 Ammonia gas is used to manufacture fertilisers. It is made by reacting together the two gases nitrogen and hydrogen. Temperatures ranging from 400–500°C are required, and the gases are at pressures about 250 times normal air pressure. A porous iron catalyst is used.

- **a** Suggest why high pressures speed up the reaction between nitrogen and hydrogen.
- **b** What are the other ways in which the reaction is speeded up?

Fig 16 This factory manufactures ammonia. The nitrogen and hydrogen react in the towers on the left.



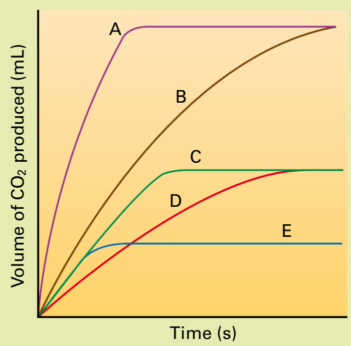
5 Kee noticed that the number of chirps a cricket makes in a minute seems to depend on the temperature. The higher the temperature, the more chirps per minute. Design an experiment to test Kee's hypothesis.



6 The table gives the results of an experiment involving five reactions between hydrochloric acid and marble (calcium carbonate).

Reaction	1	2	3	4	5
Volume of conc. acid (mL)	60	30	30	15	60
Volume of water (mL)	60	30	30	15	60
Temperature (°C)	40	20	40	40	40
Marble (c = chips) (p = powdered)	c	c	c	c	p

The graph below shows the results.



- **a** For each reaction (1–5), identify the correct graph (A–E). Give reasons for each of your choices.
- **b** Which reaction was the fastest? Which was the slowest? How do you know?
- **c** Which reaction finished first?

Challenge solutions

1 Iron filings would be expected to rust more quickly than an iron nail because the filings have a greater surface area. A simple test would be to place equal masses of iron filings and an iron nail in test tubes. Expose the test tubes to some water and air under identical conditions and observe any changes carefully for several days.

2 Aluminium powder has a much greater surface area than a frypan and will react and burn with oxygen much more quickly.

3 a A higher concentration of reactants means that there are more particles to collide with each other and react.

b Increasing the surface area will increase the chance that the particles will collide and react.

4 a The high pressure of the gases increases their concentration which will increase the rate of reaction.

b The rate of this reaction has been increased by raising the temperature to 400–500°C and by using a catalyst (porous iron) which increases the surface area of the reactants.

5 The important part of any experiment is to keep everything the same except for the one variable you are testing. In this case you should only change the temperature of the cricket by putting one in a warm place and one in a cold place and counting the number of chirps per minute. It would also be a good idea to repeat this several times with different crickets.

6 a **Graph A** represents the data from experiment 5 which is at the higher temperature and uses powdered marble.
Graph B represents the data from experiment 1 which is similar to experiment 5 but uses chips rather than powder.
Graph C represents the data from experiment 3 which uses less acid than experiment 1.
Graph D represents the data from experiment 2 which is similar to experiment 3 but at a lower temperature.
Graph E represents the data from experiment 4 which uses the smallest amount of acid.

b Reaction A is the fastest because the line is steepest. This means that more gas is produced in a certain time. Reaction D is slowest because the line is the least steep.

c Reaction E finished first. The reaction is finished when the line becomes parallel with the X axis showing that there is no more gas being produced.

Hints and tips

Enzymes in the human body are proteins, which are catalysts. Refer to pages 34 and 97.

Activity notes

Burned sugar is sticky and difficult to clean. Use a porcelain evaporating basin placed on a heatproof mat.

Research

Ask students to investigate how successful hydrogen-powered buses have been. Are there any potential risks in using hydrogen as a fuel? If so, what safety precautions have been implemented? Do any local bus companies in the students' local area use such buses?

2.2 Speeding up reactions

Reactions can be speeded up by increasing:

- the temperature
- the concentration of the reactants
- the surface area of the reactants.

Reactions can also be speeded up by using **catalysts** (CAT-a-lists).

Activity

For this activity you will need 2 sugar cubes, a glass dish, matches and some ash from burnt paper.

1 Put a sugar cube on a dish and see if you can set fire to it with a match. It melts and chars but doesn't burn.

2 Now dip a second cube in some ash and again try to burn it. What happens?

The ash is acting as a catalyst for the burning of the sugar cube. It speeds up the reaction, *without being changed itself.*

Catalysts are used in industry to control the speed of reactions and to reduce the costs of producing chemicals. For example, nickel is used to make margarine from vegetable oils. Self-cleaning ovens are coated with a catalyst that helps to burn small food particles that stick to the oven walls.

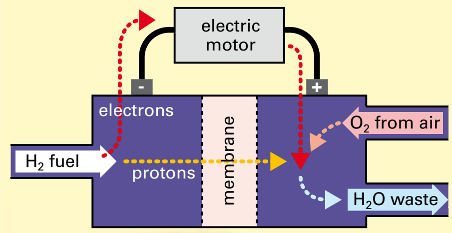
Though catalysts are mostly used to speed up reactions, they can also be used to slow down reactions. Nitroglycerine has a tendency to explode unexpectedly of its own accord. To make explosives containing nitroglycerine safer, a small amount of another chemical (urea) is added. It acts as an *inhibitor*—slowing down the reaction. Rubber perishes as a result of a slow reaction with the oxygen in the air. To slow down this reaction, an inhibitor is added to the rubber during manufacture.

Science in action

Because of the shortage of oil in the world, scientists and engineers are experimenting with alternative fuels. They have developed *fuel cells* which use the reaction between hydrogen and oxygen to produce electricity.

The key component of the fuel cell is a membrane, a sheet of plastic coated with a platinum catalyst. The catalyst splits hydrogen gas into protons and electrons. The protons pass through the membrane, and the electrons pass out of the cell as an electric current. When the protons and electrons meet again on the other side of the membrane, they combine with oxygen from the air to form water. As long as there is a supply of hydrogen, the cell continues to produce electricity.

In 2004 three experimental Mercedes-Benz buses were introduced in Perth. They run on hydrogen, and in the photo below you can see the exhaust of pure water above the bus.



Learning experience

Make a set of flash cards with questions or words on them for the students to answer or write definitions for. Students could make their own cards and test each other. The back of the card should contain the answer to the question, or the definition of the word. This is a handy revision tool for the students for their own private study, and a class revision tool for the teacher before tests or other assessment tasks.

Learning experience

Hydrogen peroxide (H_2O_2) decomposes into water and oxygen. Manganese dioxide (MnO_2) acts as a catalyst and speeds up the reaction. Using a fume cabinet, you could show this by putting a hydrogen peroxide solution (6%) in a large measuring cylinder and adding a small amount of MnO_2. Use a glowing taper to show oxygen is present. Gloves and safety glasses are essential, and you need to take great care not to get any of the strong H_2O_2 solution on you. Only fill the measuring cylinder with the peroxide to about one-fifth of the cylinder's volume.

Investigate

4 ACTION OF CATALYSTS

Aim

To investigate whether manganese oxide and other substances act as catalysts for the decomposition (breakdown) of hydrogen peroxide.

Materials

- beaker, eg 250 mL
- fresh hydrogen peroxide solution (3%)
- 6 test tubes and test tube rack
- iron filings
- sand or dust
- piece of fresh potato
- piece of liver (or other red meat)
- short piece of string (jute) or taper
- spatula
- **manganese dioxide**
- **iron(III) chloride**


Toxic

Note: If you add two drops of detergent to each tube, the height of the foam produced in a certain time gives you an indication of the rate of the reaction.

Planning and Safety Check

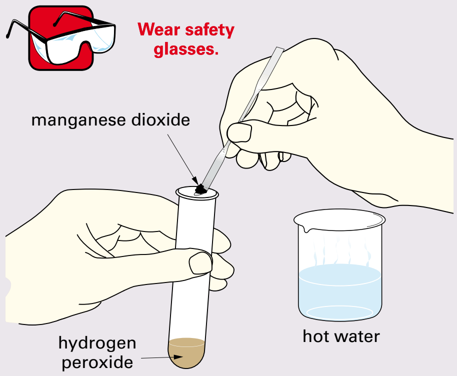
- Which substances will you test as catalysts?
- If you need a data table, design one.

Method

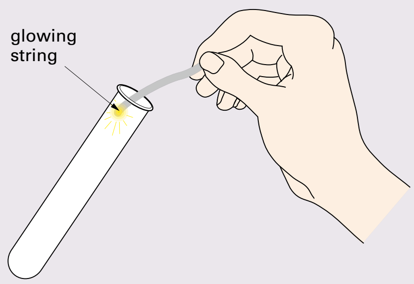
1 Add 2 mL of hydrogen peroxide to a test tube.
Is there any reaction at room temperature?

2 Half fill a beaker with hot water. Put the test tube in the hot water and watch carefully.
Record your observations.

3 Put 2 mL of hydrogen peroxide in a second test tube and add a small amount of manganese dioxide powder (about this size ●).
Record your observations.
Do this at room temperature and in hot water.



4 Light one end of the piece of string, then blow it out so that it has a glowing tip. Put this glowing tip into the test tube. If the string bursts into flame, oxygen is present.



5 Observe what is left around the mouth of the test tube.

6 Repeat the experiment using other substances instead of manganese dioxide. You could use iron chloride, iron filings, sand, a piece of fresh potato, a piece of liver (or other meat).
Record your results in a data table. For each substance tested, say whether or not it speeded up the reaction.

Hints and tips

It is advisable for the students to wear gloves when handling the hydrogen peroxide, manganese dioxide and iron filings. Familiarise yourself with the MSDS and be sure to fill in a risk assessment form.

Lab notes

- It is vital that the peroxide is ‘fresh’ or it will be mostly water and will not work satisfactorily.
- MnO_2 powder can be very messy, so use bench mats and wash hands afterwards.
- Smaller pieces (ie several millimetres) of living tissue (meat and potato) work best.
- In step 2, the water needs to be almost boiling to see a reaction.
- In step 4, a glowing ‘taper’ (skewer or ice-cream stick) also works well.
- In step 5, the droplets of water indicate a chemical reaction has occurred.

Hints and tips

Try getting the students to draw a flow diagram of how enzymes and catalysts work. Refer to Figure 23.

Assessment task

This would be a good place to set *Assessment task 2: Changing the rate of a reaction*, found on the CD.

Animation

Students should view the animation *Enzyme action* on the CD.

Discussion

1 Suggest why you heated the hydrogen peroxide in Step 2.

2 Did the manganese oxide act as a catalyst for the decomposition of hydrogen peroxide? Explain your answer.

3 What substance was produced as the hydrogen peroxide decomposed?

4 If the other product of the decomposition is water, write a word equation to describe the reaction.

5 If a catalyst is not used up in a reaction, predict what should happen if you added another 2 mL of hydrogen peroxide to the test tube after Step 5.

6 Which of the other substances you tested was the best catalyst for the decomposition of hydrogen peroxide?

try this

Some living or once-living things contain a biological catalyst that acts on hydrogen peroxide. Test various plant and animal materials to see if they contain this catalyst. You could bring these substances from home. (You may need to grind up most of the substances with sand before adding them to the peroxide. You could use a mortar and pestle to do this.)

Does boiling the substances affect their ability to act as catalysts?

Enzymes

Many chemical reactions occur in living things. These reactions need biological catalysts called **enzymes** (EN-zimes) to control them, otherwise they would occur much too slowly to keep the organisms alive. Your own body contains thousands of enzymes, each one acting to speed up, or sometimes slow down, one type of reaction. Particular enzymes do particular jobs. Those in your saliva, stomach and intestines control the digestion of food. Others assist in extracting energy from food.

Hydrogen peroxide is normally produced in the body. However, hydrogen peroxide is toxic, so the body produces an enzyme to decompose it. This enzyme is called *catalase*. It is produced in the liver, and is found in nearly all animal cells, especially in blood. That is why blood and liver rapidly decompose hydrogen peroxide, as you probably found in Investigate 4. (One molecule of catalase can decompose 44 000 molecules of hydrogen peroxide per second at 0°C.) Catalase is also found in plant cells.

Working with technology: To see an animated version of Fig 23, open the **Enzyme action** animation on the CD.

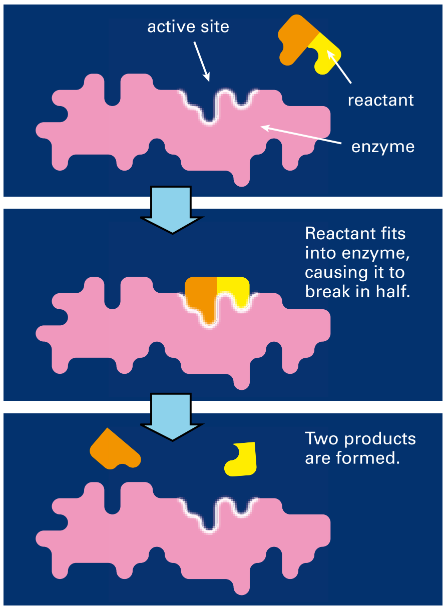


Fig 23 This model shows how an enzyme works by breaking down a reactant. Notice that the enzyme is not used up in the reaction.

Learning experience

1 Pose the question, 'Why do some washing powders contain enzymes?' Turn the question into a Think/Pair/Share activity. (A Think/Pair/Share activity encourages student participation in a non-threatening context. The students individually think about the posed question, discuss their answer with a partner and share their conclusion with the class.)

2 A further thinking question may be to explain why washing some soiled clothes in hot water causes them to be permanently stained. How might the stains be removed?

Learning experience

Students could investigate how many different enzymes there are in the human body and write down information such as the enzyme's name, what its role is, if it speeds up or inhibits the reactants, and in which part of the body it is located or functions. This could be turned into a class competition and the information presented on poster paper to be displayed around the room.

This activity links with Chapter 5 Food for life, and will help the students to link concepts rather than seeing topics as separate, unrelated blocks of science.

Check!

1 Hydrogen peroxide is best kept in a refrigerator. Why?

2 A scientist did an experiment to see how effective the following solids were as catalysts for the decomposition of hydrogen peroxide solution: copper oxide CuO, lead oxide PbO_2, manganese dioxide MnO_2. He obtained the results below in a series of experiments using equal volumes of hydrogen peroxide of the same concentration.

Solid	Mass of solid added (g)	Volume of oxygen (mL) produced in the first minute of the reaction
granular MnO_2	0.1	3
powdered MnO_2	0.1	24
powdered MnO_2	0.2	56
powdered PbO_2	0.1	90
powdered CuO	0.1	0

a Which of the solids in the table does not act as a catalyst for the decomposition of hydrogen peroxide?
b Which of the solids is the most effective catalyst for the reaction?
c Explain the differences between the results for the three tests with manganese dioxide.
d Did the scientist control variables in this experiment? If so, how?

3 Two solutions X and Y are being reacted together in an industrial plant by mixing them in a large container. Suggest at least two ways in which the reaction could be speeded up.

4 Amylases are enzymes that break down starch to form glucose (a sugar). One of these amylases is found in saliva. Mick decided to study the rate of the amylase reaction at different temperatures. He did this by timing how quickly a glucose test strip changed colour when saliva was added to a starch suspension. Below is the data table of Mick's results.

Temperature of starch solution (°C)	Time of colour change (min)
20	30
30	12
35	9
40	7

a Why did the glucose test strip change colour after the saliva was added?
b Draw a graph of the results.
c What is the relationship between temperature and reaction time? Write a generalisation.

5 Write a paragraph explaining why catalysts are important to life.

6 Suggest why some washing powders contain enzymes.

Check! solutions

1 Hydrogen peroxide is best kept in a refrigerator to slow down the reaction which forms water and oxygen. (It is also usually stored in a dark bottle to reduce the light to slow down the reaction.)

2 Analysis of the results shows the following.

a Powdered CuO does not act as a catalyst for this reaction, since no oxygen is produced.

b Powdered PbO_2 is the most effective catalyst because it produces the most oxygen.

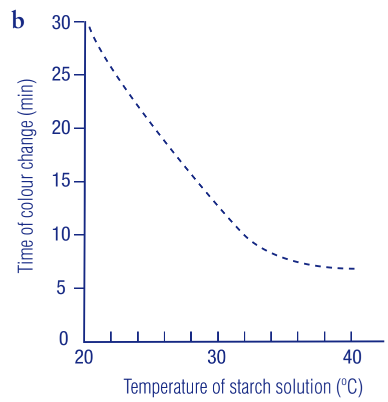
c Granular MnO_2 produces less oxygen per 0.1 g because it has a smaller surface area, while twice the mass of MnO_2 produces more oxygen.

d The variables controlled in this experiment are the volume and concentration of peroxide, the temperature and probably the type of container.

3 This reaction could probably be speeded up by using a catalyst and by warming up the contents of the large container.

4 a The test strip changed colour because the saliva changed some of the starch to sugar.

b



c For this reaction, the greater the temperature, the faster the colour of the solution changes.

5 Your paragraph could be something like this:

'Catalysts are chemicals which can speed up or slow down the rate of a chemical reaction. They are used in industry to produce many substances that we use in everyday life. They are also present in our bodies as enzymes which speed up cell reactions. They are important because they are able to produce the things that are necessary for life. For example, if a person needs energy to play sport then enzymes will cause respiration to be speeded up in the muscle cells of the body.'

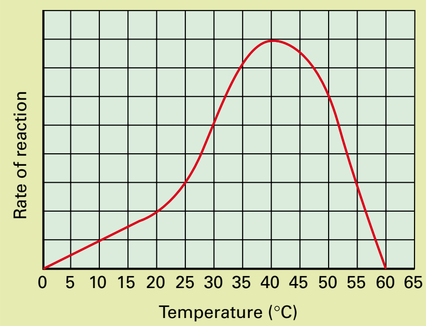
6 Some washing powders contain enzymes because they are effective in removing 'stubborn stains', particularly foods and other organic materials, by speeding up the reactions.

Hints and tips

- Hydrogen peroxide (H_2O_2) readily decomposes into water and oxygen. In solution it is used as a bleaching agent and disinfectant, and is often used in the beauty industry and hair salons. In its undiluted form, hydrogen peroxide is a thick, syrupy liquid.
- Amylase is the enzyme in saliva which helps to break down starch into glucose.

challenge

1 All enzymes are proteins, which are easily destroyed by high temperatures. The graph below shows how a particular biological reaction is affected by temperature. The reaction is catalysed by an enzyme.



a At which temperature did the reaction take place most quickly?

b What happened to the reaction rate as the temperature was raised from 0°C to 40°C?

c What happened to the reaction at 0°C and at 60°C?

d Suggest why the reaction got slower as the temperature was raised from 40°C to 60°C.

2 The thyroid gland (which is in the throat) produces a hormone called thyroxine which helps the body 'burn up' fat. People who are abnormally thin sometimes have part of their thyroid gland removed surgically. Suggest a reason for this.

3 Rennin is an enzyme produced in the stomachs of young mammals. It reacts with the protein in milk and solidifies it in a process called *clotting*.

Imagine that you have been asked to investigate how the reaction time for the clotting of milk is affected by temperature. You have a supply of rennin solution and all the necessary laboratory apparatus.

a Describe how you would carry out this experiment.

b What results would you expect?

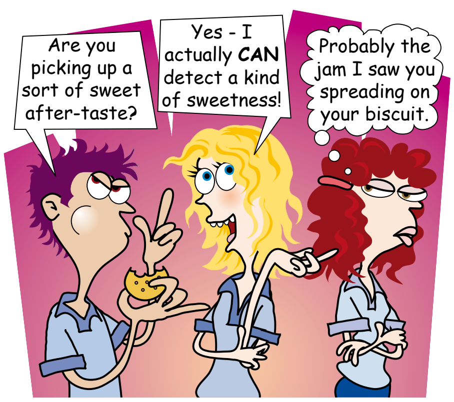
4 Enzymes help in the manufacture of substances in our bodies as well as breaking them down. Use Fig 23 on page 34 to draw a labelled diagram showing how they can manufacture a product.

try this

1 Use library resources to find out the uses of hydrogen peroxide.

2 There is a way to test the action of saliva on food. Chew a piece of dry savoury biscuit for a minute or two. Move it about with your tongue. Can you notice any changes in taste before you swallow it?

You should find that the biscuit tastes sweeter after a while. This is because the starch in the biscuit has been broken down to sugar by the enzymes in your saliva.



Challenge solutions

1 a The reaction occurred most quickly at 40°C.

b As the temperature was raised from 0°C to 40°C the reaction rate increased.

c At 0°C and 60°C the reaction stopped and the reaction rate was zero.

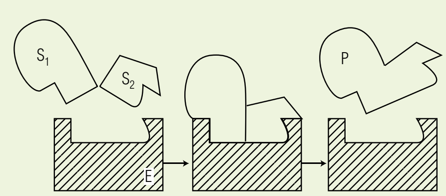
d The reaction got slower between 40°C and 60°C because the heat destroyed the properties of the enzyme.

2 One possible explanation is that the hormone thyroxine speeds up some of the reactions which control respiration in the body cells. Removing part of this gland will reduce the amount of thyroxine which is being produced and will therefore slow down chemical respiration. Because of this the person will not 'burn up' as much fat.

3 a You would design and conduct a controlled experiment in which the only thing you change is the temperature of the milk and rennin solution. In a test tube you could place 10 mL of milk and add 2 mL of rennin solution, swirl it gently and record how long it takes to clot. You would do this at room temperature and also at several other temperatures, eg at fridge temperature (5°C), body temperature (37°C) and at the temperature of hot tap water (70°C). The results could be entered in a table and used to draw a graph.

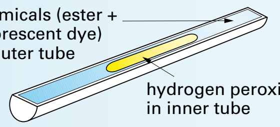
b You would expect that the time for the milk to clot would be least at about body temperature, since milk normally clots in the stomachs of young animals.

4 The figure could look something like this.



Everyday reactions

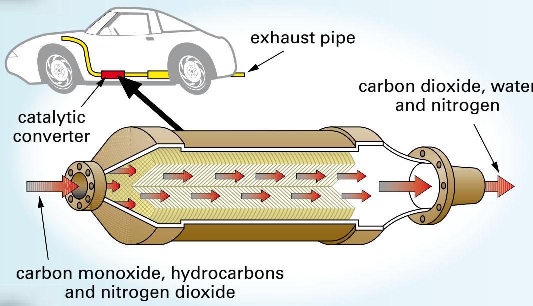
At the Sydney 2000 Olympics the people in the crowd were given light sticks (glow lights) to wave around. How do these light sticks work? They contain two parts—an outer plastic tube and an inner one. When you bend the stick you break the inner tube and the chemicals react, producing light.



- Suggest why light sticks only work for a few hours.

Cars are fitted with anti-pollution devices called **catalytic converters**. These are packed with plates that are coated with platinum or rhodium. These metals are catalysts for reactions that convert the exhaust gases to less harmful ones.

- Suggest why a catalytic converter contains so many honeycombed plates.



The rapid inflation of an airbag in a car accident is the result of a very rapid chemical reaction. When the crash sensor detects a collision, a chemical reaction occurs which fills the nylon bag with nitrogen gas in less than a second.

- Would the reaction between zinc and hydrochloric acid be suitable for inflating an airbag? Explain.

WEBwatch

For videos of crash tests with air bags, go to www.scienceworld.net.au and follow the links to **Crash test**.

Hints and tips

Do some research and come up with a more comprehensive list of everyday reactions to present to the class for the students to investigate. Purchase some glow sticks and award students for asking a 'bright idea/question', or giving a 'glowing explanation' and so on.

Homework

Do the Webwatch if you have access to computers in class, or give it as a homework exercise.

Research

Turn this activity into a mini project where small teams of students (four per group) research, explain and report their findings to the class. Allow enough brainstorming and research time. Each team should assign a *team leader* who will give an oral report to the class, a *scribe* for jotting down brainstorming ideas and research notes, an *author* who writes up the material and an *editor* who collects the artwork (illustrations, photos, models) and puts them together with the written work. All team members are *researchers*. You might like to assign each team a specific 'everyday reaction' to investigate.

Learning experience

An extension activity is for the students to make their own glow stick. This would lead nicely into endothermic and exothermic reactions (pages 38–39). The reaction between the different compounds in the glow stick releases energy in the form of light (chemiluminescence) and is therefore exothermic. If the glow stick is activated and placed in very hot water for about one minute, the chemical reaction is accelerated and the stick glows much more brightly. (There are various instructions for how to make glow sticks on the internet.)

Hints and tips

Students often muddle up endothermic and exothermic reactions. It is helpful to suggest that energy *exits* in *ex*othermic reactions; it exits to the surrounding environment.

Students often remember best by experiencing, so encourage them to feel the temperature change in exothermic and endothermic reactions. If something is releasing energy it gives out heat. If it requires energy, it feels cool. On a hot day it always seems cooler around plants and their leaves are cool to touch. Plants need energy from sunlight for photosynthesis and this process is an endothermic reaction, so the leaves stay cool.

2.3 Energy and mass in reactions

Exothermic and endothermic

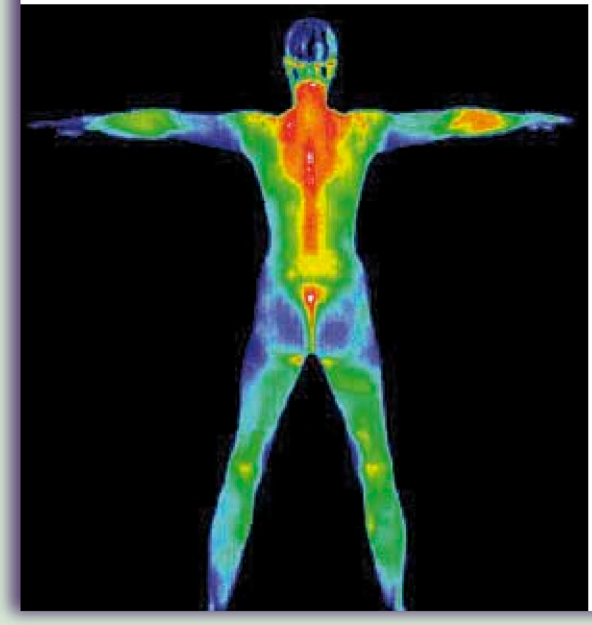
Whenever there is a chemical reaction an energy change occurs. Energy is produced in some reactions, and is needed to start other reactions.

An **exothermic reaction** is one that releases energy. This energy is usually in the form of heat, but sound, light and electrical energy can also be produced. You may have noticed that when you mix certain chemicals the test tube becomes warm, indicating that heat energy has been released. An important exothermic reaction is **combustion** (or burning), which releases heat energy, light energy and some sound energy.

Another exothermic reaction occurs inside your body during the process of respiration. Most of the energy from respiration is used to keep your body working, but some of it is released as heat. This keeps your body temperature at about 37°C, even when the temperature around you is much lower. Some exothermic reactions produce electricity. For example, the chemicals inside a torch battery react to produce electricity.

glucose + oxygen → carbon dioxide + water + ENERGY

Fig 31 Our bodies release heat in the process of respiration. In this heat image of a person, the warmest areas are white and the coolest areas are green.



An **endothermic reaction** is one where some form of energy must be supplied. For example, plants need energy from sunlight to be able to make food from carbon dioxide and water during photosynthesis.

carbon dioxide + water + ENERGY → plant food + oxygen

Sherbet is a mixture of baking soda and citric acid. When it is mixed with the water in your mouth an endothermic reaction occurs, taking heat energy from your mouth and making it feel cooler. Cold packs used for treating sports injuries work in the same way. When the pack is broken an endothermic reaction occurs, taking heat from the surroundings and making the pack feel cold.

Some endothermic reactions require electrical energy to make them go. For example, when you charge a car battery, the electricity produces chemical reactions inside the battery. Electricity is also needed for electroplating. For example, when electricity is passed through the silver nitrate solution (below), chemical reactions occur and silver moves from the rod to be deposited as a thin layer on the teapot.

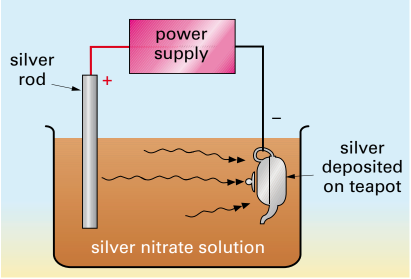


Fig 32 Electroplating a teapot

Learning experiences

1 It may be worth showing the class again what happens when calcium metal is dropped in water to demonstrate an exothermic reaction (see pages 23–24). Energy is released or 'exits', causing the beaker of water to heat up. Sensationalise the demonstration by dropping a small handful of metal into a large beaker of water on a heatproof mat. Allow the students to feel how hot the beaker is.

2 Making sherbet is a real treat for the students. Use plastic cups to hold the mixture. Students experience an endothermic reaction and are likely to remember the type of reaction by association. This way you can encourage students to link science to their everyday experiences, help demystify their world, and make science engaging and real by building a sense of connectedness with their environment.

Investigate
5 EXOTHERMIC OR ENDOTHERMIC?

Research question

Which reactions are exothermic (produce heat) and which are endothermic (take heat from their surroundings)?

Materials

- 2 test tubes
- thermometer
- datalogger and temperature probe (optional)
- zinc
- sodium thiosulfate (hypo)
- dilute **hydrochloric acid** (1M) Corrosive

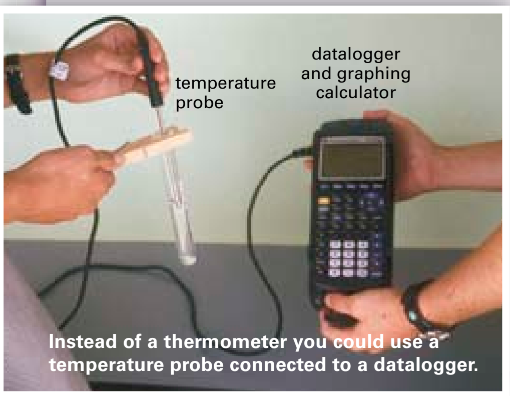
PART A

Method

1 Add dilute hydrochloric acid to a piece of zinc in a test tube. Feel the test tube.
   Is the reaction exothermic or endothermic?

2 In a second test tube, dissolve a small amount of sodium thiosulfate in water.
   Is the reaction exothermic or endothermic?

3 Your observations so far are *qualitative*. You can say that the temperature increased or decreased, but you cannot say by how much. Repeat Steps 1 and 2, but this time use a thermometer to measure the change in temperature.
   Record your *quantitative* results.



Instead of a thermometer you could use a temperature probe connected to a datalogger.

PART B

Materials

- a range of compounds, eg ammonium chloride, anhydrous calcium chloride, potassium chloride, potassium hydroxide, potassium nitrate, sodium chloride

Planning and Safety Check

Each of the salts in the list above dissolves in water. The process either releases heat or absorbs it. Your task is to design a fair test so that you can arrange the salts in order, from the most exothermic to the most endothermic.

- Write out your plan, explaining how you will control variables.
- Make a list of the equipment you will need.
- Design a data table for your results.
- Some of the salts are corrosive and some are toxic. What safety precautions will you need to take when using them?

Report

Carry out your experiment and write a report using the five headings listed in Step 3 on page 29.

try this

Investigate ways of making your results from Part B more accurate. Here are some hints.

- Measure the amount of heat produced or taken from the surroundings. To do this you need to use the formula:

  heat change (joules) = volume of water (mL) x change in temperature (°C) x 4.2

- To compare different salts accurately, you need to measure the heat change per gram of compound.
- To reduce heat transfer, you need to insulate the reaction container.

Hints and tips

- Revise what is meant by *quantitative* and *qualitative* results. Quantitative data is measurable and numeric, while qualitative data relies on description or qualities and is not measurable.
- Different substances have different capacities to hold heat energy. The specific heat capacity, *c*, is a measure of the energy needed to raise 1.0 g of a substance by 1.0°C. It takes 4.2 J to raise the temperature of 1.0 g of water by 1.0°C. The formula $Q = mc\,\Delta T$ is used in *Try This*:
  — Q is the amount of heat change (J)
  — m is the mass of substance (g)
  — c is the specific heat capacity (in J/g/°C or $\text{J g}^{-1}\,°\text{C}^{-1}$)
  — ΔT is the change in temperature (°C).

Lab notes

- In steps 1 and 2, students should hold the test tubes for a minute or so to observe a change in temperature.
- If using a datalogger, it is vital that students are familiar with the devices and have the knowledge to safely handle the probes (sensors) and clean them between tests. A general rule is that they can stop when they get three consecutive readings that are the same. Check that the hardware and software enables the graphs to be displayed in a useful way. It is a good idea to test the experiment first to make sure data collected using this technology is understandable to the students.

Hints and tips

Asking students to read this article aloud not only keeps them focused but assists those who have a preference for auditory learning. A teacher can make insights into the learning abilities of students by observing how well they can read. However, be careful not to choose a reader who you know has a language disorder, unless they are willing to read.

Science in action

Lavoisier and combustion

In the eighteenth century, scientists could not explain what happened during combustion. They were trying to explain it in terms of the 'phlogiston' theory. This theory said that all metals contained a mysterious thing called *phlogiston* (flo-JIST-on). When a metal was heated the phlogiston escaped, thus producing a new substance. However, this theory was unsatisfactory since most metals increased in mass when they were heated. If the phlogiston theory was correct, the metals should *decrease* in mass when heated; hence the problem.

A French scientist called Antoine Lavoisier (la-VWAH-zee-ay) set out to solve the combustion problem. He heated various metals in air and they all increased in mass. However, when he heated tin in a *sealed* flask, there was no change in mass. When he opened the flask, however, air rushed in and its mass increased.

From these observations, Lavoisier inferred that when the tin was heated it reacted with something in the air. He then predicted that the mass gained by the tin should be the same as the mass of air used up. If this was true, then there should be no change in mass during *any* chemical reaction. To test this hypothesis Lavoisier made more careful measurements and was able to convince himself that 'matter cannot be created or destroyed'. It can only be changed during a chemical reaction.

In 1774 Joseph Priestley, the British clergyman who had discovered oxygen, visited Lavoisier in Paris. Lavoisier saw the importance of oxygen immediately. By doing more carefully planned experiments, it was not long before he had discovered that both oxygen and nitrogen are present in air. When substances burn in air they combine with oxygen but not with the nitrogen. Lavoisier also applied his ideas to respiration in the body, and showed that food reacts with oxygen to produce energy, as in combustion. In 1786 he published the results of his experiments—and the phlogiston theory had to be abandoned.

Because he was a noble as well as an unpopular tax collector, Lavoisier was executed by guillotine during the French Revolution. He was very good at organising and interpreting information, and has been called the 'father of modern chemistry'. Perhaps the most important thing he did was to stress the need for careful measurements—one of the most important skills in science.

In the experiment on the next page you can test Lavoisier's hypothesis for yourself.

Questions

1 What was phlogiston?
2 Why was the phlogiston theory unsatisfactory?
3 What happened when Lavoisier heated metals in air?
4 Lavoisier heated tin in a sealed flask. When he opened the flask, air rushed in. How can you explain this?
5 Complete this sentence. Lavoisier discovered that air is a mixture of ______ and ______. When you burn something in air, it reacts with the ______.

Homework

Students could design their own crossword which could be submitted for marking and used as part of an end-of-topic assessment. Alternatively they could be given the supplied crossword.

Learning experience

For the more literate students, this passage could be rewritten into a play and then performed.

Experiment

DOES MASS CHANGE IN A REACTION?

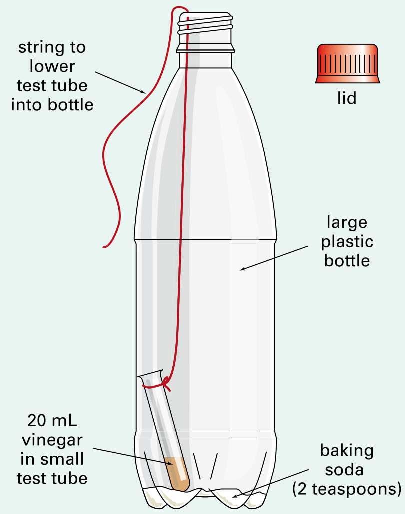
Research question

Does the mass change when vinegar reacts with baking soda?

Materials

- large plastic soft drink or sports drink bottle, with lid
- 2 small test tubes
- piece of string
- baking soda (sodium hydrogen carbonate)
- vinegar (acetic acid)
- teaspoon
- measuring cylinder
- balance (accurate to 0.01 g)

Wear safety glasses.



Planning and Safety Check

Your task is to design an experiment to answer this question:

Does the mass of the bottle and its contents change when the vinegar reacts with the baking soda?

- Study the diagram and the list of materials. In a group, discuss how you will do the experiment. When you have worked this out, write down your Method—giving in detail the steps you will take.
- Why do you need to do the experiment with and without the lid?
- List the safety precautions that will be necessary.
- Design a suitable data table to record your results. How many rows will you need? How many columns?
- Before you start, predict what you think the results of the experiment will be.

Method

Check the steps in your method with your teacher, then carry out the experiment.

Results

1 Without the lid, did the mass increase, decrease or stay the same? Suggest why this happened.

2 With the lid on, did the mass increase, decrease or stay the same? Explain.

Discussion

1 Were your results accurate? Explain.

2 Could you improve your method? How?

3 Would it be worth repeating the experiment? Explain.

Conclusion

Were your predictions in the Planning and Safety Check correct? In other words, do your results support the hypothesis that the total mass of the substances in a reaction does not change?

Hints and tips

- It may be useful to step the students through this experiment by taking time to read it together. Then start them off with the Planning and Safety Check.
- Check that students remember what a hypothesis is, and help them write a suitable one for the experiment.

Lab notes

- To avoid students not fully participating in the activity, groups should have no more than three members in them. Pairs work best.
- It should not be assumed students remember how to use a balance. Take the time to revise this by demonstrating how to use one. When using an electronic balance, it is very important to 'zero' the balance before measuring any mass.
- Make sure that students weigh the lid each time, even when it is not on the bottle.

Hints and tips

For students to understand the law of conservation of mass, it is important to emphasise that the number of atoms *before* the reaction has to equal the number of atoms *after* the reaction. If students misinterpret 'mass' as 'weight', they will struggle with the concept. Remind them that mass is how much matter something has, not its weight (which is a force).

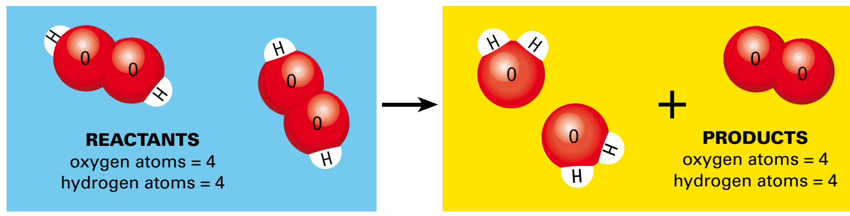
Law of conservation of mass

Many different reactions have been studied to test Lavoisier's hypothesis, and it has always proved correct. Hence the hypothesis is now called the **law of conservation of mass**.

What this means is that the number of atoms which take part in a chemical reaction is equal to the number of atoms in the products. For example, the decomposition of hydrogen peroxide to form water and oxygen can be shown using the models below. No atoms are lost in the reaction—they are simply rearranged.

> **Law of conservation of mass**
> *The total mass of the reactants is always equal to the total mass of the products.*

hydrogen peroxide	→	water	+	oxygen
$2H_2O_2$	→	$2H_2O$	+	O_2

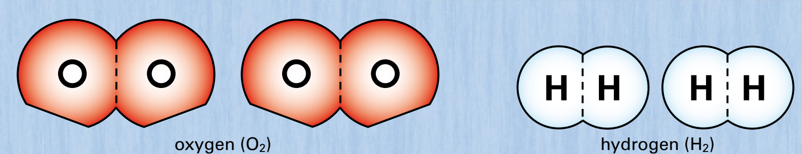


Activity

You can use cardboard cutouts to make models of chemical reactions. The cutouts below represent molecules of oxygen and hydrogen.

1. Photocopy or trace the oxygen (O_2) and hydrogen (H_2) molecules and cut them out.
2. Use the H_2 and O_2 molecules to make a molecule of hydrogen peroxide H_2O_2 as shown above. You will need to break the molecules into their atoms by cutting along the dotted lines. Unless you do this, the 'reaction' cannot occur.
3. Now take the H_2O_2 molecule apart to show that you need two of them to form two H_2O molecules and one O_2 molecule, as in the equation above.
4. Use your models to show what happens when water decomposes to form H_2 and O_2. Try to write an equation with the same number of atoms on both sides of the equation.

Working with technology: **If you have a molecular models kit you can make three-dimensional models. You may even be able to animate the equation models using computer software such as *DreamWeaver*, *Photoshop* or *Flash*.**



Activity notes

- Use two different coloured pieces of paper so the oxygen and hydrogen atoms can be easily identified.
- Different-sized polystyrene balls and skewers make good 3D models. Write on the balls with pen or marker to show which elements they are.
- To further extend the students, give them some other reactions to model using the same procedure in the activity.

Learning experience

The law of conservation of mass states that the total mass of the reactants equals the total mass of the products. But how can this be if, say, a large log is burned and you are left with a small pile of ash? Ask the students to brainstorm their ideas. Get the students to come up with other situations which may appear to defy this law and explain why they don't.

Check!

1 Copy and complete these sentences.
 a Burning is a chemical reaction that produces mainly ______ and ______.
 b The electricity produced by a torch battery is caused by a ______ ______.
 c The reaction used to silverplate a teapot needs ______ to make it go.
 d Combustion is an example of an ______ reaction.
 e ______ is a type of chemical reaction in which a substance breaks down into simpler substances.
 f The total mass of the ______ is always equal to the total mass of the ______.

2 50 mL of hydrochloric acid was added to a beaker. The mass of the beaker plus acid was found to be 151.0 g. Then 5.0 g of magnesium ribbon was added to the acid. After a fizzing reaction in which the magnesium was all used up, the mass of the beaker and its contents was 155.6 g.
 a Does this experiment agree with the law of conservation of mass? Explain.
 b How could you modify the experiment to show that mass is conserved in this reaction?

3 What forms of energy can be produced in exothermic reactions?

4 A log of wood burns, leaving a pile of ashes. What other new substances are produced during the reaction? Is the mass of the new substances produced during the reaction the same as the mass of the log to start with? Explain your answer.

5 Keeping in mind the law of conservation of mass, explain the following.
 a When a match burns, the mass of the charred wood and ash left is *less than* the original mass of the match.
 b When steel wool burns, the mass of the blackened material is *more than* the original mass of the steel wool.
 c As a plant grows, the mass of the plant is *more than* its original mass.

challenge

1 What are the similarities and differences between combustion and respiration?

2 a When two molecules of hydrogen peroxide decompose, how many molecules of water are formed? How many molecules of oxygen? (Hint: use the equation on the previous page.)
 b If a million molecules of hydrogen peroxide decompose, how many molecules of oxygen will be produced?

3 a Joseph Priestley produced oxygen by decomposing mercury oxide by heating. Write a word equation for this reaction.
 b Write a word equation for what happens when mercury is heated and reacts with air (oxygen).

4 Lavoisier found that metals increased in mass when heated, yet a diamond (carbon) burnt away completely. Try to explain what happened, using a word equation if possible.

5 Indira finds that 7 grams of iron filings combine with exactly 4 grams of sulfur to form 11 grams of iron sulfide. She repeats the experiment using 5 grams of iron filings and 5 grams of sulfur.
 a How much iron sulfide will be formed?
 b One of the reactants will be left unreacted this time. Which one, and how much of it will be left?

try this

Next time your lawn is mowed, make a large heap from the lawn clippings. Several days later open the heap with a garden fork and put your hand close to the grass. Write an inference to explain your observations.

Check! solutions

1 These are the completed sentences.
 a Burning is a chemical reaction that produces mainly *heat* and *light*.
 b The electricity produced by a torch battery is caused by a *chemical reaction*.
 c The reaction used to silverplate a teapot needs *electricity* to make it go.
 d Combustion is an example of an *exothermic* reaction.
 e *Decomposition* is a type of chemical reaction in which a substance breaks down into simpler substances.
 f The total mass of the *reactants* is always equal to the total mass of the *products*.

2 a No, the results of this experiment do not entirely agree with the law of conservation of mass. There is a difference of 0.4 g between the mass of the reactants and the products. It is reasonable to suggest that this is the mass of gas which escaped.
 b One way to modify the experiment would be to seal the container so that the gas cannot escape.

3 Exothermic reactions produce heat energy, and sometimes light, sound and electrical energy.

4 When a log of wood burns the new substances produced are ashes (carbon), water vapour and carbon dioxide. The mass of all these products should be equal to the mass of the reactants. However the mass of all of the products is hard to measure because the gases escape into the air during the fire.

5 a When a match burns, some of the mass is given off in the form of carbon dioxide and water vapour. These are released into the air.
 b When steel wool burns, its mass increases because it combines with oxygen from the air to form a black substance.
 c As a plant grows, it uses carbon dioxide from the air and water from the soil to make its own food. This accounts for the increase in mass.

Challenge solutions

1 The main similarities are that in both cases fuel and oxygen are required, and heat and carbon dioxide are produced. The main difference is the rate of the reaction. In an organism respiration proceeds slowly, whereas in combustion it proceeds very quickly until all the fuel or oxygen is used up.

2 a Two molecules of water and one molecule of oxygen are formed.
 b Half a million (500 000) molecules of oxygen will be produced.

3 a mercury + oxygen ⟶ mercury oxide
 b mercury oxide ⟶ mercury + oxygen

4 Diamond is pure carbon. When it burns it produces a gas carbon dioxide.
carbon + oxygen ⟶ carbon dioxide

5 Elements always combine in the same proportions when they form a particular compound.
 a If 7 g of sulfur forms 11 g of iron sulfide then 5 g produces $\frac{5}{7} \times 11 =$ 7.9 g of iron sulfide.
 b If 7 g of iron reacts with 4 g of sulfur then 5 g will react with $\frac{5}{7} \times 4 = 2.9$ g of sulfur. If you start with 5 g you will have 2.1 g left over.

Main ideas solutions

1 rate
2 increases, temperature
3 concentration
4 area
5 catalysts
6 exothermic, endothermic
7 conservation, products

Review solutions

1 **C**—Some reactions occur very slowly, eg rusting.

2 **A** (**C** is unlikely since John repeated the experiment several times with the same result.)

3 **A**, **C** and **E** are exothermic—they release energy. **B** and **D** are endothermic—they need energy.

4 **A**, **C**, **D** and **E** can all indicate the rate of a reaction.

MAIN IDEAS

Copy and complete these statements to make a summary of this chapter. The missing words are on the right.

area
catalysts
concentration
conservation
endothermic
exothermic
increases
products
rate
temperature

1 Some reactions occur slowly, while others occur quickly. The speed of a reaction is called its _____.
2 The rate of a reaction usually _____ as the temperature increases. Similarly, the rate usually decreases as the _____ decreases.
3 Increasing the _____ of the reactants usually increases the rate of a reaction.
4 Increasing the surface _____ of the reactants usually increases the rate of a reaction.
5 _____ are substances that increase the rate of a reaction without being used up.
6 Reactions which release energy are called _____. Reactions which take in energy are called _____.
7 The law of _____ of mass says that the total mass of the reactants in a chemical reaction is always equal to the total mass of the _____.

Try doing the Chapter 2 crossword on the CD. Working with technology

REVIEW

1 Which of the following is *not* true?
A Heating sometimes causes a reaction.
B Some reactions produce electricity.
C Reactions usually take only a few seconds.
D Reactions sometimes produce colour changes.

2 John heated a solid in a test tube and found that its mass decreased. He repeated the experiment several times—with the same result. Which of the following is the *most likely* explanation for the decrease in mass?
A The solid gave off an invisible gas during heating.
B Some of the solid melted into the test tube during heating.
C John spilt some of the solid during the experiment.
D The test tube expanded when heated and became lighter.

3 Which of the following reactions are exothermic, and which are endothermic?
A acid reacting with lead in a car battery
B baking a loaf of bread
C combustion
D photosynthesis
E respiration inside your body

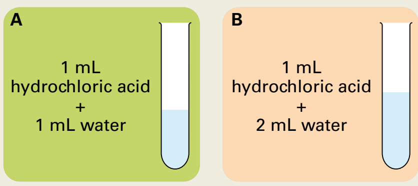
4 Which of the following can be used as an indication of how fast a chemical reaction occurs? (There may be more than one answer.)
A how much product is formed in a given time
B how rapidly the solutions are mixed
C how much heat is given off in a certain time
D how quickly the reactants are used up
E how long it takes to observe a change

REVIEW

5 What effect does each of the following have on a chemical reaction (speeds it up, slows it down or has no effect)?

a adding water to the reactants
b heating the reactants
c increasing the *amount* of each reactant
d increasing the *concentration* of the reactants
e lowering the temperature of the reactants
f using a catalyst
g using the reactants in powdered form

6 Peter has set up two test tubes as shown. If he adds the same amount of zinc filings to each tube, predict which reaction will be faster. Explain your answer.



7 To each of four test tubes, Carol added 1 mL of hydrogen peroxide and 5 drops of liquid detergent. She warmed the tubes by placing them in a beaker of hot water, then added substances A, B and C as shown in the table.

In each tube the mixture frothed up, and Carol measured the height of the foam.

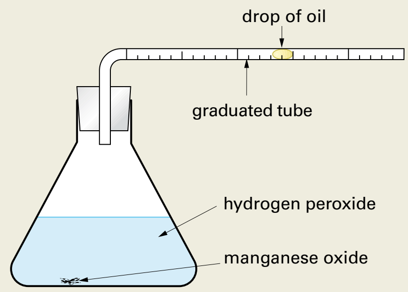
Test tube	Substance added	Height of foam produced (cm)
1	–	2
2	A	8
3	B	5
4	C	2

a Are any of the three substances catalysts for the decomposition of hydrogen peroxide? Which one(s)? How do you know?
b What is the purpose of test tube 1?

8 Flour in a sack will not burn very well, even when heated with a blowtorch. However, flour dust in the air in a flour mill burns so rapidly at room temperature that a small spark can cause it to explode violently.

How can you explain this difference in reaction rates?

9 The apparatus shown was used to measure the volume of oxygen produced when the catalyst manganese oxide was added to hydrogen peroxide solution.



Time (min)	0	1	2	3	4	5	6
Volume (mL)	0	15	20	23	24	25	25

a Draw a graph displaying the results.
b How long did it take for 10 mL of oxygen to be produced?
c How much oxygen was produced in $1\frac{1}{2}$ minutes?
d How long did the reaction take to reach completion?
e How did the rate of the reaction change with time?
f It was suggested that powdered copper is a better catalyst for the decomposition of hydrogen peroxide than manganese oxide. Write a brief plan of an experiment to find out if this is true.

Check your answers on pages 317–318.

5 **a** slows it down, since the reactants are less concentrated
b speeds it up
c has no effect, since the *concentration* of the reactants is the same
d speeds it up
e slows it down
f speeds it up
g speeds it up, since the reactants have a larger surface area (see page 28).

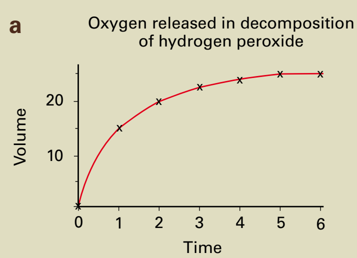
6 The reaction in test tube A will be faster than the reaction in tube B. This is because the acid in tube A is more concentrated (less water) than that in B.

7 **a** **A and B**
b Nothing was added to test tube 1, so that the reactions in the other tubes could be compared with it. This test tube is called a *control*.

8 For the flour to burn, it must react with the oxygen in the air. To do this, the flour must come into contact with the air.

Very little of the flour in the sack is in contact with the air, so the flour burns very slowly. However, there is a large area of contact between flour dust and the air. So the flour burns very rapidly. (See page 28.)

9 **a**



b 10 mL were produced in about ½ minute.
c about 18 mL
d about 5 minutes (graph no longer rising)
e The reaction was fast to start with (steep slope), then gradually slowed until it stopped after 5 minutes.
f Repeat the experiment using the same apparatus, the same volume of hydrogen peroxide, but powdered copper instead of manganese oxide. Work out when the reaction stops, as in **d**. If the reaction is complete in less than 5 minutes, then powdered copper is a better catalyst than manganese oxide.