> 4.4 Keeping a fetus healthy

In this topic you will:

- think about how the development of a fetus is affected by the health of the mother
- find out how diet, smoking and drugs can affect fetal health.

Getting started

In Stage 8, you learnt about the different nutrients that a person needs to stay healthy.

Can you list all of these, and say what each one is needed for?

Do you think a woman is likely to need the same diet when she is pregnant as before she was pregnant?

Key words

fetal

fetus

A healthy pregnancy

For the first nine months of its life, a new human being grows inside its mother. During these nine months, it is called a **fetus**. A fetus is a baby before it is born. Every pregnant mother hopes that her baby will be healthy when it is born.

You have learnt a lot about the human body. You know about the nutrients that it needs, how it uses respiration to release useful energy, and how it excretes waste substances. A fetus growing in its mother's body needs to do all of these things.

The fetus relies on its mother to supply it with everything that it needs, and to remove the substances it needs to excrete. If the pregnant mother makes sure that she stays healthy, this helps the fetus to stay healthy too.

The substances that the fetus needs are brought to it in its mother's blood. But the mother's blood does not mix with the blood of the fetus. The two blood systems come very close together, but do not touch. The substances that the fetus needs diffuse from the mother's blood to the fetus's blood. The substances that the fetus needs to excrete diffuse in the opposite direction.

Diet

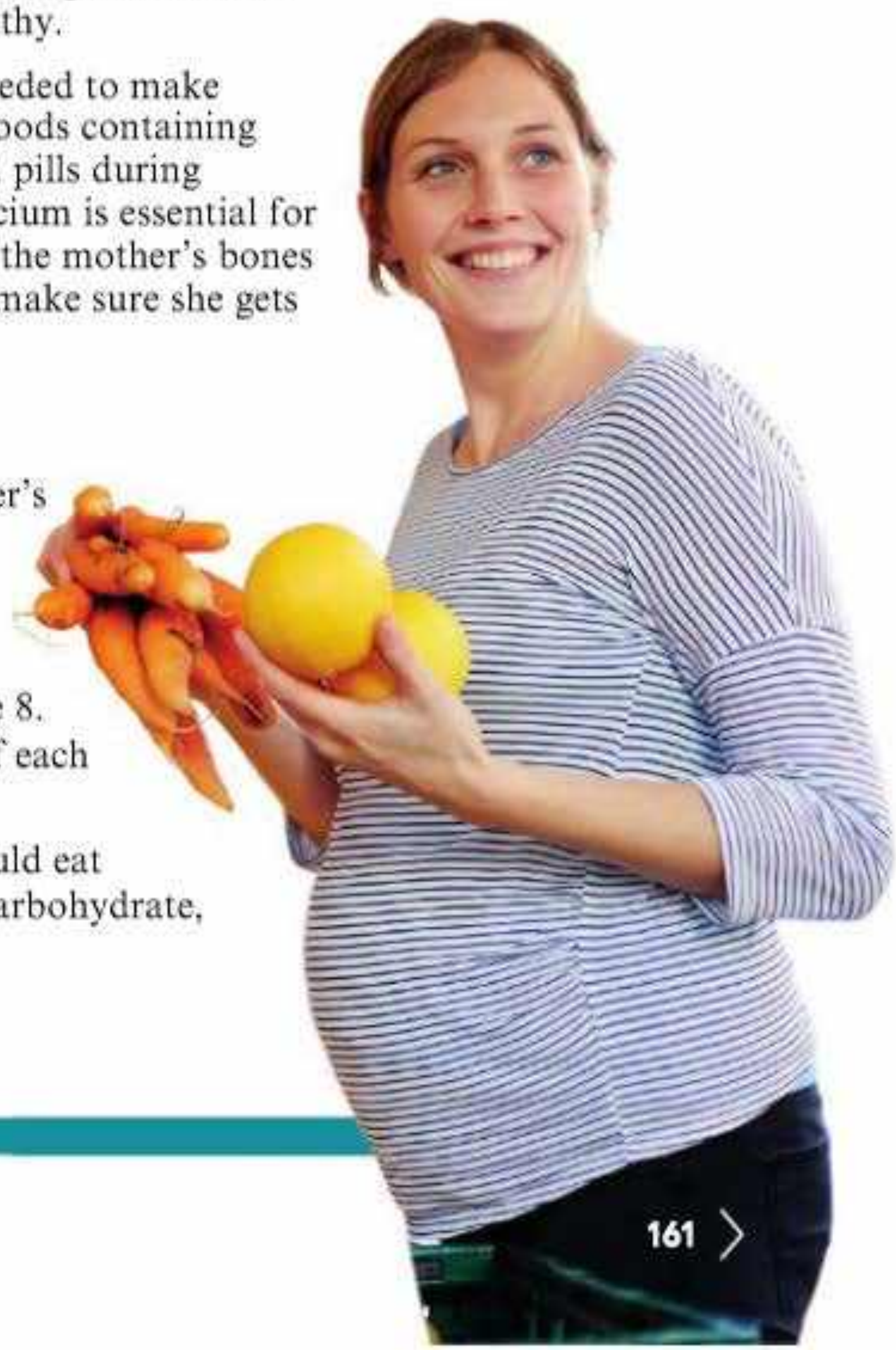
Eating well is always important, but it is especially important during pregnancy. A good diet during pregnancy has a big effect on **fetal** health.

When she is pregnant, a woman needs to eat a balanced diet. This means that she should eat some of all the different nutrients that are needed to stay healthy. She needs to eat a little bit more than usual because some of the nutrients that she eats are passed to the growing fetus.

Protein is needed to help the fetus to produce new cells and grow, so the mother must make sure she eats plenty of foods containing protein. The mother also needs protein for herself, to keep her muscles strong and working well. She also needs extra protein to make extra haemoglobin – she needs more because her blood has to transport oxygen to give to her fetus, as well as enough for herself. Of course, her fetus also needs to make haemoglobin for itself.

Carbohydrate supplies energy. Glucose is a carbohydrate, and cells get their energy by combining glucose with oxygen in respiration. Both the mother and her fetus need carbohydrate for this, so she needs to eat enough carbohydrate to make sure they both have enough energy. But she should not eat too much, or the extra could be changed to fat and make her put on too much weight, which is not healthy.

Vitamins and minerals are very important. Iron is needed to make haemoglobin, so the mother needs to eat plenty of foods containing iron. Sometimes, it can help if the mother takes iron pills during pregnancy, if she cannot get enough in her diet. Calcium is essential for helping the baby to grow strong bones, and to keep the mother's bones and teeth in good health. The mother also needs to make sure she gets plenty of vitamins in her diet.



Questions

1. List **three** substances that move from the mother's blood into her fetus's blood.
2. List **two** substances that the fetus excretes, which are removed by the mother's blood.
3. You learnt about vitamins A, C and D in Stage 8. Explain why a pregnant mother needs plenty of each of these vitamins in her diet.
4. Suggest some foods that a pregnant woman could eat that would supply her with plenty of protein, carbohydrate, iron, calcium and vitamins A, C and D.

Activity 4.4.1

Display about diet during pregnancy

Work in a group of three or four for this activity.

You are going to make a display about the importance of eating well during pregnancy.

First, you need to collect your information.

Here are some ideas:

- Look on the internet for information about advice for pregnant women and what they should eat.
- Talk to people you know who are mothers. Did they eat differently when they were pregnant? Did they find it easy to eat a healthy diet?
- Find pictures that relate to diet during pregnancy.
- If you visit a doctor's surgery or health centre, ask if they have any leaflets about how to eat well during pregnancy.

Use your information and pictures to produce a bright and interesting display that will catch people's attention and explain why a good diet is important during pregnancy.

Self-assessment

When you have finished your display, look carefully at other people's work.

What have they done really well? What could be better?

Does seeing other people's displays make you want to change your own?

Smoking cigarettes

In Stage 8, you learnt how smoking can harm health. Tobacco smoke contains carbon monoxide, nicotine and tar. When a pregnant woman smokes, carbon monoxide and nicotine diffuse from her blood into the fetus's blood. It is as though the fetus is smoking too.

Carbon monoxide in the blood reduces the amount of oxygen that haemoglobin can transport. This means that the fetus's cells get less oxygen, so they cannot respire as much and they cannot release as much energy as they normally would. This can affect the development of the fetus. Babies born to mothers who smoked during pregnancy tend to be smaller than babies born to non-smoking mothers.

Nicotine is an addictive drug. It can damage blood vessels, so it is not good for a developing fetus to have nicotine in its blood.

In many countries, cigarettes come with warnings about health. This packet has a warning for pregnant mothers.

Drugs

A drug is something that is taken into the body, and that affects the way the body works.

Some drugs are good for health. Antibiotics are drugs that kill bacteria in the body. They are used to cure the infections caused by bacteria. Antibiotics are an example of a medicinal drug. Some painkillers, such as aspirin, are also medicinal drugs. Without medicinal drugs, many more people would die or suffer pain from illnesses that we can now cure.

But other drugs are not so good for us. We have seen how nicotine, the drug in cigarettes, can harm the health of both a pregnant woman and her fetus. Any drug that we do not need can cause harm. These drugs can be even more harmful to a fetus than to an adult person.

Most drugs that a pregnant woman takes will go into her fetus's blood. So the fetus is taking the drug too.

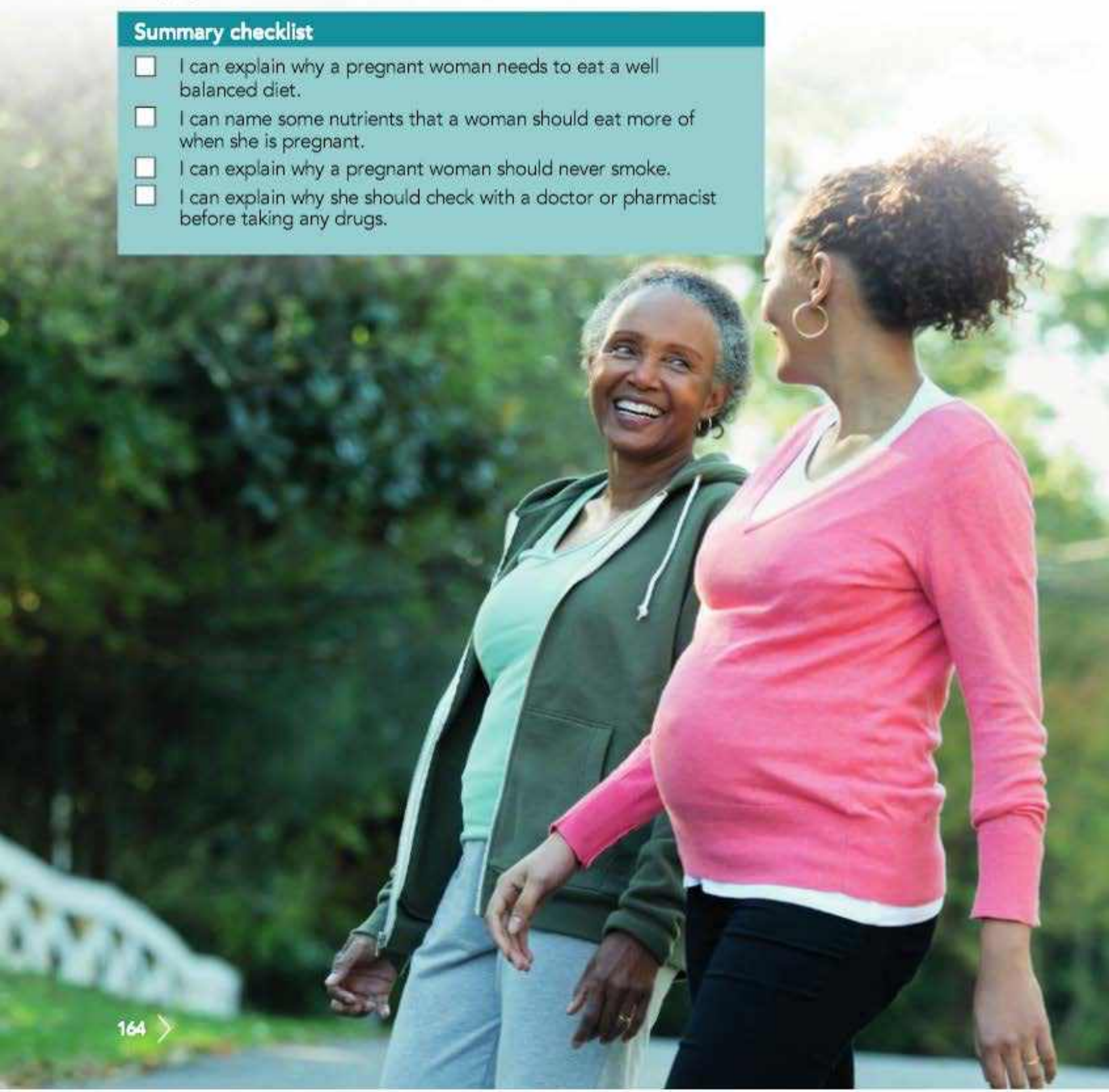
One country has these recommendations for women during pregnancy:

- If she regularly takes a prescribed drug for her own health, she should check with her doctor or a pharmacist to see if it is safe for her to keep on taking it. She should not stop taking it without checking first.
- She should check with her doctor whether it is safe for her to take drugs that do not need a prescription such as aspirin.
- She must stop smoking.

- She should avoid alcohol.
- She should never take illegal drugs at all, but it is especially important to avoid these during pregnancy.
- There is some evidence that caffeine – a drug in coffee and cola drinks – harms a developing fetus. Most doctors recommend that pregnant women should not drink a lot of coffee or cola.

Summary checklist

- [ ] I can explain why a pregnant woman needs to eat a well balanced diet.
- [ ] I can name some nutrients that a woman should eat more of when she is pregnant.
- [ ] I can explain why a pregnant woman should never smoke.
- [ ] I can explain why she should check with a doctor or pharmacist before taking any drugs.



Project: How scientists linked smoking to health

It is not easy to do experiments on human health. For example, if we want to find out how smoking affects fetal health, we cannot ask some women to smoke during pregnancy, and others not to smoke, and then compare the health of their babies.

Instead, scientists try to collect information from as many people as possible. They look for correlations between smoking and fetal health. They publish details about how they did their study, and their results. Other scientists can then look at this information and decide for themselves what they think the results show.

In this project, you will contribute to a class presentation or display, about the work that scientists have done about how smoking affects health.

Here are some questions to research. Choose one of them, or think of another question of your own about how scientists have found out about the effects of smoking on health.

Some of the questions have several parts – do not worry if you do not have time, or cannot find information, about every part.

- When did scientists first begin to think that smoking was bad for health? What made them think this? How did they share their ideas?
- What evidence is there that smoking is bad for health?
- What evidence is there that smoking has a negative effect on the development of a fetus?
- How have people responded to this evidence? Has the number of people smoking decreased in most countries? Has the number of women smoking during pregnancy decreased in most countries?

Check your progress

4.1 Choose the word that matches each description.

bladder kidney urea ureter urethra urine

a This organ filters the blood. [1]

b A tube that carries urine from the kidneys to the bladder. [1]

c A waste substance made in the liver from excess proteins. [1]

d Where urine is stored before leaving the body. [1]

e A tube that carries urine to the outside of the body. [1]

f A liquid containing urea dissolved in water. [1]

4.2 Copy and complete these sentences about plants and water.

Choose words from the list.

You can use each word once, more than once or not at all.

air gas leaves liquid

root hairs soil stomata xylem vessels

Plants take up water from the .... into their .... [2]

The water flows through .... which carry it to the plant's .... [2]

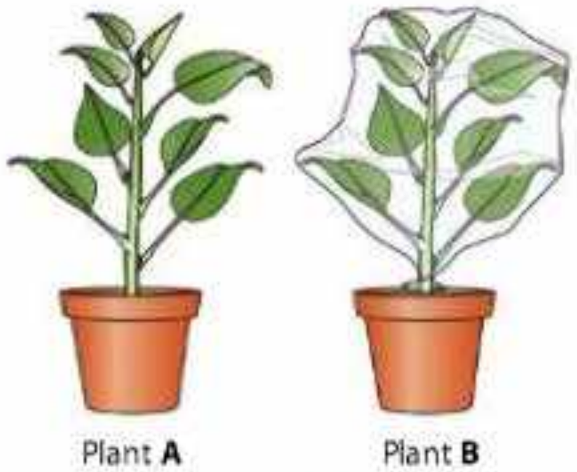
In the leaves, a lot of the water changes from .... to .... [2]

It diffuses out of the leaf through the .... [1]

4.3 Arun did an experiment using two plants in pots.

The diagram shows the two plants that he used.

Arun measured the mass of each plant at the same time every day for seven days. The table shows his results.



Day	1	2	3	4	5	6	7
Mass of plant **A** + pot in g	945	925	901	877	855	832	808
Mass of plant **B** + pot in g	960	952	946	940	936	932	929

Arun used his results to calculate how much mass each plant lost each day.

Day	1 to 2	2 to 3	3 to 4	4 to 5	5 to 6	6 to 7
Loss of mass of plant **A** + pot in g	20	24	24	22	23	24
Loss of mass of plant **B** + pot in g	8	6	6	4	4	

a What apparatus could Arun use to measure the mass of the plants in their pots? **[1]**

b Calculate how much mass plant B lost from day 6 to day 7. **[1]**

c Calculate how much mass plant A lost during the experiment. Choose the fastest way you can use the data to do this, and show your working. **[3]**

d Calculate the mean loss of mass per day for plant A during the experiment. **[1]**

e During the experiment, was more mass lost from the soil, or from the plant? Use the results in the table to explain your answer. **[3]**

f At the end of the experiment, Arun found little drops of water on the inside of the bag that covered plant B. Explain how they got there. **[3]**

4.4 The table shows the recommended daily masses of some nutrients that a woman should try to eat when she is not pregnant, and when she is pregnant.

Nutrient	When not pregnant	When pregnant
Protein in g	45.0	60.0
Calcium in g	0.8	1.2
Iron in mg	15.0	30.0

a Write **one** sentence about each nutrient, to explain why the woman needs to eat more of it when she is pregnant. **[3]**

b For each nutrient, name **one** food that she could eat that contains plenty of that nutrient. **[1]**

c Suggest why it is **not** recommended that she eats more fat when she is pregnant. **[1]**

d Explain why a woman should not smoke cigarettes when she is pregnant. **[2]**

5 Reactivity

> 5.1 Reactivity and displacement reactions

In this topic you will:

- use the reactivity series of metals to predict which metals will displace others from a solution of their salts
- carry out some displacement reactions.

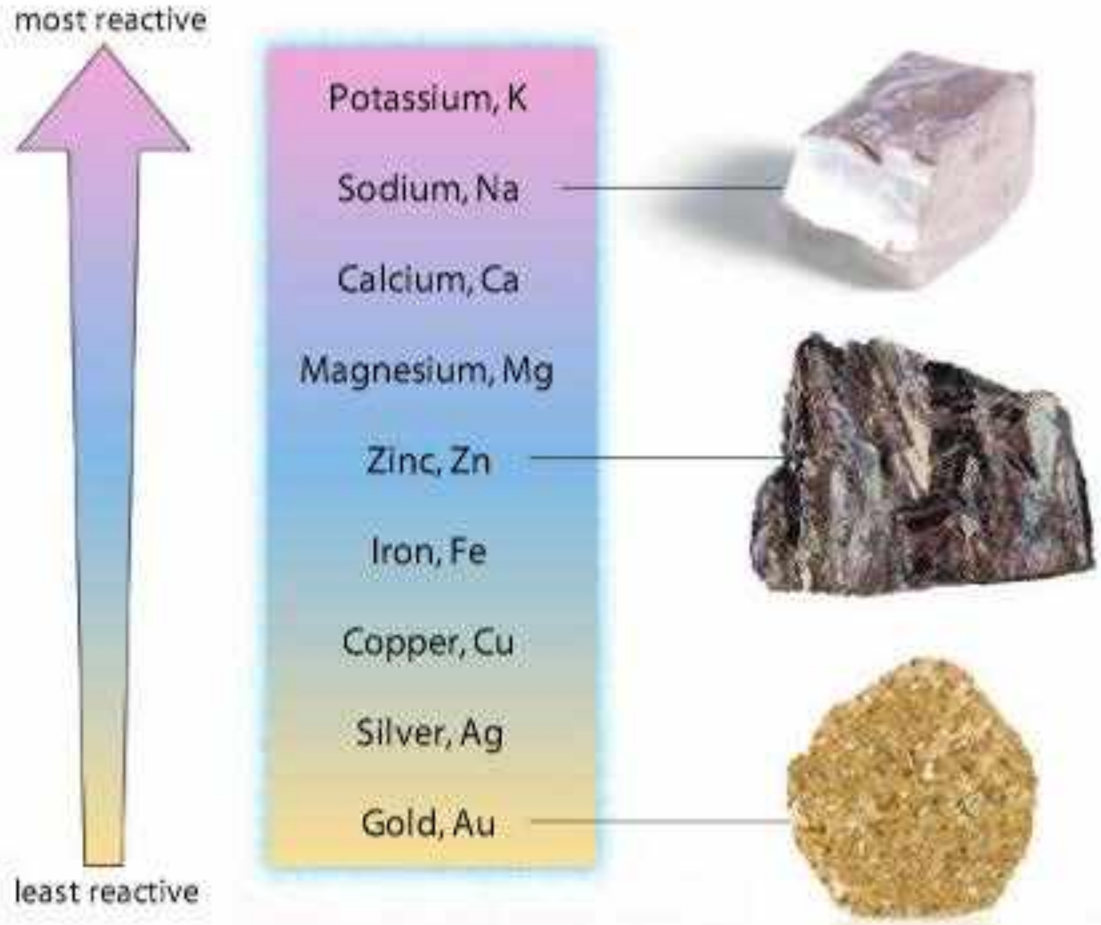
Getting started

Discuss with a partner how you can tell if a chemical reaction has taken place. Share your ideas with another pair. Be prepared to share your ideas with the class.

Key words

reactivity
reactivity series
displacement reaction

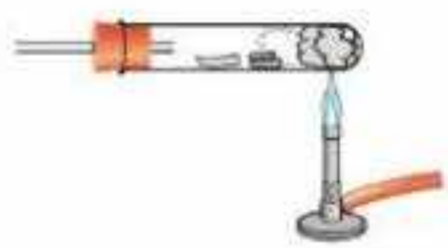
The reactivity series



In Stage 8, you learnt that some metals are more reactive than others, by looking at the reaction of the metals with oxygen, water (or steam) and dilute acid. Some metals are much more reactive than others. You can use the results of all the investigations, to place the metals in the order of their **reactivity**.

This list is called the **reactivity series**. It has the most reactive metals at the top and the least reactive at the bottom.

This table shows a summary of the reactions of the metals in the reactivity series.

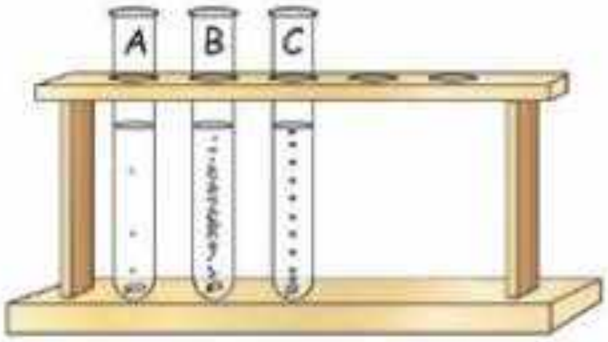
<table>
<tr><th>Metal</th><th>Reaction with oxygen</th><th>Reaction with water</th><th>Reaction with diute acid</th></tr>
<tr><td>potassium (extension material)</td><td rowspan="2">burns brightly when heated to form an oxide
</td><td rowspan="2">very vigorous reaction in cold water, the hydroxide is formed
</td><td rowspan="3">violent reaction and very dangerous
</td></tr>
<tr><td>sodium (extension material)</td></tr>
<tr><td>calcium</td><td rowspan="2">burns brightly in air when heated to form an oxide
</td><td rowspan="2">slow reaction in cold water to form the hydroxide
</td></tr>
<tr><td>magnesium</td><td rowspan="3">reaction, which becomes less vigorous as you go down the list
</td></tr>
<tr><td>zinc</td><td rowspan="3">slow reaction when heated to form an oxide
</td><td rowspan="2">reacts with steam but not water to form an oxide
</td></tr>
<tr><td>iron</td></tr>
<tr><td>copper</td><td rowspan="3">no reaction with steam or water
</td><td rowspan="3">no reaction
</td></tr>
<tr><td>silver</td><td rowspan="2">no reaction
</td></tr>
<tr><td>gold</td></tr>
</table>

Questions

1 a The metal lithium is missing from the reactivity list, suggest where it should be placed.
  b Give your reasons for placing lithium in this position.

2 a Platinum is a precious metal that is used for jewellery. Platinum stays shiny for a long time. Where in the list would you place the metal platinum?
  b Give your reasons for placing platinum in this position.

3 Small samples of three metals, A–C, have been added to dilute hydrochloric acid, as shown opposite. Which metal is most reactive? How could you tell?



4 Write a word equation for the reaction between zinc and sulfuric acid.

5 Write the word equation for the reaction between magnesium and oxygen.

Activity 5.1.1

Learning the order

In this activity, you will try various methods to help you learn the order of the metals in the reactivity series. Work with a partner.

Method 1: Mnemonics

Make up a mnemonic to help you remember the sequence of the metals in the reactivity series. (A mnemonic is a sentence in which the first letter of each word is the same as the first letter of the things you want to remember.) You could use either the first letters of the names of the metals or their symbols. Ask your partner to test you and then you test your partner. Write down your mnemonic for the reactivity series on a poster and share it with the class.

Method 2: Ordering cards

Write the names of the metals on individual pieces of card or paper. Try to arrange the cards in the correct order as fast as possible. Who was the most accurate? Who was the fastest?

Method 3: Pick a card

Use the cards from Method 2. Place them face down on the desk. One of you picks a card and shows it to your partner. The partner must name a metal that is more reactive than the one on the card and a metal that is less reactive than the metal on the card. If there are no metals more or less reactive than the one on the card, the partner must state that fact. Take it in turns to pick a card.

What methods do I find most helpful when I need to learn facts?

Displacement reactions

If you place a clean iron nail in a beaker containing copper sulfate solution, there is an interesting reaction.

The blue copper sulfate solution changes to a slightly paler colour. The most remarkable thing that happens is that the nail looks a different colour. It has become copper coloured. What has happened in this reaction?

The word and symbol equations for this reaction are:

copper sulfate + iron → iron sulfate + copper

$$CuSO_4 + Fe \rightarrow FeSO_4 + Cu$$

The iron nail has become coated with copper. Iron is more reactive than the copper that it has 'pushed out' from the copper sulfate and has reacted to form iron sulfate. This 'pushing out' is called displacement, so this type of reaction is called a **displacement reaction**. A more reactive metal can replace a less reactive one in a salt.

If a copper nail was placed in a solution of iron sulfate there would be no reaction because copper is less reactive than iron. Copper cannot displace the iron in the iron sulfate.

Questions

Use the reactivity series to answer these questions.

6 Which is the more reactive metal: zinc or copper?

7 Can zinc displace the copper in copper sulfate?

8 Which is more reactive – silver or magnesium?

9 Can silver displace the magnesium in magnesium sulfate?

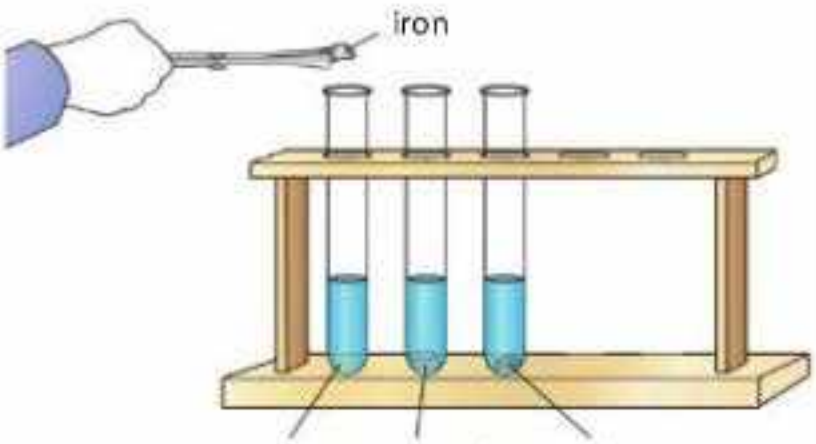
Think like a scientist

Displacing metals

You will need:

- solutions of copper sulfate, magnesium sulfate, iron sulfate and zinc sulfate; small pieces of the metals iron, zinc, copper and magnesium; test tubes, test tube rack, forceps, safety glasses.

Method



1. Read through all the instructions and prepare a results table. (You will need to think about this carefully – there are lots of different results to record.)
2. Pour copper sulfate solution into three test tubes so that each is about a third full.
3. Add a small piece of iron to one test tube, a small piece of magnesium to the second and a small piece of zinc to the third test tube.
4. Leave the test tubes for a few minutes.
5. Observe carefully and record your observations.
6. Repeat steps 2 to 5 using magnesium sulfate solution and the three metals copper, iron and zinc.
7. Repeat steps 2 to 5 using iron sulfate solution and the three metals copper, magnesium and zinc.
8. Repeat steps 2 to 5 using zinc sulfate solution and the three metals copper, iron and magnesium.

Questions

1. How do you know that one metal has displaced another from its salt?
2. Which of the four metals was the most reactive?
3. Which of the four metals was the least reactive?

Summary checklist

- [ ] I can use the reactivity series of metals to predict which metals will displace others from a solution of their salts.
- [ ] I can carry out some displacement reactions safely.

5.2 Using the reactivity series and displacement reactions

In this topic you will:

- use displacement reactions to identify an unknown metal
- learn about some useful displacement reactions.

Getting started

Work with a partner. One of you writes down the name of a metal in the reactivity series in the middle of a piece of paper. Pass the paper to your partner and they add the name of the metal that is just above or just below the first metal. Then the first person adds the name of the metal that is just above or below the metals on the paper. Do this until you have completed the reactivity series. Share your list with the class. How well did you do?

Key words

molten
ores

Using displacement reactions

Using the fact that more reactive metals can displace less reactive ones from their salts can be very useful in a number of ways. It is possible to use displacement reactions to help identify an unknown metal.

Think like a scientist

Identifying a mystery metal

Your task is to identify a mystery metal. It is one of the metals listed on the reactivity series. You are going to investigate which metal it could be. You can make observations of the metal; for example, you can investigate its appearance and its reactions with water, oxygen and dilute acid. This will give you some useful information. You could also use displacement reactions.

Part 1: Planning the investigation

Plan an investigation to identify the mystery metal. You must use some displacement reactions.

Safety

You do not know what this metal is, so treat it with care and pick it up using forceps.

Method

1 First, you will need to identify the equipment and chemicals you will use.
2 Write a step-by-step method of what you will do.
3 For each part of the investigation, indicate what information you will get from that part, and how it will help you to identify the mystery metal.

Part 2: Carrying out the investigation

When you have shown your plan to the teacher and had it approved you may carry out the investigation.

Safety

Make sure you have carried out a risk assessment.

Method

1 Record the results of each test you carry out.
2 If you decide to change your plan as you get more information about the mystery metal, ask your teacher first.
3 Keep a record of any changes you decide to make to your plan and the reasons for the change.

Questions

1 What do you think the mystery metal is?
2 Give reasons for your answer. Explain how the results of each test you carried out helped you decide what the mystery metal is.
3 Did you change your plan as you got more information about the metal? Explain how and why you changed your plan.

Using displacement reactions in industry (extension material)

Aluminium is a metal that is above zinc and below magnesium in the reactivity series shown in Topic 5.1. Aluminium will displace iron from solid iron oxide if it is heated.

aluminium + iron oxide → aluminium oxide + iron

This reaction releases a lot of energy. It is an exothermic reaction. The temperature gets so high that the iron that is produced is **molten** (in a liquid state). The melting point of iron is 1535 °C.

In the photograph you can see the reaction being used to weld railway rails together. Often, the rails need to be welded in situ (in other words, on the railway lines and not in a workshop where you have all the welding equipment you will need). The iron oxide and aluminium powder react in a container placed on the rails. The molten iron produced in the reaction is shaped and used to join the rails together. This reaction is called the thermite reaction.

In order for the thermite reaction to take place, the iron oxide and aluminium mixture has to be ignited. This is done using another exothermic reaction – this time between magnesium powder and barium nitrate. This reaction provides the energy to start the displacement reaction between the aluminium and iron oxide.

Displacement using carbon (extension material)

Carbon is not a metal, but it can be used to displace some metals from their compounds. Carbon will displace zinc, iron, tin and lead from their **ores**. An ore is a rock that contains a metal compound.

People discovered that carbon could displace iron around 3500 years ago. They discovered that iron ore heated with charcoal (a form of carbon) at very high temperatures produced molten iron. Today this displacement reaction is still carried out, but on a large scale, in a blast furnace.

The iron ore is mainly iron oxide. This reacts with carbon to form iron and carbon dioxide.

The word equation for this reaction is:

iron oxide + carbon → iron + carbon dioxide

A modern blast furnace

The controls in a modern blast furnace

Questions

1 Can iron displace aluminium from aluminium oxide? Explain your answer.

2 Why is the thermite reaction useful for welding rails?

3 The early blast furnaces were in areas where there were supplies of iron ore and a lot of coal mining. Why do you think this was?

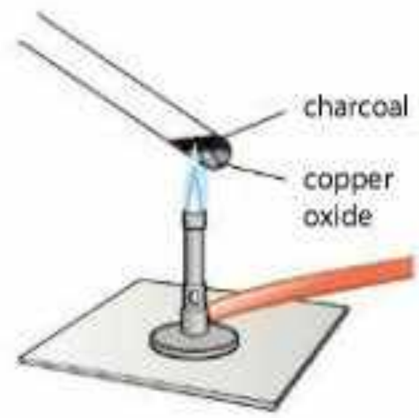
Think like a scientist

Extracting metals using carbon

In this task you will use carbon to try to displace a metal from its oxide. Remember that carbon will only displace a metal that is less reactive than itself.

You will need:

- safety glasses, copper oxide powder, charcoal powder, spatula, test tube or boiling tube, heatproof mat, Bunsen burner



Method

Remember your safety! Wear safety glasses.

1 Place a spatula of copper oxide in a test tube or boiling tube.

2 Add a spatula of charcoal powder on top of the copper oxide. Do **not** mix the powders together.

3 Heat the two layers strongly in a Bunsen flame for five minutes.

4 Allow the tube to cool and then look carefully at where the layers meet.

5 Record your observations.

Questions

1 Has there been a reaction between the copper oxide and the carbon? Give reasons for your answer.

2 If there has been a reaction, write a word equation for it.

3 What evidence does this experiment give you about the reactivity of carbon?

4 Where would you place carbon in the reactivity series? Give a reason for the position you suggested.

What things do you need to think about when carrying out practical work so that you stay safe?

Summary checklist

- [ ] I can use displacement reactions to help identify an unknown metal.
- [ ] I can describe some useful displacement reactions.

5.3 Salts

In this topic you will:

- explain what a salt is
- give some examples of salts and their uses
- prepare a salt by reacting a metal with an acid
- prepare a salt by heating a metal oxide with an acid.

Getting started

- With a partner, write word equations for **three** displacement reactions.
- Now write word equations for **two** displacement reactions that cannot happen.
- Write all five equations on a piece of paper and swap them with another pair of learners.
- Can you identify the reactions that would not take place?

Key words

carbonate
chloride
citrates
crystallisation
formula (plural: formulae)
nitrate
salt
sulfate

What is a salt?

When you think about **salt**, you probably think of the salt you put in your food as flavouring. This is sodium **chloride**. You have met other salts during your science course: copper **sulfate**, silver **nitrate** and calcium **carbonate**, for example.

Many salts have important uses in everyday life. The photographs show some examples.

Sodium chloride salt is used to preserve food and, as table salt, to flavour food.

Gymnasts use the salt magnesium carbonate to keep their hands dry so that they do not slip on the apparatus.

Calcium sulfate is a salt that is used to make blackboard chalk.

Aluminium sulfate is added to dyes to help them stick to fibres.

These soya seeds are coated with copper sulfate. It stops fungi growing on the seeds when they are planted.

Ammonium nitrate is used as a fertiliser to help crops to grow well.

Acids and salts

Every day, the chemical industry makes hundreds of thousands of tonnes of different salts. Many of the methods for making salts start with acids.

All acids contain hydrogen. The table below gives you the **formulae** of the three common acids you find in the laboratory. The table also shows some examples of the salts that can be formed from these acids.

Two other acids you may meet are carbonic acid and citric acid. Carbonic acid is a weak acid that is formed when carbon dioxide reacts with water. Salts made from carbonic acid are called carbonates. Citric acid is found in fruits, such as oranges and lemons. Salts formed using citric acid are called **citrates**.

Name of acid	Formula	Salts formed from the acid	Example of salt	Formula of salt
hydrochloric acid	HCl	chlorides	sodium chloride	$NaCl$
sulfuric acid	H_2SO_4	sulfates	copper sulfate	$CuSO_4$
nitric acid	HNO_3	nitrates	potassium nitrate	KNO_3

Questions

1 Think about what you have already learnt about acids.

   a What are the properties of acids?

   b Name some everyday products that contain acids.

2 Which elements are present in nitric acid?

3 Which elements are present in sulfuric acid? How many atoms of each element make up one particle of sulfuric acid?

4 a What is similar about the formula for hydrochloric acid and the formula for sodium chloride?

   b What is different about these two formulae?

5 The illustration below shows a label on a jar of orange jam.

> **ALLERGY ADVICE:** NO NUTS.
>
> SUITABLE FOR VEGETARIANS.
>
> **INGREDIENTS:** SUGAR, ORANGES, WATER, CONCENTRATED LEMON JUICE, SODIUM CITRATE, CITRIC ACID, BITTER ORANGE OIL.
>
> PREPARED WITH 30 G OF FRUIT PER 100 G.

   a Which ingredient is a salt?

   b Do some research to find out why this ingredient is added to some kinds of food.

Activity 5.3.1

Researching a salt

Choose a salt to research. You could use one of those mentioned in this topic or choose another. You should use the internet or library to find the answers to these questions:

- How is this salt obtained or made?
- What is the salt used for?

Present what you have found out in an interesting way. You could make a poster, give a short talk or make a slide show.

How can I find out where else salts are used in everyday life?

Making salts using a metal and an acid

You have reacted metals with dilute acids before. It is often a good way to make salts.

The general equation for the reaction of metals with acid is:

acid + metal → salt + hydrogen

The word and symbol equations for the reaction between zinc and hydrochloric acid are:

zinc + hydrochloric acid → zinc chloride + hydrogen

$$Zn + 2HCl \rightarrow ZnCl_2 + H_2$$

Zinc reacting with hydrochloric acid

Questions

6 Which of the compounds in the above equation is a salt?

7 Which acid would you add to the metal magnesium to make the salt magnesium sulfate?

8 Write the word equation for the reaction between iron and hydrochloric acid.

9 Why would it be dangerous to prepare sodium chloride by reacting sodium with hydrochloric acid?

Think like a scientist

Making the salt zinc sulfate

You will need:

- 250 cm^3 beaker, dilute sulfuric acid, measuring cylinder, zinc metal, evaporating basin, pipeclay triangle and tripod, Bunsen burner, tongs, heatproof mat, safety glasses.

Safety

Be careful when heating the evaporating basin as the solution may spit and burn you.

Method

1 Pour about 50 cm^3 of sulfuric acid into a 250 cm^3 beaker.

2 Add 1–5 g zinc metal to the acid in the beaker.

3 Once the mixture stops fizzing pour it into the evaporating dish.

4 Heat the evaporating dish very gently until you see crystals forming at the edge of the solution.

5 Remove from the heat and leave for a few days to form crystals. This is the process of **crystallisation**. If you need to remove the evaporating basin from the tripod, use a pair of tongs and place the evaporating basin on a heatproof mat.

Questions

1 Write the word equation for this reaction.

2 What are the important practical points you will need to consider when you evaporate this solution?

3 Which do you think is the better way to produce large crystals – heating the evaporating dish until there is very little liquid left or leaving it to evaporate slowly?

4 How could you investigate which is the best way to produce large crystals?

Making salts using a metal oxide

Some metals will not react with acids to make salts. For example, silver and copper are too unreactive to displace hydrogen from an acid, so we have to find another way of making salts from unreactive metals. We can do this by starting with a metal oxide.

The general equation for this reaction is:

metal oxide + acid → salt + water

In this example we can make copper sulfate by heating copper oxide with sulfuric acid. The word and symbol equations for this reaction are:

copper oxide + sulfuric acid → copper sulfate + water

$$CuO + H_2SO_4 \rightarrow CuSO_4 + H_2O$$

Think like a scientist

Making the salt copper sulfate

Work out what equipment you will need to make copper sulfate.

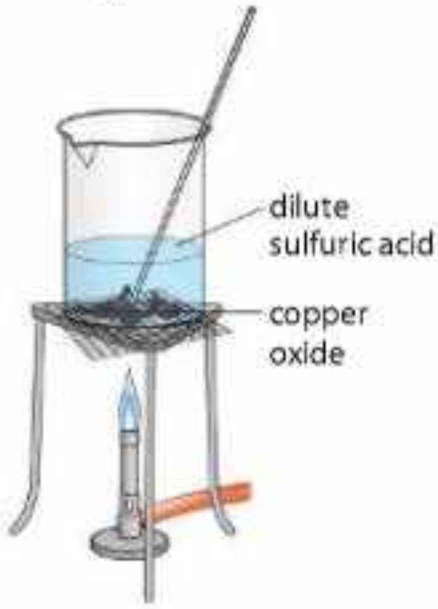
Consider the risks you might encounter as you carry out the operation and how you can reduce them.

Safety

Remember not to boil the acid. Use low heat. Be careful when heating the evaporating basin as the solution may spit and burn you.

Method

1. Pour about 100 cm^3 of dilute sulfuric acid into a 250 cm^3 beaker. Add black copper oxide powder to the acid in the beaker.
2. Heat the mixture very gently, stirring all the time.



Continued

3 When the mixture changes colour to blue, turn off the heat. Allow the mixture to cool.

4 Filter the mixture. The filtrate is a solution of copper sulfate. Pour this into an evaporating basin.

5 Place the evaporating basin on the pipeclay triangle on the tripod and heat very gently until you see crystals forming at the edge of the solution. Remove from the heat and leave for a few days to crystallise.

Questions

1 Make a list of the equipment you will need.

2 Write a risk assessment for each stage of the process.

3 Suggest why the mixture was filtered.

4 Suggest how you could use a similar method to make copper chloride.

5 Write the word equation for the reaction to make copper chloride from copper oxide.

6 Write the word equation for the reaction between copper oxide and nitric acid.

Summary checklist

- [ ] I can explain what a salt is.
- [ ] I can list some examples of salts and state their uses.
- [ ] I can prepare a salt safely by reacting a metal with an acid.
- [ ] I can prepare a salt safely by heating a metal oxide with an acid.

› 5.4 Other ways of making salts

In this topic you will:

- prepare a salt by using an acid and a carbonate
- prepare a salt using neutralisation
- carry out risk assessments for practical work
- use word and symbol equations.

Getting started

Make a list of the properties of acids and of alkalis (for example: pH of more than 7, all contain hydrogen, turn universal indicator solution blue). Make sure the properties of acids and alkalis are mixed together. Exchange your list with a partner and sort the properties into those of acids and those of alkalis. How well did you do?

Key words

bases
crystallise
erodes
limestone
neutralisation

Metal carbonates and acids

Carbonates – such as calcium carbonate – are salts. Carbonates can be formed by the reaction of a metal with carbonic acid.

We can use carbonates to form other salts by reacting them with an acid.

For example:

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

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

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

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

acid + carbonate → salt + water + carbon dioxide

The line above shows the general equation for these reactions. The rock **limestone** is made of calcium carbonate. It is damaged when it reacts with acid rain and **erodes**.

The skeletons of coral are made from calcium carbonate and react with acids. This happens when the oceans become slightly more acidic as more carbon dioxide dissolves in the water.

This piece of coral is reacting in hydrochloric acid. How can you tell that a reaction is taking place?

Questions

1. Write the word equation for the reaction between magnesium carbonate and nitric acid.
2. Write the symbol equation for the reaction between magnesium carbonate and sulfuric acid.
3. How could you check that the gas given off in these reactions is carbon dioxide?

Think like a scientist

Preparing a salt from acid and a carbonate

You are going to prepare copper chloride, using the reaction between copper carbonate and hydrochloric acid.

Work out what equipment you will need to make copper chloride.

Consider the risks you might encounter as you carry out the operation and how you can reduce them.

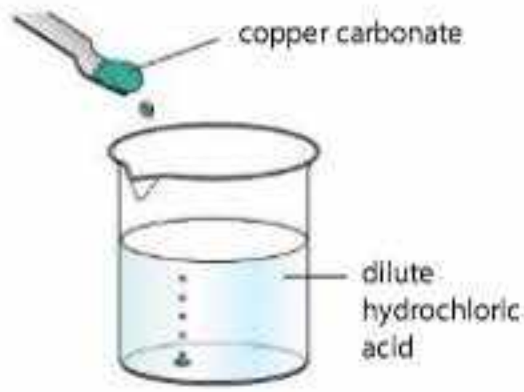
Safety

Take care when heating the solution (step 5), as it may spit and burn you.

Method

1 Place 25 cm^3 of hydrochloric acid in a small beaker.

2 Add a spatula of copper carbonate.



3 Add more copper carbonate until it stops reacting. You should have a small amount of unreacted copper carbonate left in the beaker. (This is called adding excess copper carbonate. It makes sure that all the acid has reacted.)

4 To purify your copper chloride you will need to remove the excess copper carbonate. Filter the mixture. The unreacted copper carbonate will be trapped in the filter paper.

5 Pour the filtrate into an evaporating basin and heat it gently. This will remove the water and leave you with pure copper chloride.

6 Stop heating the evaporating basin when you see some crystals around the edge of the solution.

7 Leave for a few days to cool and evaporate slowly to **crystallise**.

Continued

Questions

1 Read through the method and make a list of all the equipment you will need.

2 Carry out a risk assessment for each step of the method.

3 What did you observe when you added copper carbonate to the hydrochloric acid?

4 Which gas is given off during this reaction?

5 Write the word equation for your reaction.

6 Describe the appearance of the copper chloride you have made.

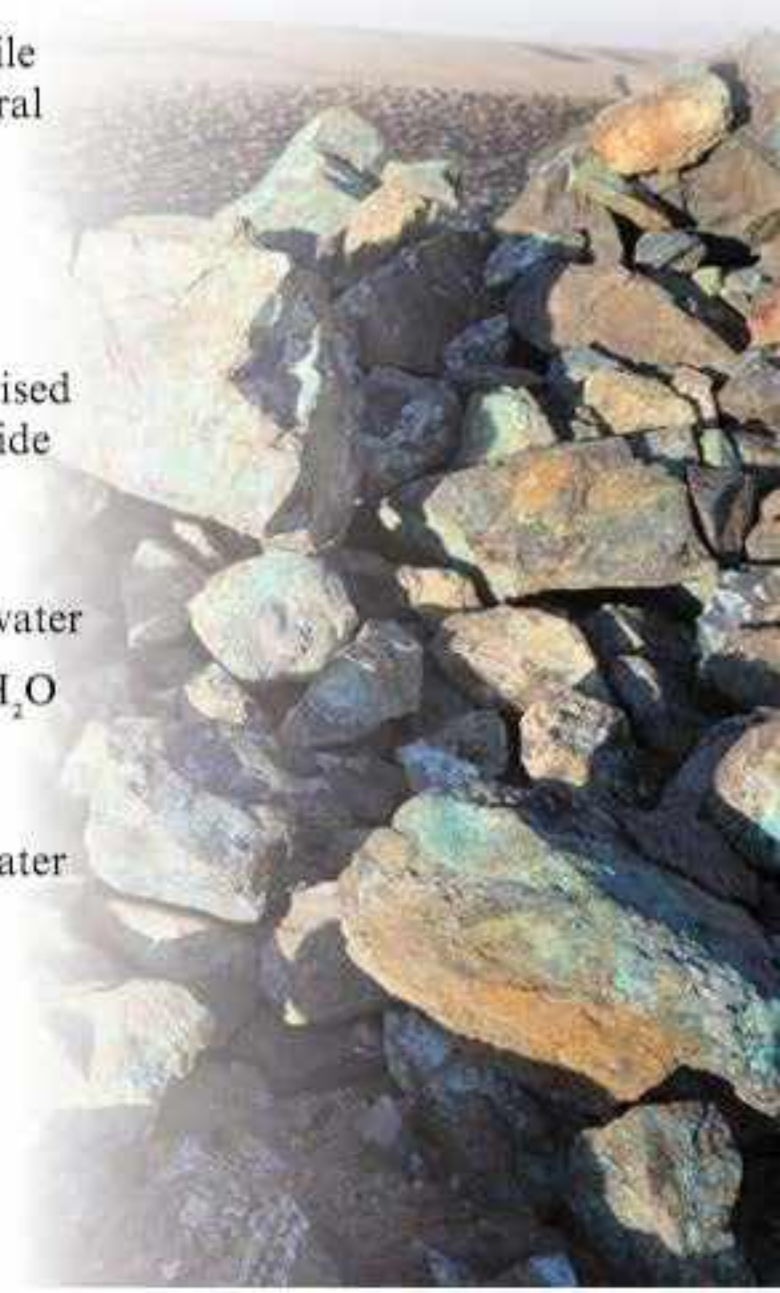
7 Which substances in your word equation are salts?

8 Using your observations from this experiment, what can you say about the solubility of copper carbonate and copper chloride in hydrochloric acid? (Think about what happened when you filtered the liquid from the beaker.)

9 Suggest how you could use copper carbonate to make copper sulfate.

How did writing a risk assessment help you to think about what you could do to avoid any safety problems?

Salts in rocks



The blue-green colours in these rocks in the Atacama Desert in Chile tell you that they contain copper salts. This bright blue-green mineral in the rock is called malachite. It is made from copper carbonate.

Forming salts by neutralisation

Alkalis react with acids to neutralise them. When an acid is neutralised by an alkali, a salt is produced. For example, when sodium hydroxide reacts with hydrochloric acid, the salt sodium chloride is formed. The other product is water.

sodium hydroxide + hydrochloric acid → sodium chloride + water

$$NaOH + HCl \rightarrow NaCl + H_2O$$

The general equation for **neutralisation** reactions is:

acid + alkali → salt + water

Questions

4 How can you test to see if a liquid is an acid or an alkali?

5 What word is used to describe a solution that is neither acid nor alkali?

6 What are the properties of alkalis?

Think like a scientist

Preparing a salt by neutralisation

Work out what equipment you will need to make a salt by neutralisation.

Consider the risks you might encounter as you carry out the operation and how you can reduce them. Before you begin the practical work, answer questions **1** and **2**.

Safety

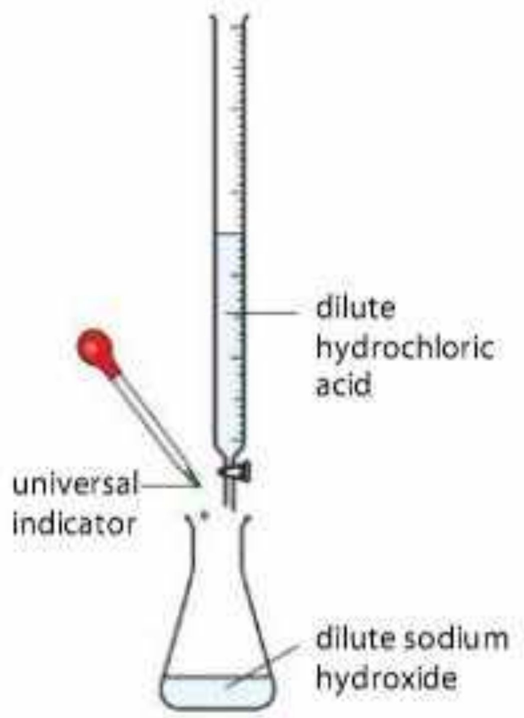
Take care when heating the filtrate (step 8), as it may spit and burn you.

Method

1 Place hydrochloric acid in a burette.

2 Measure out 20 cm^3 of the sodium hydroxide into a small flask.

3 Add a few drops of universal indicator solution.



4 Add the acid from the burette slowly, swirling the flask (moving it gently round) as you add the acid.

5 When the universal indicator changes to green you have produced a neutral solution.

Continued

6 Add a spatula of charcoal powder to the green solution. Mix it with a glass rod. The charcoal takes the green colour of the universal indicator out of the solution.

7 Filter the mixture.

8 Place the filtrate into an evaporating basin and heat gently.

9 Stop heating when you see some crystals around the edge of the solution.

10 Leave the evaporating basin for a few days. The water will evaporate slowly, leaving crystals of the salt.

Questions

1 Read through the method and make a list of all the equipment you will need.

2 Carry out a risk assessment for each step of the method.

3 What colour is the universal indicator solution in the sodium hydroxide?

4 What colour is universal indicator solution in a neutral solution?

5 Why do you need to swirl the flask as you add the acid?

6 Imagine that you accidently add too much acid from the burette. What could you do to form a neutral solution?

7 What salt is formed in this reaction?

8 Write the word equation for this reaction.

9 Describe the salt crystals you obtained.

Alkalis and bases

When a metal oxide dissolves in water, it forms an alkaline solution. Metal oxides are called **bases**. Soluble metal bases form alkalis when they dissolve in water.

For example:

sodium oxide + water → sodium hydroxide

Sodium oxide is a base. The sodium hydroxide is an alkali.

Some metal oxides are not soluble in water, for example iron and copper oxide. So they do not form alkalis. But they can still react with acids to form salts.

copper oxide + sulfuric acid → copper sulfate + water

$$CuO + H_2SO_4 \rightarrow CuSO_4 + H_2O$$

Questions

7 What is the difference between a base and an alkali?

8 Write the word equation for the reaction between magnesium oxide and sulfuric acid.

9 Write the symbol equation for the reaction between magnesium oxide and sulfuric acid.

10 Suggest how you could use iron oxide to make iron chloride.

How does writing an equipment list help me to think about what I need to do in a practical task?

Summary checklist

- [ ] I can prepare a salt using neutralisation.
- [ ] I can write risk assessments for practical tasks.
- [ ] I can use word and symbol equations.

5.5 Rearranging atoms

In this topic you will:

- look at the rearrangement of atoms in chemical reactions
- learn what happens to the mass of reactants and products in a reaction
- learn what happens to the energy involved in chemical reactions
- carry out practical work safely.

Getting started

- On a piece of paper write down the formulae for five compounds, write each one on a new line.
- Then write the names of an acid, a salt, an alkali and a metal oxide, write each one on a new line.
- Swap your paper with a partner and try to write the name of the compound against each formula and write the formula against each name.
- How well did you do? Were all the formulae that were written correct?
- Discuss them with your partner.

Key words

crucible

endothermic reactions

exothermic reaction

the law of conservation of energy

the law of conservation of mass

Looking at chemical reactions

In chemical reactions, atoms form new combinations. Atoms that are on their own may join together with other atoms. Atoms that are bonded with other atoms may separate, forming new combinations with other atoms.

In the reaction between iron and sulfur, the iron and the sulfur atoms that were there at the start of the reaction are still there at the end. They have just rearranged themselves. We can represent this reaction by drawing the atoms, writing a word equation or by writing a symbol equation.

$Fe + S \longrightarrow FeS$

iron + sulfur ⟶ iron sulfide

In a chemical reaction, no atoms are lost. No new atoms are produced. The atoms are simply rearranged into new combinations.

When you look at any of the equations for the reactions in this topic you can see that the elements that are present in the reactants are also present in the products.

Here is the equation for the reaction between magnesium and hydrochloric acid.

$Mg + HCl \longrightarrow MgCl_2 + H_2$

magnesium + hydrochloric acid ⟶ magnesium chloride + hydrogen

The magnesium metal in this reaction is a reactant. The magnesium is still present in the products as part of the salt magnesium chloride. The element hydrogen is present in the reactants as part of the compound hydrochloric acid. In the products it is present as hydrogen gas. The element chlorine is present in the reactants as part of the compound hydrochloric acid and in the products it is part of the salt magnesium chloride.

This is an important idea. No element that is present in the reactants disappears from the products. No new element appears in the products.

Look carefully at the symbol equation. Not only does it tell you which elements are present in the reactants and products but how many of each atom is present. In the reactants there is one atom of magnesium and in the products there is one atom of magnesium. In the reactants there are two atoms of hydrogen and in the products there are two atoms of hydrogen. In the reactants there are two atoms of chorine and in the products there are two atoms of chlorine.

Questions

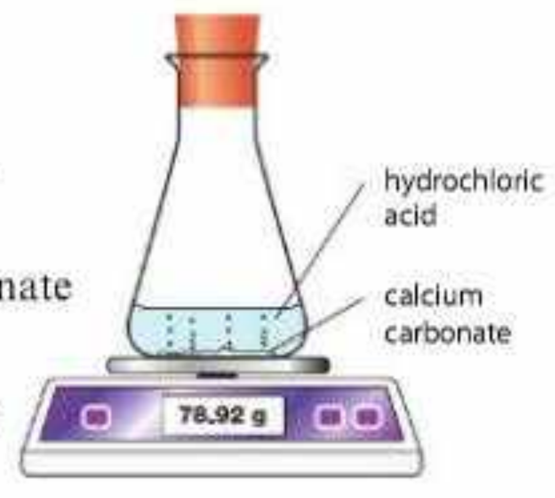
1 Look back at the reaction between copper carbonate and hydrochloric acid in Topic 5.4.

- **a** Which product of this reaction contains the element copper?
- **b** Which reactant contains the element hydrogen?
- **c** Which product contains the element hydrogen?
- **d** Which reactant contains the element carbon?
- **e** Which product contains the element carbon?

2 In the reaction between copper oxide and sulfuric acid in Topic 5.3:

- **a** Atoms of which elements are present at the start of the reaction?
- **b** How many of each kind of atom are represented in the reactants shown in the equation?
- **c** Atoms of which elements are present at the end of the reaction?
- **d** How many of each kind of atom are represented in the products shown in the equation?

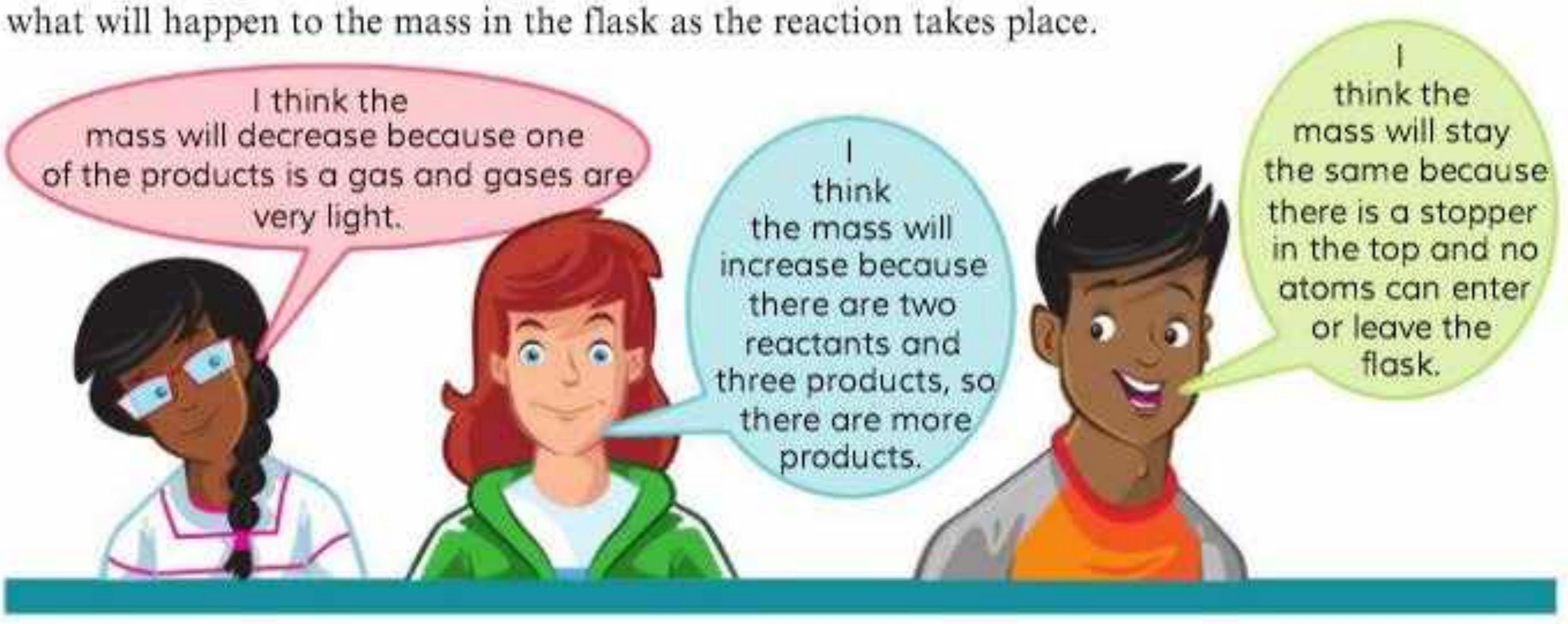
Conservation of mass



Atoms have mass. If no atoms are gained or lost during a chemical reaction, then no mass is gained or lost either.

Zara, Sofia and Arun carry out the reaction between calcium carbonate and hydrochloric acid.

They place some calcium carbonate in a flask, add the hydrochloric acid and place the stopper in the top of the flask. They place the flask on a top pan balance. They each have different ideas about what will happen to the mass in the flask as the reaction takes place.



When the three students carry out the reaction they find that the mass has not changed. Arun's idea was correct and so was his reason.

In chemical reactions the elements you begin with are the ones you end the reaction with. Nothing is added or taken away. The mass you begin with is the mass you end with.

This important idea is called **the law of conservation of mass.**

Think like a scientist

The law of conservation of mass

You will need:

- safety glasses, top pan balance, flask with stopper, calcium carbonate, dilute hydrochloric acid

Method

Place some calcium carbonate in a flask, add hydrochloric acid and place the stopper in the top of the flask. Place the flask on a top pan balance. Observe the reading on the top pan balance.

Questions

1 What did you observe happening in the flask?

2 Write a word equation for this reaction.

3 Which salt is made in this reaction?

4 Some students found the mass of each piece of apparatus and each chemical separately before they mixed the chemicals together in the flask, put the stopper in and placed the flask on the top pan balance. Do you think the mass of all the items added together will be the same as the reading on the balance at the end of the reaction? Give a reason for your answer.

Questions

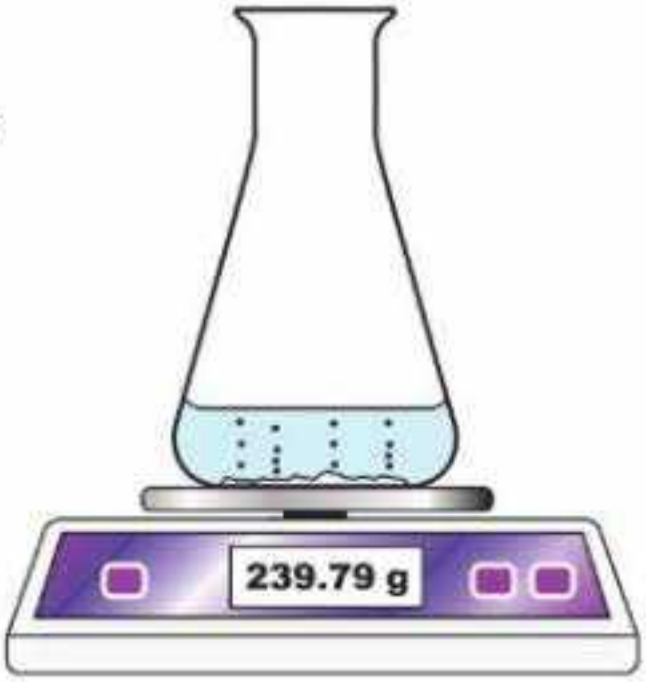
3 A learner reacts 37g of magnesium with 150g of sulfuric acid. What will be the total mass of the products of this reaction?

4 If a learner starts with 10g of magnesium in the reaction above, how much magnesium will be present in the magnesium sulfate that is produced?

Not the results you expect?

When you add calcium carbonate to hydrochloric acid, there is a chemical reaction.

Arun places a flask of hydrochloric acid on a top pan balance and carefully adds calcium carbonate. He measures the mass of the flask and the contents at the beginning of the reaction and after 10 minutes. These are his results:



Time in minutes	Mass of flask and contents in g
0	250
10	207

The law of conservation of mass tells you that there must be the same mass at the end of the reaction as at the start. In Arun's experiment the mass appears to decrease. Why is this?

The word equation for this reaction is:

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

The carbon dioxide gas escapes into the air because the flask is open. You then cannot measure its mass. So, it appears as if the mass decreases as the reaction continues. The elements present are all present in the products. Remember, water is made from hydrogen and oxygen atoms.

Questions

5 In the reaction between calcium carbonate and hydrochloric acid:

a Which **one** of the reactants contains the element oxygen?

b Which **two** of the products contain the element oxygen?

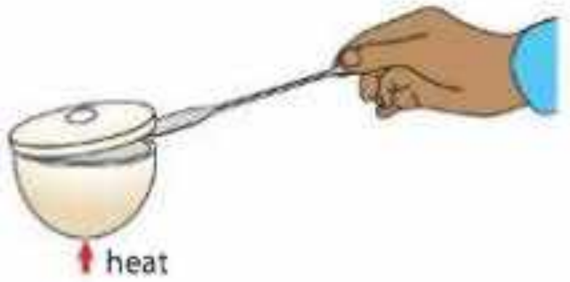
c Where does the element hydrogen in the water come from in this reaction?

6 Explain what Arun should have done to show that mass is conserved in a chemical reaction.

Another surprising result

Here is another reaction that produces a result that is a surprise to some people.

Some magnesium is placed in a **crucible**, and the mass of the crucible with the magnesium is recorded. The crucible is heated very carefully. The lid of the crucible is lifted from time to time during the heating to allow the air in. After heating, the mass of the crucible with contents is measured again.



A reaction takes place when the magnesium is heated. After the reaction, the crucible contains white ashes. The mass of the ashes is more than the mass of the magnesium at the start of the reaction.

Some people think that the ashes will be lighter because the ashes look smaller than the magnesium. They see the flames escaping from the crucible, so they think something has been lost.

However, the word equation explains what happens.

magnesium + oxygen → magnesium oxide

There is an increase in mass because oxygen from the air has combined with the magnesium.

A French scientist called Antoine Lavoisier carried out this experiment in 1772. He repeated it many times and found he had an increase in mass every time. He could not explain why this happened. Finally he came up with the idea that when something burns it combines with a gas from the air. He also found that the gas from the air that is involved in burning is involved in respiration as well. He named the gas oxygen.

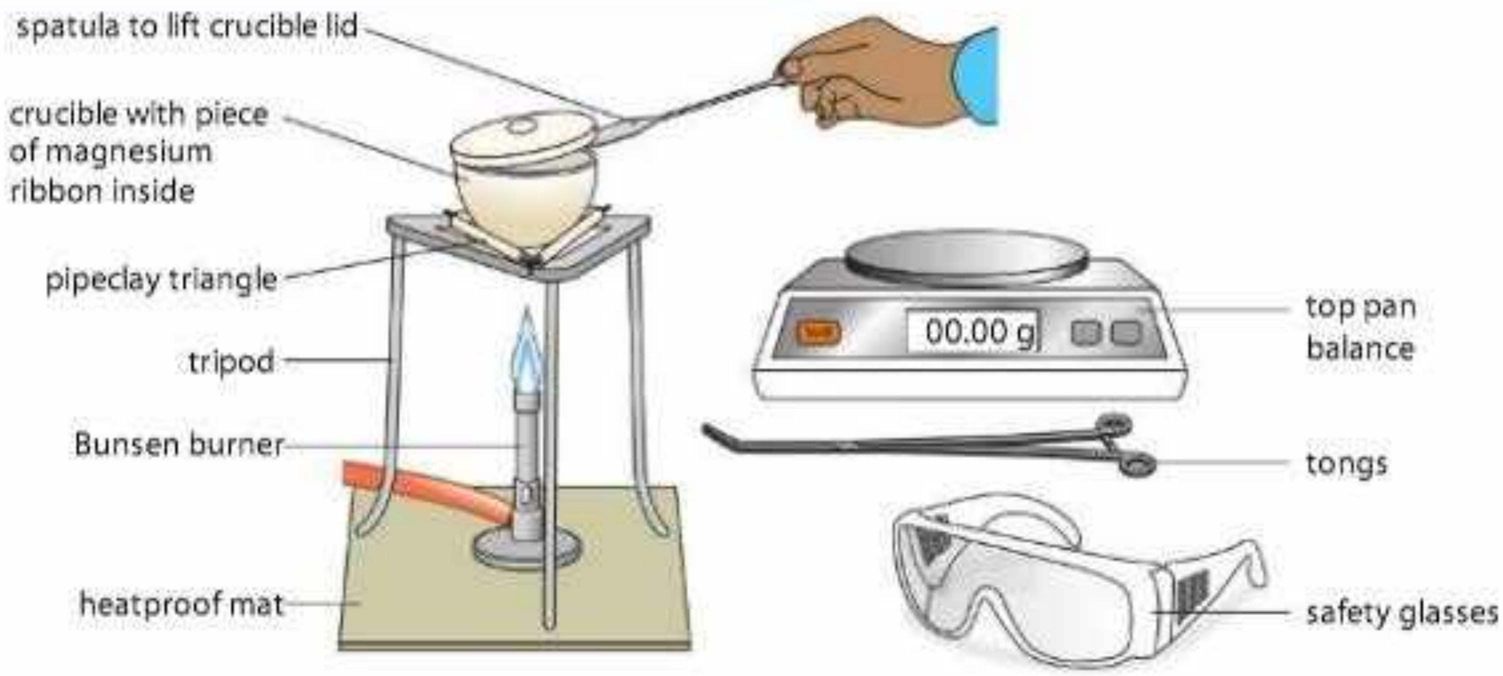
These early scientists managed to get accurate results with very simple equipment. How can I ensure my results are always as accurate as possible?

Think like a scientist

Burning magnesium in air

You will need:

- the apparatus shown in the diagram.



Method

1. Find and record the mass of the crucible and lid.
2. Place a piece of magnesium ribbon in the crucible and find and record the mass of the crucible, lid and magnesium.
3. Calculate the mass of the magnesium.
4. Assemble the apparatus as shown in the diagram. During the heating process you will need to lift the lid from time to time to allow the air to enter. Use a spatula or the tongs and be careful so that none of the ash inside is lost. The contents of the crucible will glow and change. The crucible will remain hot for a long time – do not touch it. Once there is no more reaction, allow the crucible to cool.
5. Find and record the mass of the cool crucible, lid and contents.
6. Calculate and record the mass of the contents.
7. Calculate the difference between the mass of the magnesium and the mass of the product after heating.

Continued

Questions

1 What has happened to the mass after heating?

2 Explain why this has happened.

3 What is the name of the product of this reaction?

4 What safety risks are there in this experiment?

5 Why did you need to lift the lid of the crucible from time to time?

6 What do you need to be careful about to make sure none of the product is lost before you find its mass?

Energy and chemical reactions

All chemical reactions involve energy.

Energy is used to break bonds in the reactants and energy is released when new bonds are formed in the products. When metals react with water or acids, energy is released, as thermal energy or sometimes as light or sound or kinetic energy. For example, in the reaction between potassium and water the potassium catches fire, gets so hot that it melts, burns with a pinkish purple flame and hisses or explodes. It also moves across the surface of the water.

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

potassium + water → potassium hydroxide + hydrogen

In this reaction, less energy is needed to break bonds in the reactants than is released when bonds form in the products. This is an **exothermic reaction**.

In other chemical reactions it takes more energy to break bonds in the reactants than is released when the bonds form in the products. These reactions are called **endothermic reactions** and they take in energy. For example:

sodium hydrogencarbonate + citric acid → sodium citrate + water + carbon dioxide

This reaction happens when we eat sherbet sweets. They give us a cool refreshing feeling in our mouth when we eat them.

When this reaction takes place, energy is transferred from the environment (your mouth). The energy is transferred to chemical energy stored in the bonds of the products.

Whether a chemical reaction takes in energy or releases energy there is no overall change in the amount of energy during the reaction. This is because energy cannot be created or destroy. This is **the law of conservation of energy**.

Energy may be transferred from one form to another but the same amount of energy remains after the reaction as before. This is true of every chemical reaction.

Summary checklist

- [ ] I can use word and symbol equations to describe chemical reactions.
- [ ] I can explain what is meant by the law of conservation of mass.
- [ ] I can explain what is meant by the law of conservation of energy.
- [ ] I can carry out practical work safely.

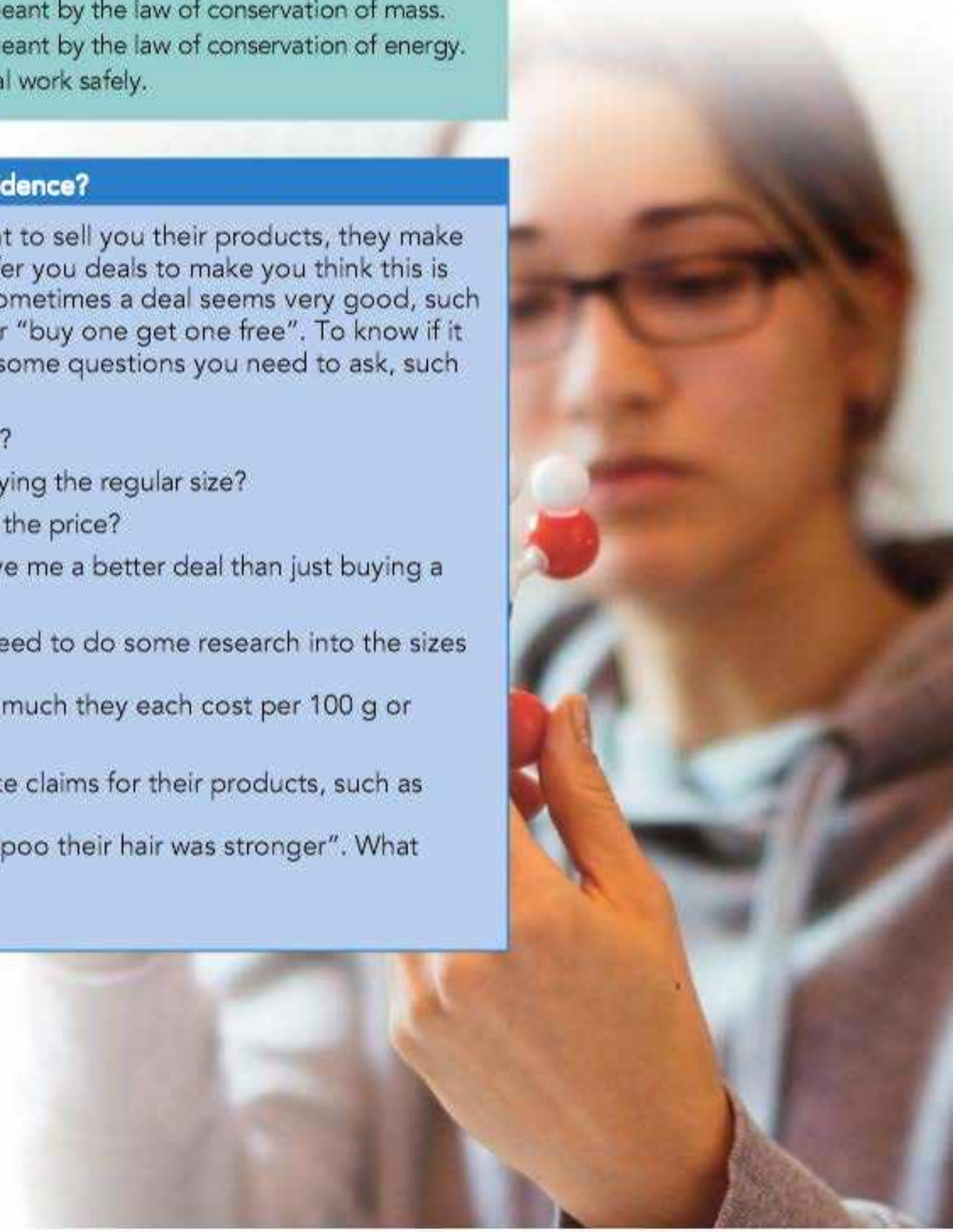
Project: Where is the evidence?

When manufacturers want to sell you their products, they make claims about them, or offer you deals to make you think this is the best brand to buy. Sometimes a deal seems very good, such as "50% extra for free" or "buy one get one free". To know if it is a good deal there are some questions you need to ask, such as:

- 50% more than what?
- Is it cheaper than buying the regular size?
- Have they increased the price?
- Does buying two give me a better deal than just buying a larger size?

To find out, you would need to do some research into the sizes and prices of the
packs and work out how much they each cost per 100 g or 100 cm^3.

Some manufacturers make claims for their products, such as "80% of women said
that after using this shampoo their hair was stronger". What does this mean?



Continued

Here are some points you will need to consider:

- Stronger than what?
- How do the women know this?
- How could you find out?
- How many women did they ask?

Which type of hair: long, short, curly or straight?

Another claim might be that this painkiller medicine gets to work on your body twice as fast.

Some points you will need to think about here are:

- Twice as fast as what?
- How do you know?
- How can you prove it?
- Would it work the same on everyone?

These advertisements are often worded very carefully because some countries have rules about what advertisements are allowed to say.

Some claims can be investigated, but others are much more difficult because they are subject to opinion.

Work in groups of two or three.

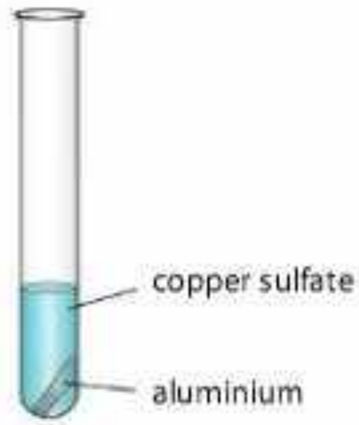
Your tasks:

1. Find out about the advertising rules in your country. Make a poster or other presentation to give a quick overview.
2. Choose one deal or advertisement based on the size of the item purchased, for example "50% extra free" or "buy one get one free". Work out if this is really a good deal or if buying the normal item is better value. Show how you worked this out and present your findings.
3. Choose one advertisement based on claims such as "kills 99% of germs" or "92% of women say this face cream reduced their wrinkles after two weeks". Make a list of the questions you will need to ask. What investigations could you carry out to test these claims? Can you prove if these claims are true?

Make a presentation of your findings.

Check your progress

5.1 Arun places a piece of aluminium metal in a test tube of copper sulfate.



A reaction takes place.

The word equation for this reaction is:

aluminium + copper sulfate → aluminium sulfate + copper

- **a** How can Arun tell that a reaction has taken place? **[1]**
- **b** Why is this reaction called a displacement reaction? **[1]**
- **c** Arun then places some zinc in a solution of lead nitrate. A displacement reaction takes place. Write a word equation for this reaction. **[2]**
- **d** He then places some copper into a solution of sodium chloride. No reaction takes place. Give a reason for this. **[1]**

5.2 (Extension question) The word equations below represent some displacement reactions.

aluminium + copper sulfate → aluminium sulfate + copper

aluminium + lead nitrate → aluminium nitrate + lead

lead + copper sulfate → lead sulfate + copper

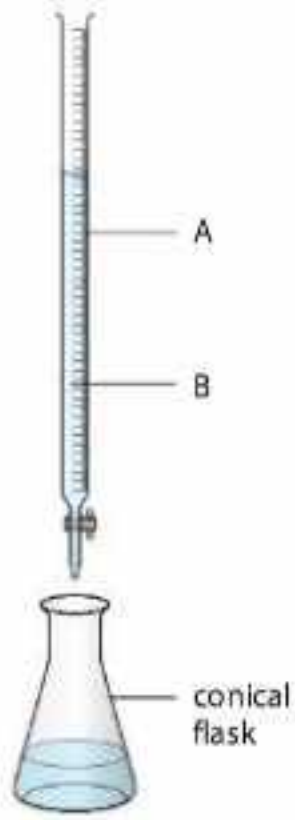
lead + silver nitrate → lead nitrate + silver

- **a** Use the word equations to decide which of the four metals, aluminium, copper, lead or silver, is the most reactive. **[1]**
- **b** Decide if a reaction will take place when lead is placed in a solution of magnesium sulfate. If you think there will be a reaction, write the word equation. **[1]**
- **c** Decide if a reaction will take place when iron is placed in a solution of lead nitrate. If you think there will be a reaction, write the word equation. **[1]**

5.3 The diagram shows an experiment where zinc metal is added to sulfuric acid.

- **a** What is the name of the gas given off in this reaction? [1]
- **b** How could you test for this gas? [2]
- **c** What salt is formed in this reaction? [1]
- **d** How do you know when all the acid has reacted? [1]
- **e** Write the word equation for this reaction. [2]

5.4 Zara is making crystals of the salt potassium chloride by neutralisation. The diagram shows some of her apparatus set up.



- **a** What is the name of the piece of apparatus labelled A? [1]
- **b** What is the name of the liquid labelled B? [1]
- **c** Describe how she can obtain crystals of the salt. [3]

6 Sound and space

> 6.1 Loudness and pitch of sound

In this topic you will:

- find out about the amplitude of a sound wave
- find out about the frequency of a sound wave
- learn how amplitude is linked to loudness
- learn how frequency is related to pitch
- learn how to recognise amplitude and frequency from a diagram of a sound wave (waveform).

Getting started

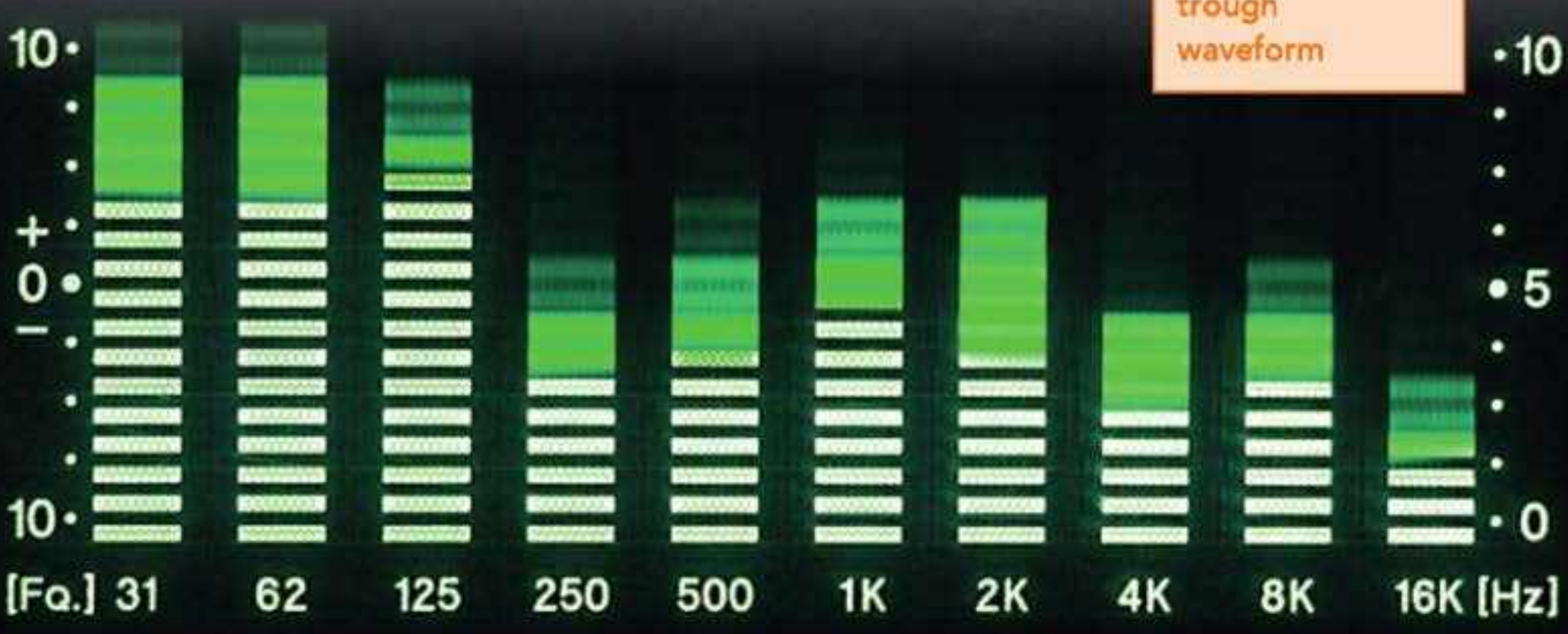
Work in groups to discuss answers to these questions.

1 Describe how a sound wave travels through air. Use ideas about particles in your answer.

2 What is common to all objects that make sound?

Key words

amplitude
frequency
loudness
oscilloscope
peak
pitch
trough
waveform



Loudness and amplitude

In Stage 7 you learnt that sound is made when objects vibrate.

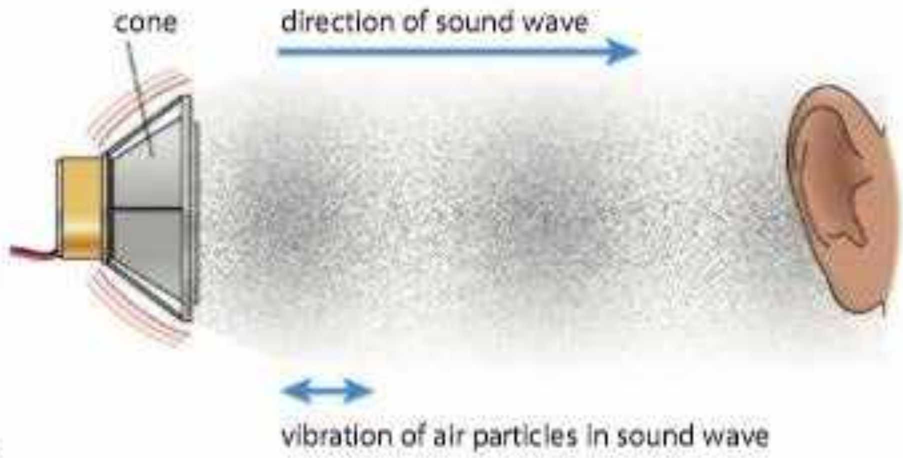
The **loudness** of a sound is a way to describe how quiet or loud a sound appears. Loudness depends on two variables:

- how much the object is vibrating – the greater the distance of each vibration, the louder the sound
- how far away the vibrating object is – the further away the quieter the sound that we hear.

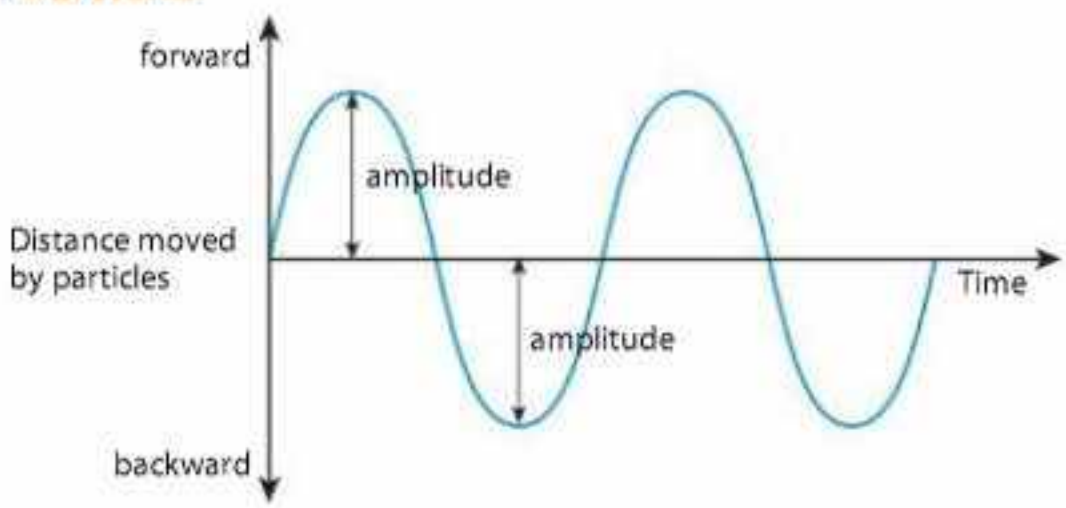
The greater the distance of each vibration in the object, the greater the distance that particles in air will be pushed and pulled.

Sounds get quieter when the distance from the vibrating object increases because of energy dissipation. You learnt about energy dissipation in Stage 7.

You learnt in Stage 7 that when a sound wave travels forward in air the particles move backwards and forwards, as shown in the diagram.



The movement of particles in air is diffi cult to draw in a sound wave, but is easier to draw in a graph. The graph shows the distance that the particles move forward and backward with time. The shape of this graph is sometimes called a **waveform.**



The maximum distance that particles move, either forward or backward in a sound wave, is called the **amplitude**.

You can measure the amplitude in two ways.

The amplitude is the distance from zero to the top, or **peak**, of the graph.

The amplitude is the distance from zero to the bottom, or **trough**, of the graph.

Both these distances are equal in a graph of the same sound wave.

The peak is the highest point of the graph and the trough is the lowest point.

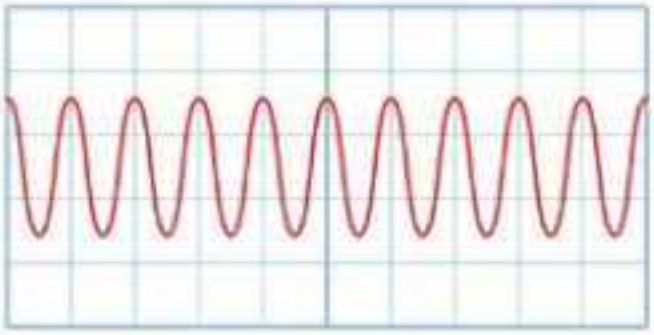
As the distance or range of the vibration increases, the loudness increases. You can also say that as the amplitude of a sound wave increases, the loudness of the sound increases.

A piece of equipment called an **oscilloscope** displays waveforms of sound waves. An oscilloscope uses a microphone to detect the sound and then produces a waveform of the sound on a screen.

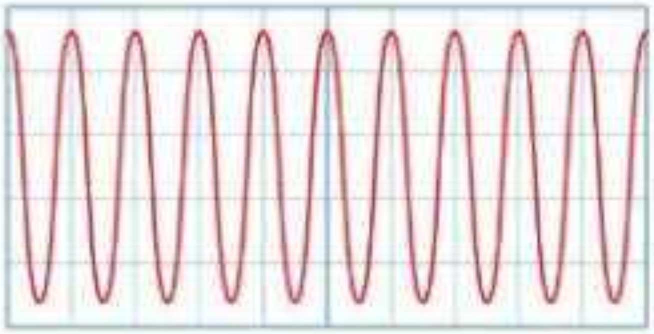
In this photo, the microphone is attached to the oscilloscope by the black wire.

The next diagram shows how a quieter sound and a louder sound compare when the waveforms are seen on an oscilloscope.

The louder sound has a larger amplitude than the quieter sound.



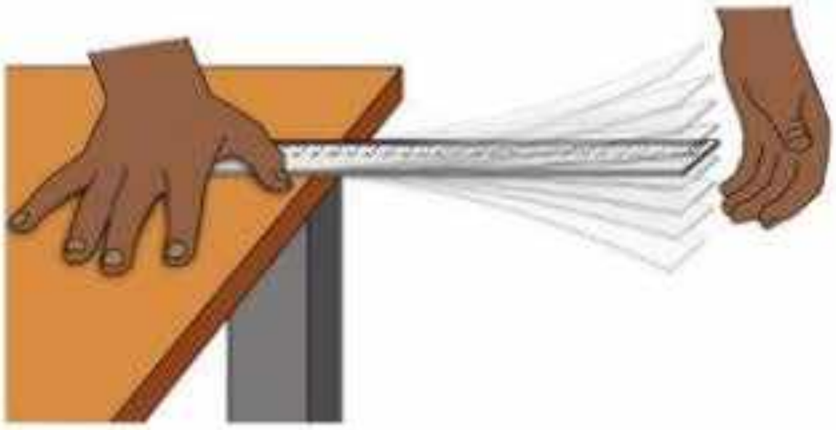
quieter sound has smaller amplitude



louder sound has larger amplitude

Pitch and frequency

When you vibrate a ruler while holding the ruler at the edge of a desk, the vibrations make sound.



When the vibrating ruler is moved so the length of the vibrating part is shorter, then the **pitch** of the sound changes. The pitch of a sound is how high or low the sound appears on a musical scale.

The reason that the pitch of the sound from the vibrating ruler changes is because the speed of the vibrations change.

The faster the vibrations, the higher the pitch of the sound.

The speed of vibrations is measured by the number of complete vibrations per second. In Stage 8 in the topic on speed, you learnt that per means 'in each'. The number of vibrations in each second is called **frequency**. As the frequency of a sound wave increases, the pitch of the sound also increases.

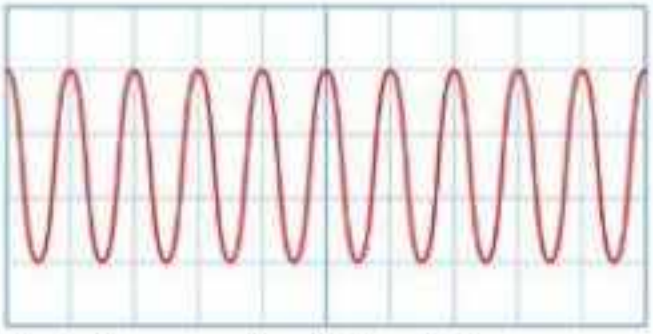
Frequency is measured in a unit called hertz or Hz.

A frequency of 500 Hz means that 500 complete vibrations happen every second.

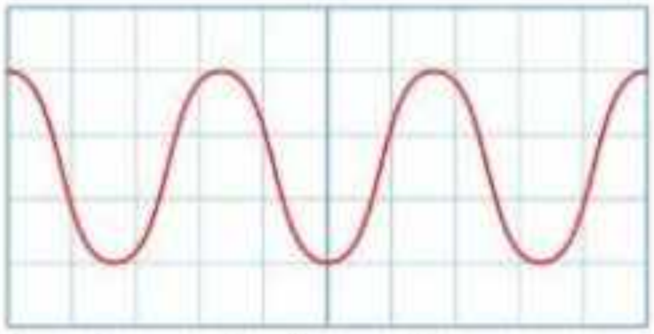
Look back at the graph that shows amplitude. The horizontal axis of this graph is time, so a wave with a higher frequency will have more waves in the same time.

As with amplitude, we can use an oscilloscope to compare the frequencies of sound waves of different pitches.

The next diagrams show how a higher pitch sound and a lower pitch sound compare when the waveforms are seen on an oscilloscope.



higher frequency has higher pitch



lower frequency has lower pitch

You will also notice from the waves of higher and lower pitch, that their amplitudes are the same. That means the loudness of both these sounds are the same.

Usually, vibrating objects that are shorter make higher pitch sounds than those that are longer.

This picture shows a musical instrument called a gayageum. The strings are plucked to make them vibrate. The pegs, called bridges, can be moved to change the length of each string that vibrates. The shorter the string, the higher the pitch.

Questions

1 a Describe the link between amplitude and the loudness of a wave.

b Describe the the link between frequency and the pitch of a wave.

2 a Which of these describes the amplitude of a sound wave? Write **one** letter.

A The maximum distance that particles move from their position when there is no wave.

B The total distance that particles move forward and move backward in the wave.

C The number of times that particles vibrate backwards and forwards every second.

D The direction that particles move in the wave compared to when there is no wave.

b Which of these describes the frequency of a sound wave? Write **one** letter.

A The maximum distance that particles move from their position when there is no wave.

B The total distance that particles move forward and move backward in the wave.

C The number of times that particles vibrate backwards and forwards every second.

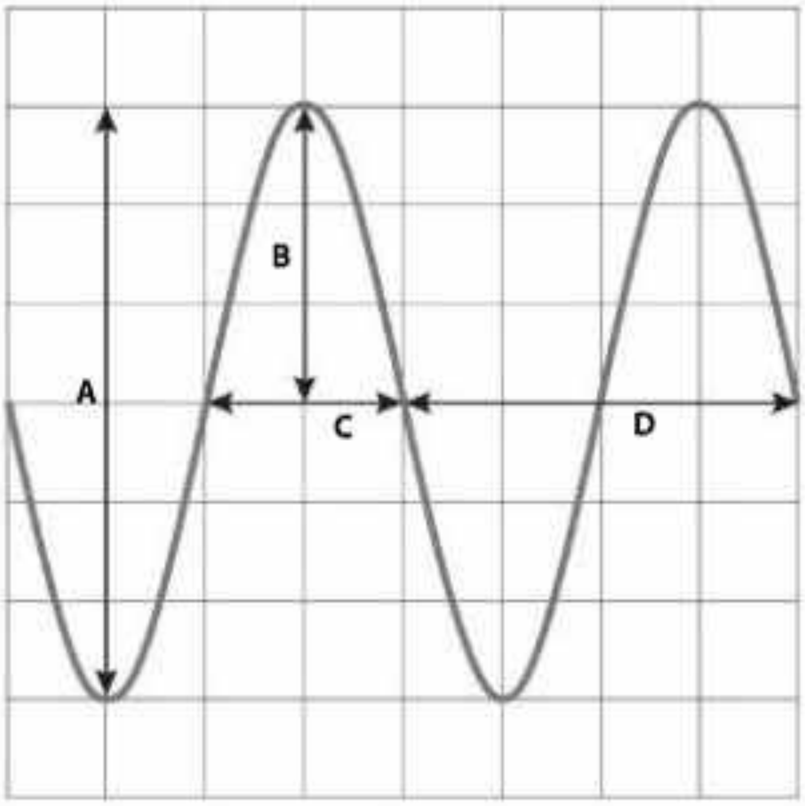
D The direction that particles move in the wave compared to when there is no wave.

3 This is the waveform of a sound displayed on an oscilloscope screen.

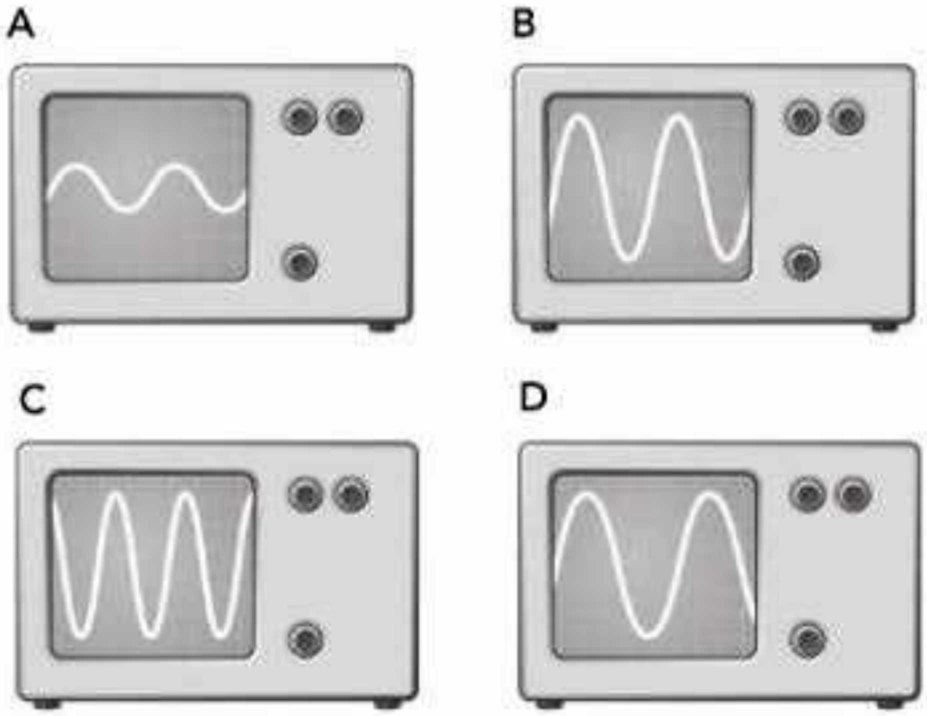
Write down:

a the letter that represents the amplitude of the wave

b one letter that shows a measurement that depends on the frequency of the wave.



4 Look at the four sound waveforms, A, B, C and D.



Copy and complete these sentences. Choose your answers from the list below.

increases **decreases** **stays the same**

a When the sound changes from A to B, the amplitude of the wave ....

b When the sound changes from A to B, the loudness of the sound ....

c When the sound changes from C to D, the pitch of the sound ....

d When the sound changes from C to D, the loudness of the sound ....

e When the sound changes from C to D, the frequency of the wave ....

Activity 6.1.1

Pitch and frequency in music

In this activity, you will look at the trends in frequencies of musical notes.

A piano is a musical instrument that makes sound when strings inside the piano vibrate.

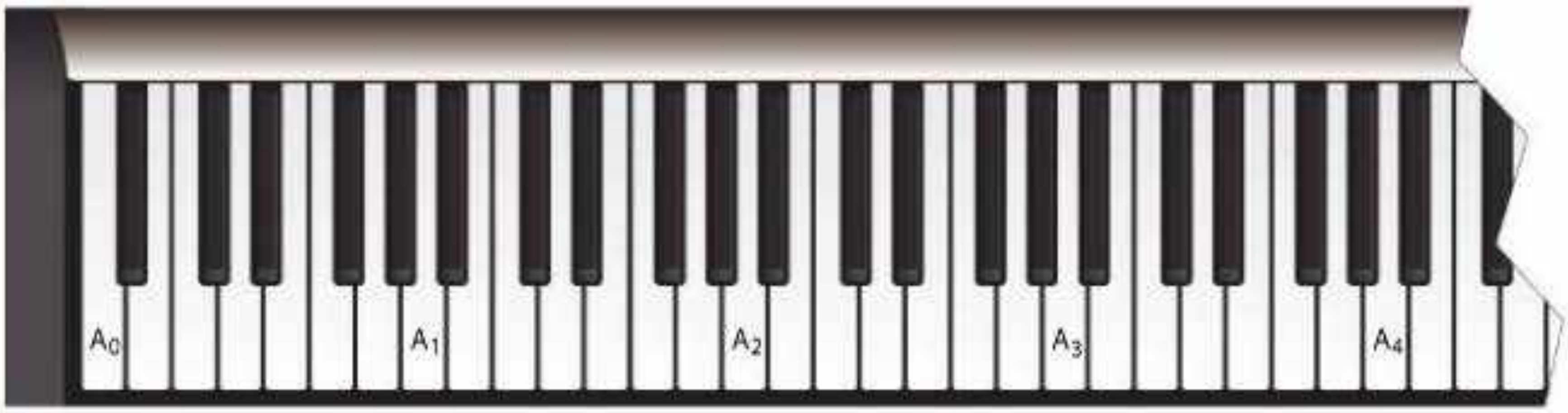
The strings are made to vibrate by pressing keys. The piano player presses the keys with their fingers.

The key at the left of the piano makes a string produce a note called A_0

After an interval of notes called an octave, there is another note called A_1

After the next octave, the next note is A_2

These are shown on the diagram.



The frequencies of the A notes are shown in the table.

name of note	frequency in Hz
A_0	27.5
A_1	55.0
A_2	110
A_3	220
A_4	440

Questions

1 Describe the trend in the frequencies of the notes shown in the table.

2 Use the information in the table and in the diagram to predict how the pitch of the notes changes from left to right on the piano keys.

3 The piano can also produce the notes A_5 A_6 and A_7

Use the trend in the table to predict the frequencies of these three notes.

Continued

4 Many pianos have pedals that can be pressed using the player's feet. One of the pedals decreases the loudness of the note without changing the pitch. Suggest what this pedal does, if anything, to:

a the amplitude of the string vibration

b the frequency of the string vibration.

Think like a scientist

Vibrations in a ruler

In this investigation, you will investigate the variables affecting the vibration of a ruler.

When you make a ruler vibrate at the end of a desk, the vibrations are too fast to measure. In this activity, you will make a ruler vibrate more slowly so that measurements can be made.

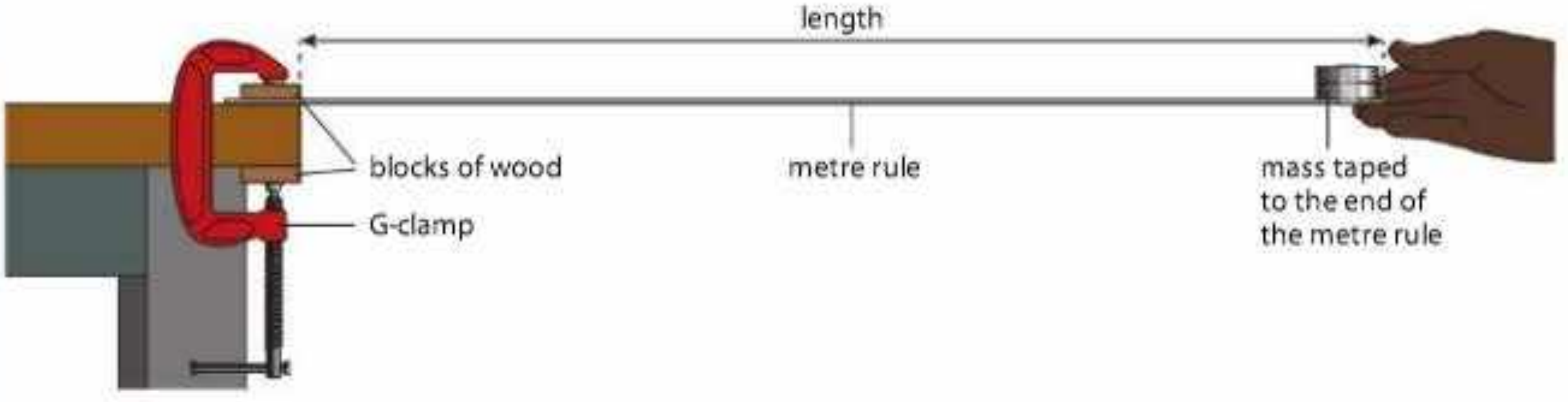
You will need:

- metre rule or half-metre rule made from wood, metal screw clamp (G-clamp), selection of masses, adhesive tape, stopwatch.

Safety

Do not stand with your feet under the ruler. Use masses that will not cause the ruler to break. Make sure the clamp is strong enough to hold the ruler when it is vibrating.

Set up the equipment as shown in the diagram.



In this investigation, you will keep the length the same and change the mass.

Method

1 Decide on what preliminary measurements are needed to determine the range of masses that will be used. Try to use a minimum of five different masses.

Continued

2 The frequency of the vibration is the number of times the ruler moves from the lowest position back to the lowest position in 1 second. A good method for finding this is to count the number of complete vibrations in 10 seconds, then divide your result by 10. This gives the frequency in Hz, which is the number of vibrations in 1 second.

3 Carry out the investigation using the range of masses that you selected.

Questions

1 Record your results in a table with these columns:

- mass
- number of vibrations in 10 seconds
- frequency.

Remember to include units, where needed, in the column headers.

Remember to include all your repeat measurements in the table.

2 Calculate the average frequency for each mass.

3 In this investigation, state:

a the independent variable

b the dependent variable

c two control variables.

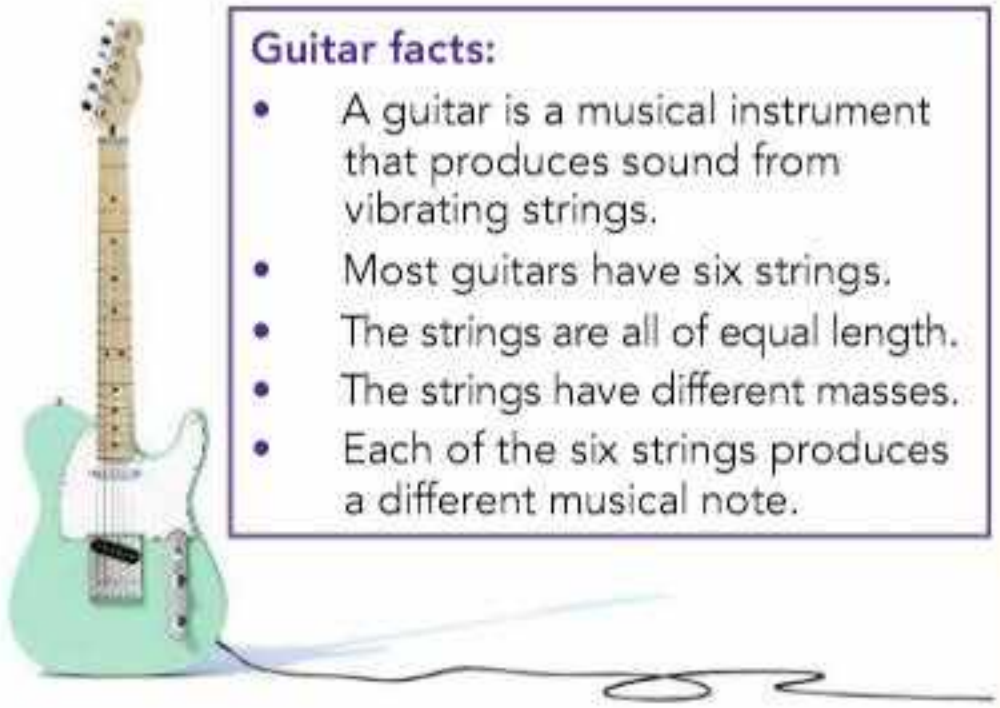
4 Plot a line graph of your results. Put frequency on the *y*-axis and mass on the *x*-axis.

5 Describe the trend in your results.

6 Read the guitar facts, then use your results and the facts about the guitar to answer these questions.

a Suggest how the frequency of vibration of a guitar string depends on the mass of the string.

b Suggest how the pitch of the musical note from a guitar string depends on the mass of the string.



Guitar facts:

- A guitar is a musical instrument that produces sound from vibrating strings.
- Most guitars have six strings.
- The strings are all of equal length.
- The strings have different masses.
- Each of the six strings produces a different musical note.

Continued

c A guitar player can change the pitch of the note from each string by placing a finger on the string and pushing the string down against the metal cross pieces (frets). This makes the vibrating length of the string shorter. Describe how you could change the metre rule experiment to investigate the effect of length on frequency. Include:
- the independent variable and how you would change it
- the dependent variable and how you would measure it
- any control variables
- a prediction of the results.

Self-assessment

For each of these statements, decide on how confident you are.
Give yourself 5 if you are very confident and 1 if you are not confident at all.

- I understand why it is better to count vibrations in 10 seconds rather than in 1 second
- I understand how the frequency of vibration depends on mass
- I know how to write a plan for an investigation that someone else could follow.

Summary checklist

- [ ] I can describe what is meant by the amplitude of a sound wave.
- [ ] I know how loudness of a sound depends on the amplitude of the sound wave.
- [ ] I can describe what is meant by the frequency of a sound wave.
- [ ] I know how the pitch of a sound depends on the frequency of the sound wave.
- [ ] I can recognise changes in amplitude and frequency from a graph of the wave or an oscilloscope display.

6.2 Interference of sound

In this topic you will:

- find out how sound waves can reinforce each other to make louder sounds
- find out how sound waves can cancel each other out to make no sound.

Getting started

Work in groups.

1. Each person in the group should draw a wave on a piece of paper.
2. Compare all the waves that have been drawn in the group.
   a. Sort the waves in order from smallest amplitude to largest amplitude.
   b. Sort the waves again, this time from smallest frequency to largest frequency.

Key words

interference
reinforce

Interference

Water waves are a useful analogy for sound waves. Particles in water waves do not move in the same way as particles in a sound wave, but the analogy helps explain how waves behave.

If you dip your finger in and out of water, you can make waves as shown in the picture.

If you make two sets of water waves, you can watch what happens when the waves meet each other. If you move your fingers at the same frequency and with the same amplitude, you can make a pattern like the one in the next picture.

The effect that is produced when the waves meet each other is called **interference**.

Sound waves also produce interference when they meet each other.

Interference can only happen when the waves are of the same type. Sound waves can interfere with each other. Sound waves cannot interfere with water waves.

Interference is easiest to detect when the waves have the same frequency and the same amplitude.

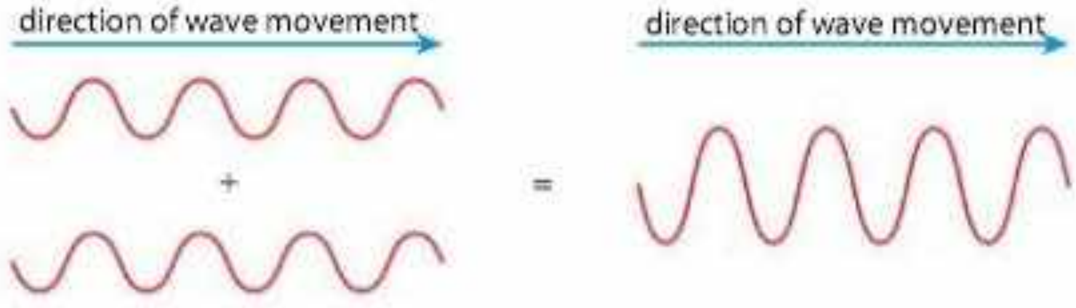
Interference can produce two effects: the waves can reinforce or the waves can cancel each other.

Waves that reinforce

The word **reinforce** means to make stronger.

If you look carefully at the picture of the water waves interfering, you can see a pattern. Part of the pattern is made by waves reinforcing each other. These parts appear with waves of larger amplitude than either of the individual waves. In this pattern, there are only small areas with waves that have reinforced.

Waves will reinforce when they meet with the peaks together and with the troughs together. This is shown in the diagram.



Two waves can interfere to reinforce when the wave peaks arrive together.

If you look carefully at the diagram, you will see that:

- the amplitudes of the two waves that interfere are added together
- the frequency of the two waves that interfere does not change.

When sound waves interfere to reinforce, the amplitude of the sound wave increases.

You will recall from the previous topic that the loudness of a sound wave depends on its amplitude.

That means, that when two sound waves reinforce, the sound becomes louder.

Sound waves can meet and reinforce where there are two sources of the same sound.

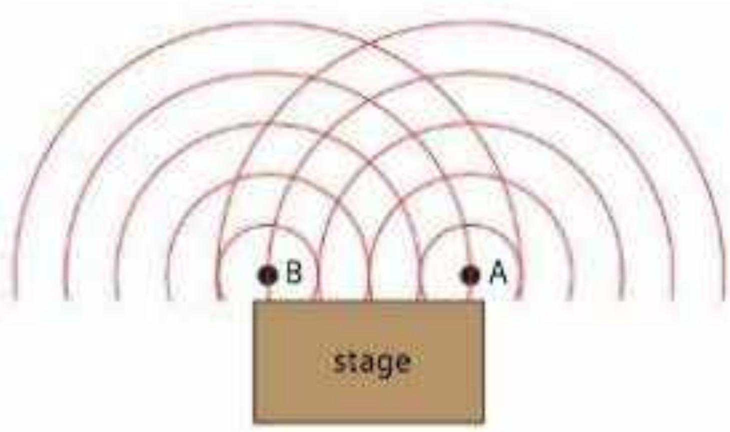
The picture shows the stage for a music concert. There are two loudspeakers – one on either side of the stage.

At certain places in the audience, people may hear sounds of a particular pitch louder than usual. This can be caused by the sound waves from the two loudspeakers meeting and reinforcing.

This diagram shows the pattern of sound waves that could be produced from these loudspeakers.

The curved lines in the diagram represent peaks in the sound waves. Where two of these lines cross, the waves will reinforce. A person at that position will hear a louder sound.

Sound waves will also reinforce where two troughs meet, but this is difficult to show in the diagram.

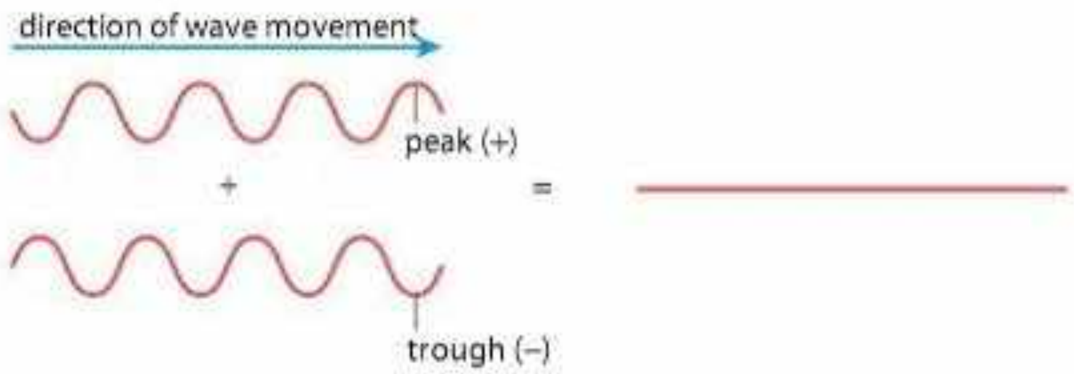


Waves that cancel

Waves will cancel when they meet with the peaks and troughs together. The word cancel in the context of waves means adding together to make zero.

Think of a peak as the wave's maximum *positive* amplitude, and a trough as the wave's maximum *negative* amplitude. When you add a positive number to a negative number of equal size, you get zero; for example, $2 + (-2) = 0$.

This is shown in the diagram.



Two waves can interfere to cancel when the wave peaks of one meet troughs of another of equal amplitude.

If you look carefully at the diagram, you will see that the amplitudes of the two waves that interfere are added together to become zero.

When sound waves interfere to cancel, the amplitude of the sound wave becomes zero, the result is no sound. For two sound waves to cancel completely, their frequencies must be the same and their amplitudes must be the same.

Noise-cancelling headphones work by making sound waves cancel. The headphones pick up the sound from the surroundings, then analyse the sound wave and create another sound wave with the same amplitude and frequency, but out of phase with the original wave This new sound wave is used to cancel the sound wave from the surroundings. This is shown in the diagram.

It is not likely that the sound waves from loudspeakers A and B at the concert will ever completely cancel so people hear nothing. This is because the sound waves from loudspeakers A and B at the concert will be reflected off objects, including off people in the audience. These reflected sound waves would add many more waves to the pattern in the diagram, making it very unlikely that only two identical waves will be present to cancel.

Questions

1 a Which of these will always result in a louder sound being heard?

Write **one** letter.

A two sound waves cancel C two sound waves reflect

B two sound waves reinforce D two sound waves refract

b Which of these will always result in no sound being heard?

Write **one** letter.

A two sound waves cancel C two sound waves reflect

B two sound waves reinforce D two sound waves refract

2 a Describe how two sound waves must meet in order to reinforce.

b Describe how two sound waves must meet in order to cancel.

3 The table gives information for two waves that will meet to reinforce. Copy the table and complete the missing information about the one wave that is formed.

two waves before reinforcing		one wave after reinforcing	
frequency in Hz	amplitude in mm	frequency in Hz	amplitude in mm
450	0.5		

4 Two sound waves have equal frequencies of 600 Hz. The amplitude of one of the waves is 0.25 mm.

a State the amplitude of the other wave required for the two waves to cancel.

b State the amplitude after the waves cancel completely.

Activity 6.2.1

Reinforcing and cancelling waves

In this activity, you will use water waves as an analogy for sound waves, to observe reinforcing and cancelling.

You will need:

- shallow tray to hold water, piece of white sheet material to put in the base of the tray, piece of wood with two identical nails that are part-way into the wood as shown in the diagram – the distance between the nails should be less than half the width of the tray.

Method

1. Put water in the tray to a depth of about 2–3 cm.
2. Put the white sheet at the bottom of the tray. This is to make the waves easier to see.
3. Hold the piece of wood above the tray so the heads of the nails are just touching the water surface.
4. Move the wood up and down so the heads of the nails make waves in the water.
5. Observe the pattern where the waves meet.

Questions

1. Suggest why both nails are attached to the same piece of wood and not dipped into the water separately. Use the words frequency and amplitude in your answer.
2. Copy and complete the sentences.
   a. In the areas where there is larger amplitude, the two waves are said to

      ....
   b. In the areas where there is zero amplitude, the two waves are said to

      ....
3. This demonstration can be done with sound, but it is more difficult.
   a. Suggest two sources of sound that could be used to produce two sound waves of equal frequency and equal amplitude.
   b. Even in a room with no other sounds, it is very difficult to make two sound waves cancel so you do not hear anything. Suggest why.

Think like a scientist

Listening to sound waves reinforcing

In this investigation, you will listen to the effect when sound waves reinforce.

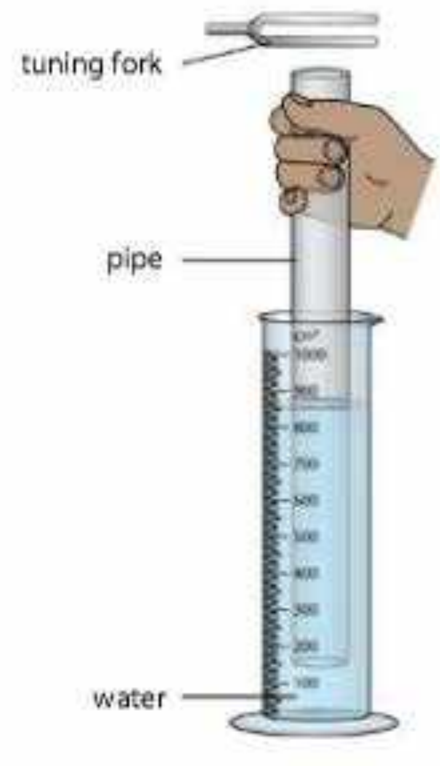
In Stage 7, you learnt that sound waves can reflect. It is possible to make a sound wave reflect so that the reflected wave reinforces the wave from the sound source.

You will need:

- tuning forks or a small sound source with constant frequency, piece of plastic pipe 4 cm or more diameter and about 70 cm long, deep water container such as a large sink or wide measuring cylinder, metre rule.

Method

1. Set up the equipment as shown in the diagram.
2. Strike the tuning fork so it makes a sound.
3. Hold the tuning fork over the open end of the pipe.
4. Move the pipe up or down to a new position in the water so the length of pipe above the water changes.
5. Listen for an increase in loudness of the sound from the tuning fork.
6. Strike the tuning fork again, if needed, and adjust the length of the pipe above water so the sound is loudest.
7. Measure the length of the pipe above water.
8. Repeat steps 1–7 with a tuning fork of different pitch.



Questions

1. Find out the frequencies of the tuning forks that you used.
2. Record your results in a table.
3. Describe the trend in the results that links the frequency to the length.
4. Use this trend to explain how the range of notes produced by wind instruments depends on the length of the wind instrument.

Summary checklist

- [ ] I know how sound waves reinforce.
- [ ] I know what happens to the loudness of a sound when sound waves reinforce.
- [ ] I know how sound waves cancel.
- [ ] I know what happens to the loudness of a sound when sound waves cancel.

6.3 Formation of the Moon

In this topic you will:

- describe evidence for the collision theory for the formation of the Moon.

Getting started

Work in groups.

Discuss how the Solar System was formed from a cloud of dust and gas in space.

Key words

collision theory

Where did the Moon come from?

In the early twentieth century, scientists thought that the Moon was formed by splitting away from the Earth, soon after the Earth was formed.

Calculations showed that, if this theory was correct, the Moon would still be slowly moving away from Earth. Accurate measurements made more recently have shown that the Moon *is* still moving away from Earth – at a rate of about 4 cm each year.

These calculations could not completely confirm the theory that the Moon had formed by splitting away from the Earth.

In 1974, it was suggested that the Moon was formed in a different way, called the collision theory.

Collision theory for formation of the Moon

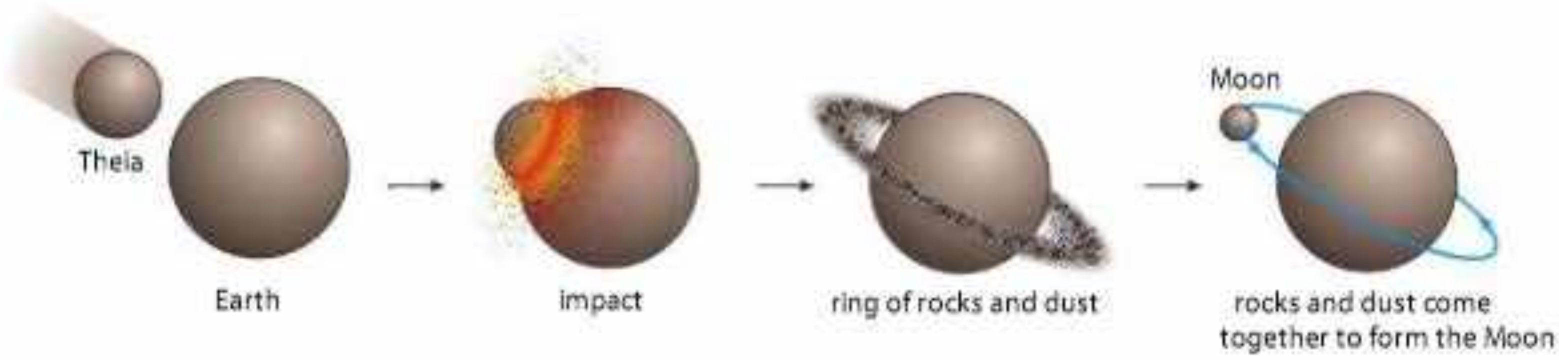
The **collision theory** (also called the giant impact hypothesis) is another theory of how the Moon was formed. There is more evidence that supports the collision theory than any other current theory.

The collision theory refers to a collision that happened relatively soon after the formation of the Solar System.

A newly formed planet, about the same size as Mars, collided with the newly formed Earth.

Scientists have called the colliding planet Theia. The picture – drawn by an artist – shows what the collision between Earth (left) and Theia may have looked like.

The collision would have caused rocks and dust to break away from both planets. The theory states that Earth was formed from the two planets joined together. The Moon was formed when the rocks and dust was pulled together by gravity. These stages are shown in this diagram:



Evidence that supports the collision theory	Evidence that contradicts the collision theory
The Moon is less dense than the Earth. Samples of rock from the Moon show that its surface was once molten. The Moon has a small iron core, similar to the Earth. There is evidence outside the Solar System of similar collisions causing rings of rock and dust. The collision theory fits with the theory of how the Solar System was formed. The composition of rocks on the Earth and the Moon are the same.	The surface of the Earth does not appear to ever have been molten. A collision that formed the Moon would have caused the surface of the Earth to melt. The surface would have later solidified. Venus has no moon. Collisions in the early years of the Solar System would have been common and scientists would have expected Venus to have a moon formed in the same way. The composition of rocks on the Moon would be expected to be more similar to rocks on Theia than rocks on Earth. In fact, the composition of the Moon is more similar to Earth.

Questions

1 The collision theory suggests that an object called Theia collided with Earth.

Which of these planets is closest in size to Theia? Write **one** letter.

A Mars B Earth C Neptune D Jupiter

2 Which of these statements could explain why the composition of rocks on the Earth and on the Moon is very similar? Write **one** letter.

A The Moon is mostly formed from Theia's rocks and the Earth only has a small quantity of Theia's rocks.

B The Earth is mostly formed from Theia's rocks and the Moon only has a small quantity of Theia's rocks.

C Rocks from Theia and Earth were completely mixed during the collision.

3 The planet Mars has two moons called Phobos and Deimos. Scientists have evidence that Phobos and Deimos are asteroids that were captured by the gravity of Mars, so they remain in orbit around Mars.

Suggest how the composition of rocks on Phobos and Deimos would compare with the rocks on the planet Mars if Phobos and Deimos were:

a originally asteroids

b formed by a collision of another object with Mars.

4 Models of the formation of the Solar System show that collisions between planet-sized objects would have been common soon after the Solar System formed. Suggest why these collisions are no longer common.

Activity 6.3.1

Evidence for the collision theory

In this activity, you will do your own research to find evidence.

Work in groups of three or four.

Use an internet search engine to find out more about the collision theory of the formation of the Moon. Some scientists call it the giant impact hypothesis, so you should also search for that.

Try to find:

- websites other than general encyclopaedia sites
- information that you can understand
- evidence that supports the collision theory
- evidence that contradicts the collision theory
- other theories on how the Moon was formed.

Produce a report on what you find. Write this in your own words as much as possible. Your report can take any form.

Include:

- the websites where each piece of information was obtained
- which websites you thought were most reliable
- whether any of the websites were biased
- why you had to use secondary sources rather than first-hand experience
- which theory you think is correct and why.

Summary checklist

- [ ] I know the collision theory for the formation of the Moon.
- [ ] I know the evidence for the collision theory.

› 6.4 Nebulae

In this topic you will:

- discover that nebulae are clouds of dust and gas in space
- learn how stars can form in nebulae.

Getting started

Work in groups to discuss the answers to these questions.

1 Describe how the planets in the Solar System were formed.

2 List ways in which planets and stars are

a different

b the same.

Key words

nebulae (singular: nebula)

northern hemisphere

southern hemisphere

stellar nurseries

Nebulae

Nebulae are clouds of dust and gas in space.

The word nebulae is plural. The singular is **nebula**.

The gases found in nebulae are mostly hydrogen and a smaller quantity of helium. The particles of gas and dust are very far apart in nebulae. A nebula the same size as the Earth would have a mass of only a few kilograms!

Most nebulae are very large. Some are more than 10 000 times bigger than the Solar System!

Some nebulae form when giant stars reach the end of their life. These giant stars then explode, sending dust and gas over a wide area of space.

There are many nebulae visible from Earth.

If you live in the **northern hemisphere**, one of the easiest nebulae to see is the Orion nebula, which is visible in winter. The northern hemisphere is the part of the Earth that is north of the equator. You can see the Orion nebula without a telescope. The picture shows what the Orion nebula looks like through a very powerful telescope.

If you live in the **southern hemisphere**, the easiest nebula to see is the Carina nebula. The southern hemisphere is the part of the Earth that is south of the equator. This nebula is also visible without using a telescope. The picture shows what the Carina nebula looks like through a powerful telescope.

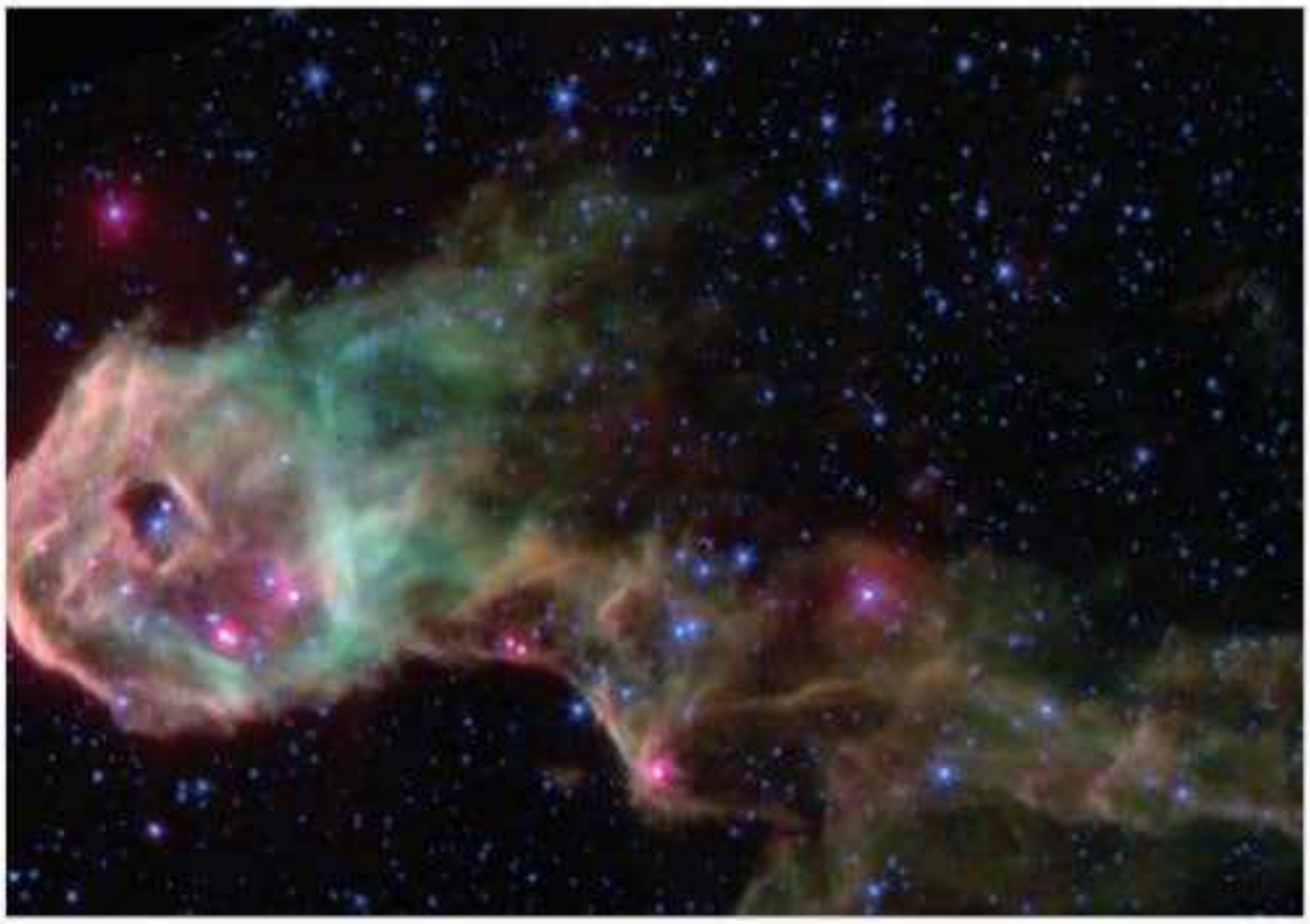
Stellar nurseries

A **stellar nursery** is an area in space where stars are formed. The word stellar can be used to describe anything about stars. A nursery is a place to care for young people, animals or plants. In this case, the word nursery applies to young stars.

Some types of nebulae act as stellar nurseries.

In a stellar nursery, the dust and gas can start to collapse together under the force of gravity. When the mass of dust and gas collects together and becomes larger, the force of gravity pulling inward increases. When this force gets very large, the pressure inside the new star also gets very large. The high pressure causes heat. The heat can cause atoms to react with each other, causing the new star to give out heat and light.

The picture shows a stellar nursery photographed from space. You can see the young stars inside the cloud. Some of these stars are only half the mass of the Sun and have not yet reached their full brightness. The light from the stars lights up the dust and gas in the cloud.



Questions

1 a Describe the features that are common to all nebulae.

  b Describe the difference between a nebula and a galaxy.

2 Name the two gases most commonly found in nebulae.

3 a Describe what is meant by the term *stellar nursery*.

  b Which of these statements is correct?

    A All nebulae act as stellar nurseries.

    B Only some nebulae act as stellar nurseries.

    C No nebulae ever act as stellar nurseries.

4 Outline the process by which a new star forms.

5 The light year, ly, is a unit of distance measurement used in space.

  The diameter of the Solar System is 0.001 ly.

  The diameter of the Orion nebula is 24 ly.

  Calculate how many times bigger the diameter of the Orion nebula is than the diameter of the Solar System.

Activity 6.4.1

Virtual tour of nebulae

In this activity, you will compare nebulae.

Some space agencies maintain websites with up-to-date photographs of nebulae and information about each one.

Many of the photographs are taken with telescopes such as the Hubble Space Telescope.

Questions

1 Find as many different types of nebula as you can. Include at least one that acts as a stellar nursery.

2 Design an information sheet that shows the different types of nebula.

3 Find out about the Hubble Space Telescope. Describe what is different about the Hubble Space Telescope compared to other telescopes used to look into space. Include this information on your sheet.

Summary checklist

- [ ] I know what nebulae are.
- [ ] I know that stars can be formed in nebulae.

6.5 Tectonics

In this topic you will:

- discover how convection currents cause movement of tectonic plates
- learn about the evidence we have for tectonic plates.

Getting started

Work in groups to discuss the answers to these questions.

1. Describe the structure of the Earth.
2. Link the model of plate tectonics to the structure of the Earth.
3. Describe some of the events that are more likely to occur at the boundaries of tectonic plates.

Key words

jigsaw
continental coasts
fossil record
alignment

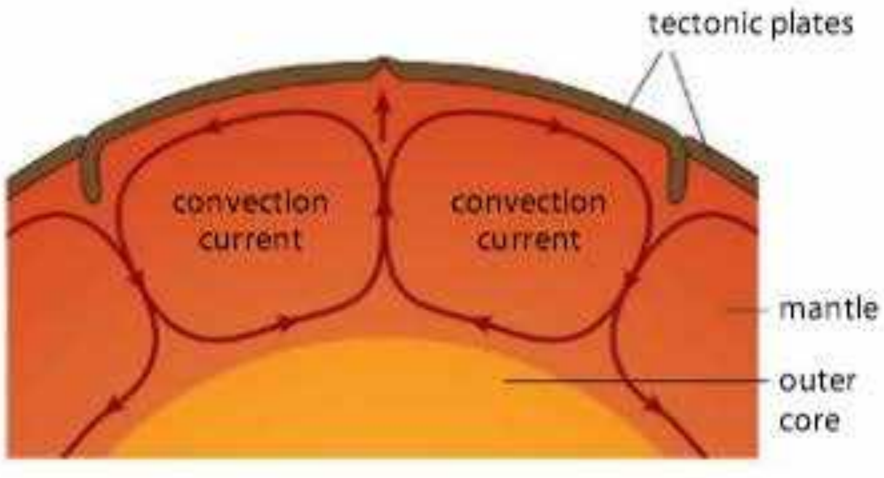
Movement of tectonic plates

You may recall from Stage 7 that the outer layers of the Earth are the solid, rocky crust, which rests on the more fluid mantle.

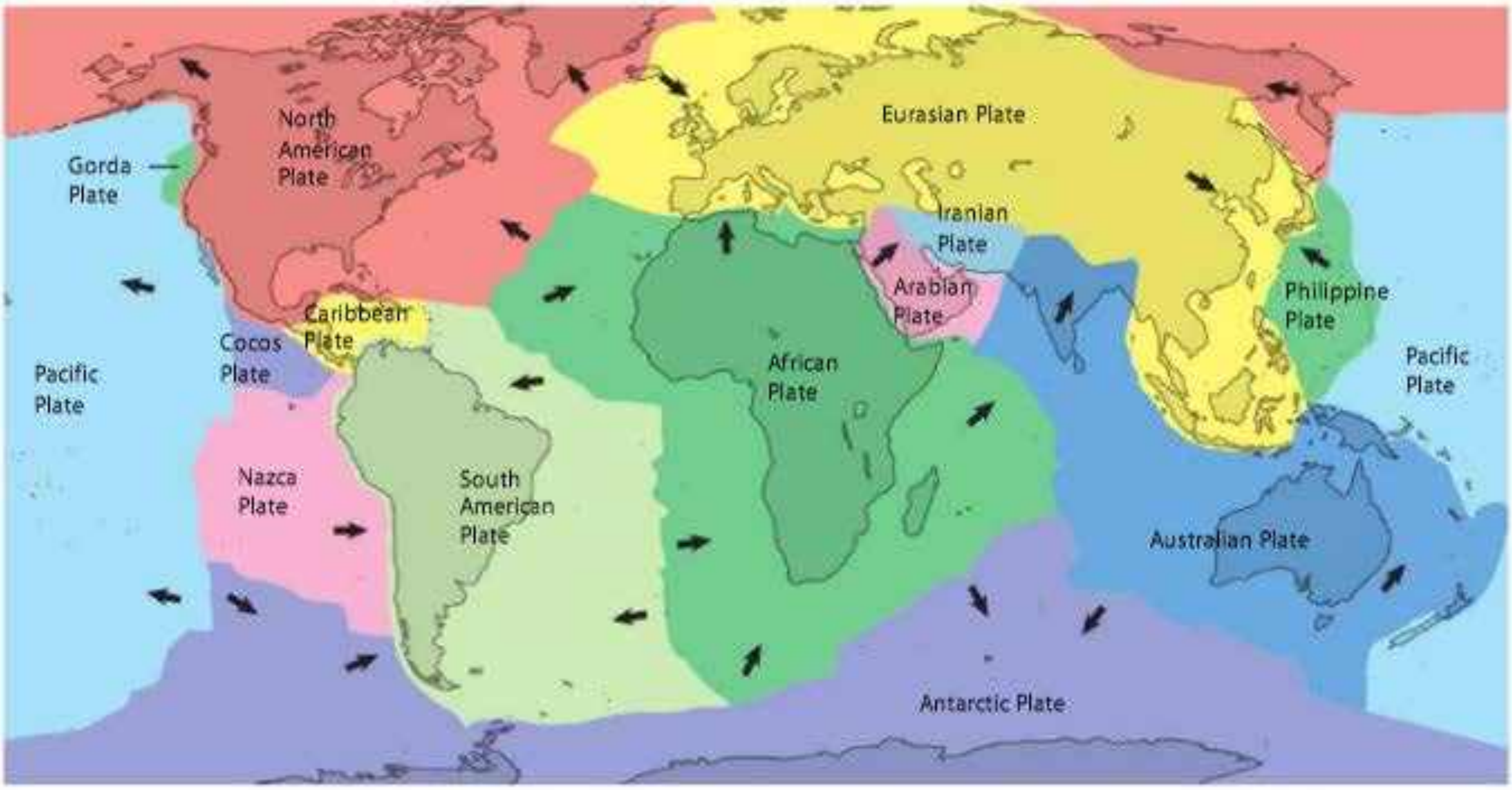
The mantle is heated from the innermost part of the Earth: the inner core. The inner core is estimated to be at a temperature of over 5000 °C! The high temperature of the inner core is due to thermal energy left over from the formation of the Earth, friction inside the Earth and the type of reactions that happen in the rocks.

You may also recall from Unit 3 that thermal energy is transferred through fluids by convection and that convection currents occur in fluids.

The inner part of the mantle gets thermal energy from the core. The fluid in the mantle then expands when heated and becomes less dense that the fluid surrounding it. This hotter, less dense fluid in the mantle rises towards the crust, cools and sinks again, resulting in a convection current.



The mantle is a very thick fluid and does not flow easily like water, so the convection currents move very slowly. As the convection currents in the mantle move across underneath the crust, the tectonic plates that make up the crust are pulled along. Just as the convection currents are slow, the movement of the tectonic plates is also slow, varying between 0.6 and 10 cm per year.



Scientists have mapped the movement of the tectonic plates

Evidence for tectonic plates

When you look at a world map, it looks like the continents could fit together like pieces of a giant **jigsaw** puzzle. A jigsaw puzzle is a picture that is cut into small interlocking pieces. The object of the puzzle is to put the pieces back together to form the original picture.

Scientists have done this with the continents on Earth. The **continental coasts** can fit together as shown in the diagram.

Scientists say that this continental jigsaw appearance is evidence for tectonic plates. There is a hypothesis that there was once only one large continent that eventually separated. The separate parts became some of the tectonic plates, and the convection currents from the mantle drove their movement.

The **fossil record** provides more evidence for tectonic plates and their movement. The fossil record is the name given to the collection of thousands of fossils that provide us with information about the time before humans were on Earth. Fossils are the remains of dead animals and plants that have turned to stone over millions of years.

Fossils of an extinct reptile called *Mesosaurus* have been found in the parts of Africa and South America that would fit together in the jigsaw model of the continents. *Mesosaurus* lived about 275 million years ago and was similar to a crocodile. These animals lived at the coast and in shallow water. It is not likely that they would have crossed the 5000 km-wide Atlantic Ocean that now separates these continents.

Fossils of *Mesosaurus* have been found in both South America and Africa (this one is in Namibia), giving evidence for tectonic plate movements.

300 million-year-old fossils of the plant *Glossopteris* have been found in Antarctica, India, Australia, Africa and South America. This gives more evidence for the hypothesis that these continents were once joined.

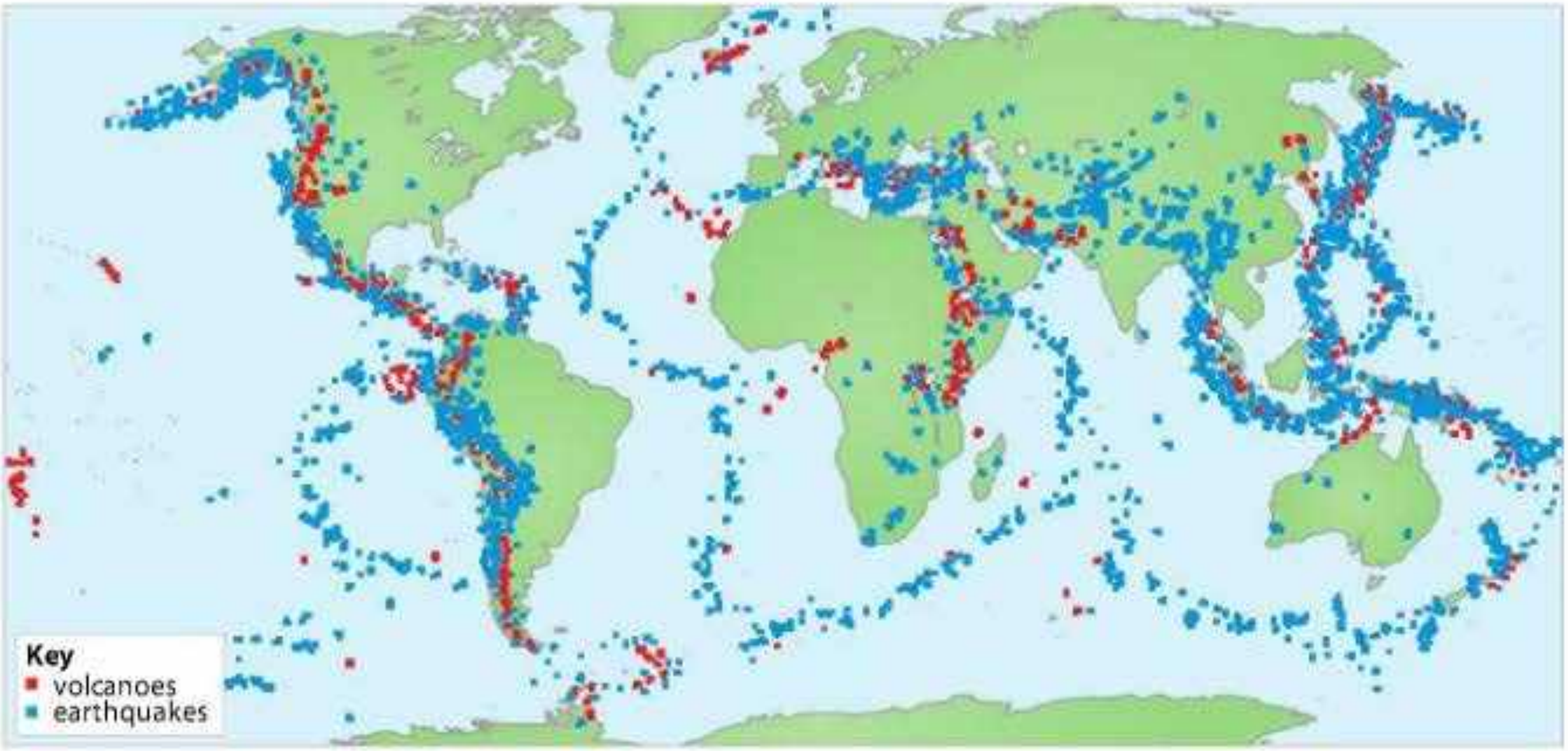
You may recall from Stage 8 that the Earth has a magnetic field. Today, the needle of a magnetic compass will point towards north, but that was not always the case. Around 780 000 years ago, the same compass needle would have pointed south! Scientists now know that the Earth's magnetic poles have swapped positions almost 200 times in the last 100 million years.

Magnetic crystals in molten rocks line up to point north in the same way as a compass needle. When the rock solidifies, scientists can use these crystals to tell the direction of the Earth's magnetic field at the time when the rock became solid. The direction that the crystals are pointing is called **alignment**. The word alignment means to line up in a particular way.

The magnetic crystals in rocks found in the middle of the Earth's oceans have been studied. In these locations, called mid-oceanic ridges, magma is coming up from the mantle and solidifying to form new rocks. This action pushes the continents away from each other. The magnetic crystals in the mid-oceanic ridges always have an alignment to north because the Earth's magnetic field is currently in that direction. Rocks further away from these ridges contain magnetic crystals with the opposite alignment. This suggests that these rocks are much older.

Fossils of the plant *Glossopteris* provide more evidence for the movement of tectonic plates.

If the hypothesis of moving tectonic plates was correct, then we would expect there to be more earthquakes and volcanoes at the tectonic plate boundaries. This is indeed the case, as shown on the map.



Most of the volcanoes and earthquakes that have been recorded occur close to the tectonic plate boundaries

Questions

1 Describe what makes convection currents in the Earth's mantle.

2 Describe what is meant by the term tectonic plate.

3 The continents of Earth appear to fit together like a jigsaw. Explain how this provides evidence for tectonic plates.

4 Describe how each of these provides evidence for the movement of tectonic plates:

  a the fossil record

  b the alignment of magnetic materials in rocks.

5 Scientists think that the Earth's magnetic field has reversed 183 times in 83 million years. Calculate the average time between reversal events.

6 Use the map shown above to discuss the statement 'Earthquakes and volcanoes always occur at tectonic plate boundaries.'

Activity 6.5.1

Pangaea

In this activity, you will look at evidence for tectonic plate movement.

Many scientists think that there was once only one large continent on Earth. They have called this continent Pangaea and they think that it existed between 335 and 175 million years ago.

Around 175 million years ago, Pangaea started to break apart. The parts moved further away until we have the continents that we recognise today.

You will need:

- atlas or printed map of the world that is about A4 size, tracing paper and a pencil, piece of card about A4 size, scissors.

Trace an outline map of the world onto the card. Carefully cut out the continents. You will not need the parts that represent the oceans.

Can you fit your continents together to see what Pangaea might have looked like?

Questions

1 Which continents fit together most easily?

2 Discuss whether Pangaea was made from only one tectonic plate or more than one.

3 Use your continents to predict how a map of the world may look 200 million years in the future.

4 The distance between the coasts of Africa and South America is currently about 5000 km. These continents separated about 140 million years ago. Use this information to calculate the average speed of their separation. Give your answer in centimetres per year.

Summary checklist

- [ ] I understand what makes tectonic plates move.
- [ ] I understand what evidence exists for tectonic plates.

Project: Impact craters

Background

Impact craters are formed when a large object from space collides with the rocky surface of a planet or moon.

The word moon can be used with either a capital M or a small m. When used with a capital, as in Moon, the word refers to the large natural object that orbits the Earth. When used with a small letter, as in moon, the word refers to any natural object orbiting another planet.

Impact craters can be found on Earth and you can also see them on the Moon. There are also impact craters on Mercury, Venus, Mars and the moons of Jupiter.

Your task

Find out how impact craters are formed in solid rock.

Next, you will develop an analogy for crater formation.

Work in pairs.

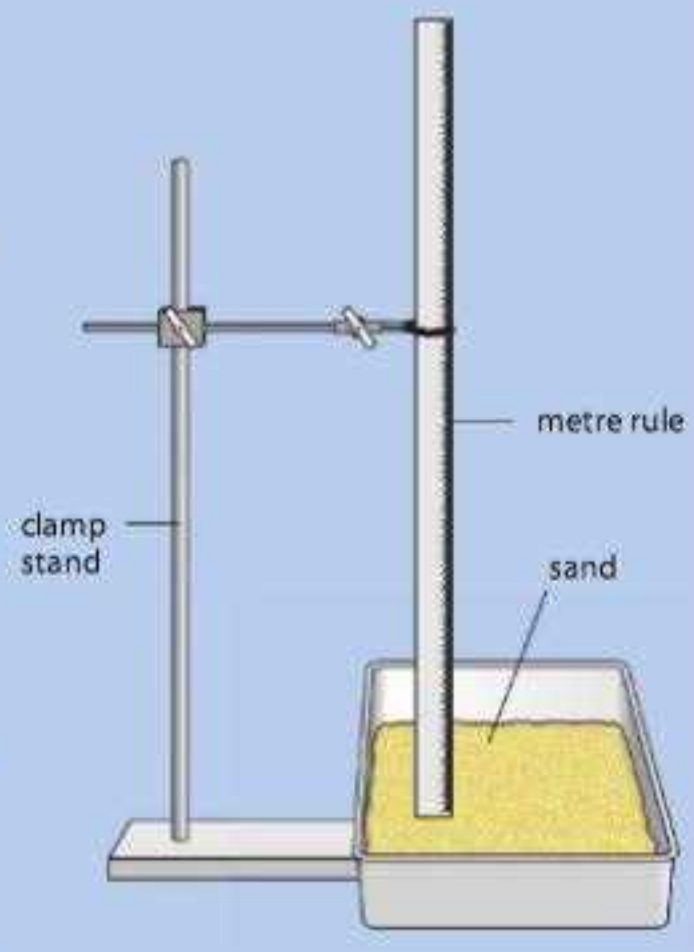
Your pair will need:

- tray to hold sand, sand, metre rule, 30 cm or 15 cm ruler, balance, various objects such as marbles and small pieces of rock.

This list includes equipment that you will need to start the investigation. You can develop the investigation to include other equipment.

Set up the equipment as shown in the diagram.

When an object is dropped into the sand, an impact crater will form in the sand.



Safety

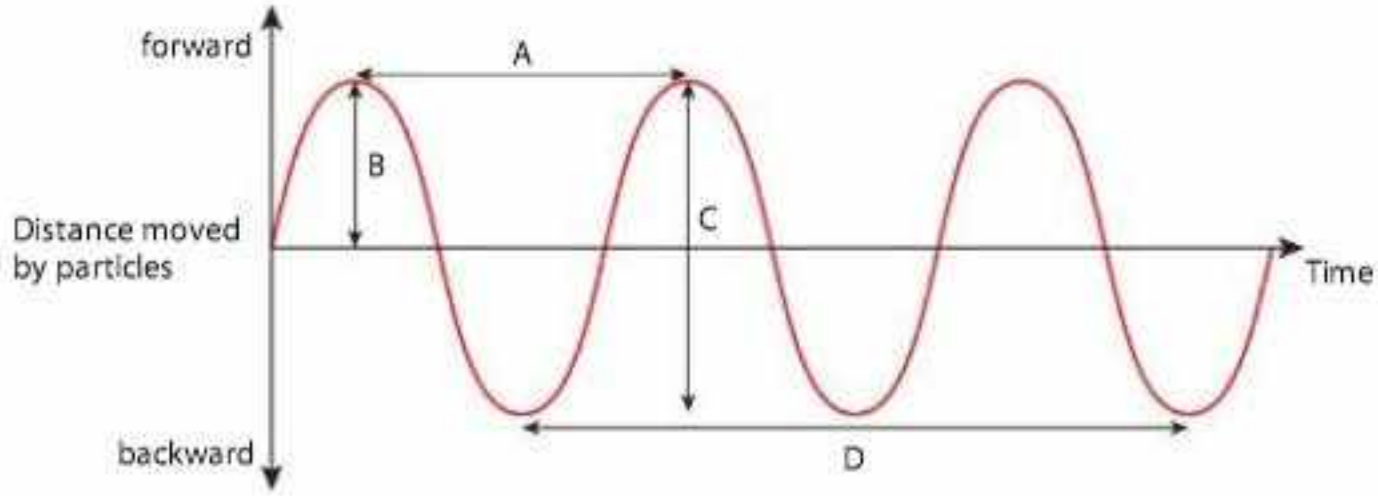
- The equipment should be on the floor so that it cannot fall.
- Safety glasses should be worn so that particles ejected from the crater cannot enter eyes.
- Do not stand on tables or chairs to drop objects.
- Make sure objects can only fall into the tray and do not stand with your feet close to the tray.

Continued

- Make a list of variables that you think will affect the diameter and depth of the impact crater.
- Predict how each of these variables will affect the diameter and depth of the crater.
- Investigate each variable in turn, making sure to control each of the other variables.
- Make drawings of the crater to show the shape when seen from the top and also from the side. Add labels to show where you measured the diameter and depth of the crater.
- Record your results in separate tables for each variable.
- Describe any trends in your results for each variable.
- State whether any of your results matched your prediction.
- This investigation is an analogy for impact crater formation on Earth. Describe the strengths and weaknesses of this analogy.
- Suggest any improvements to the method that would make the analogy better.

Check your progress

6.1 The graph shows how the particles in a sound wave move with time.



Which measurement shows the amplitude?

Give **one** letter. **[1]**

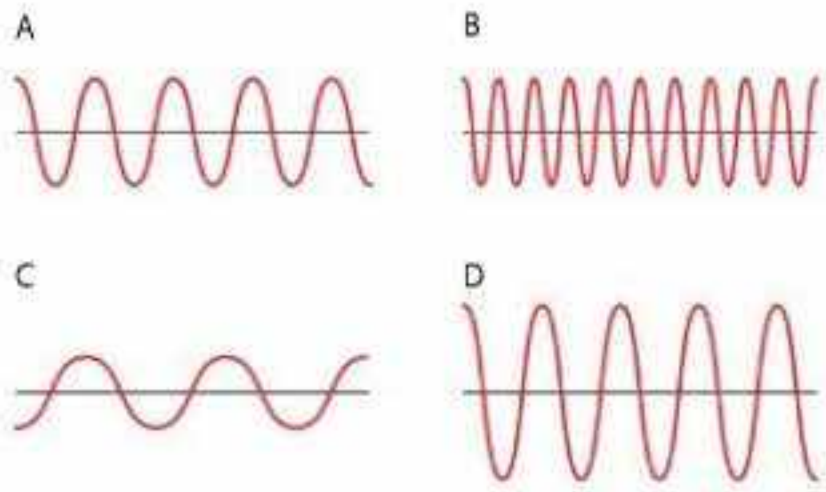
6.2 Describe what happens to a sound when these changes are made.
All other variables stay constant.

a The amplitude increases. **[1]**

b The frequency increases. **[1]**

c The number of waves per second increases. **[1]**

6.3 The diagram shows how four different sounds appear as waveforms on an oscilloscope.



Write the letter of the wave that represents:

a the sound with the highest pitch **[1]**

b the quietest sound with the lowest pitch. **[1]**

6.4 Draw diagrams to show how two sound waves of equal frequency and amplitude can

a meet each other to reinforce **[3]**

b meet each other to cancel. **[3]**

6.5 Many scientists think that the collision theory explains how the Moon was formed.

a Describe the events in the collision theory. **[4]**

b Describe two pieces of evidence that support the collision theory. **[2]**

6.6 a Explain what is meant by each of these terms:

i nebula **[2]**

ii stellar nursery. **[2]**

b When stars are first formed, they are more difficult to see than older stars that are the same distance from Earth. Suggest two reasons why the young stars are more difficult to see. **[2]**

6.7 Describe how each of these provides evidence for tectonic plates:

a the shapes of the present-day continents **[1]**

b the fossil record **[1]**

c the alignment of magnetic materials in rocks. **[1]**

7 Genes and inheritance

> 7.1 Chromosomes, genes and DNA

In this topic you will:

- learn that chromosomes contain genes
- find out what genes and chromosomes are made of.

Getting started

Discuss these questions with a partner. Then share your ideas with the rest of the class.

Atoms and cells both contain a nucleus.

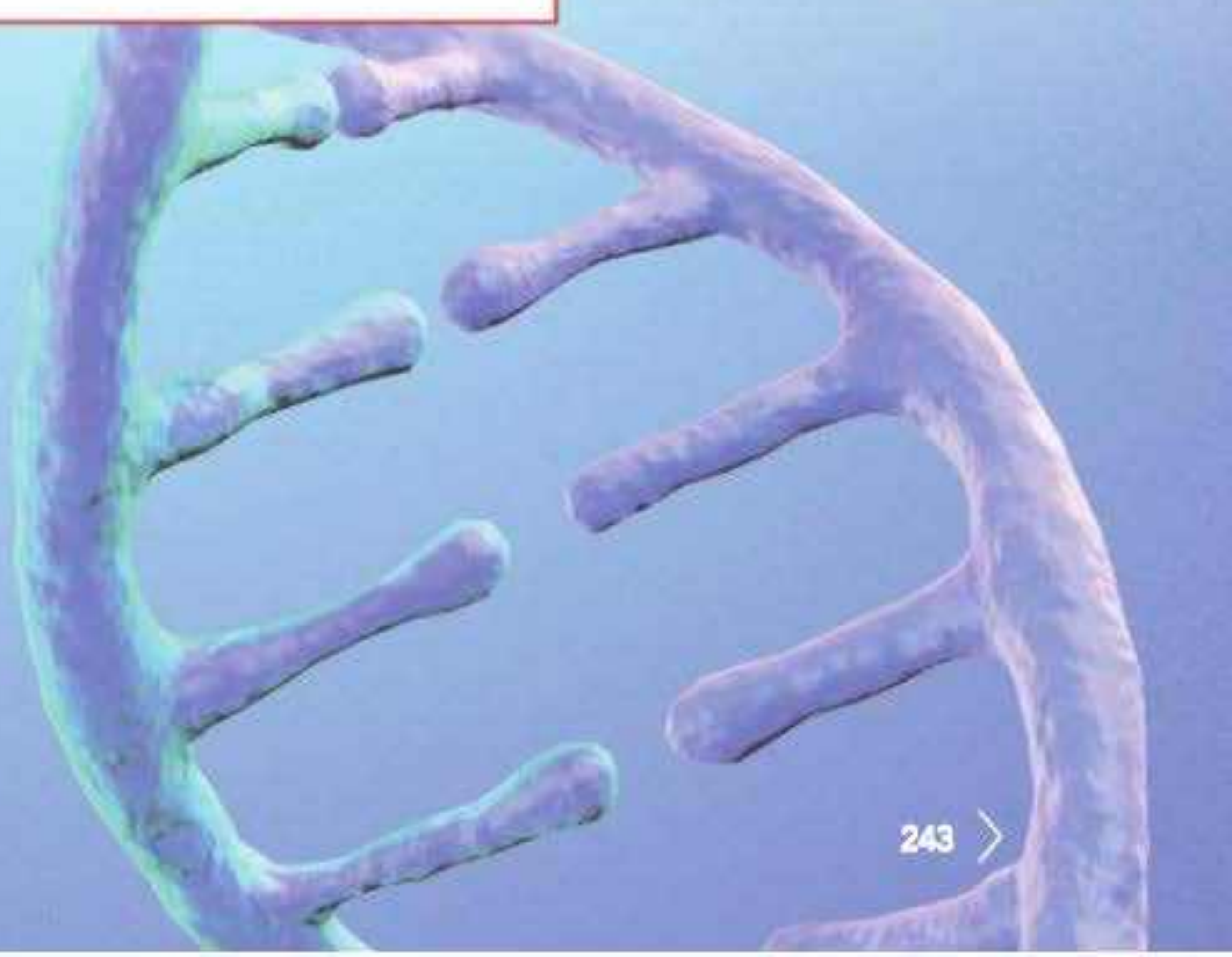
1 Why do you think these very different structures have the same name?

2 Which one is larger?

3 What does the nucleus of a cell do?

Key words

chromosomes
DNA
genes



Chromosomes

In Stage 7, you learnt that the nucleus of a cell controls its activities. In this unit, you will learn much more about how it does this.

The nucleus of every cell contains threads called **chromosomes**. Chromosomes were discovered in the nineteenth century. This was when scientists first had sufficiently powerful microscopes, and were first able to see very small things, such as the structure of cells.

When you looked at cells using a microscope, you almost certainly did not see any chromosomes. This is because chromosomes only become visible with a light microscope when a cell is dividing. Chromosomes also need to be coloured using special stains, in order to be able to see them.

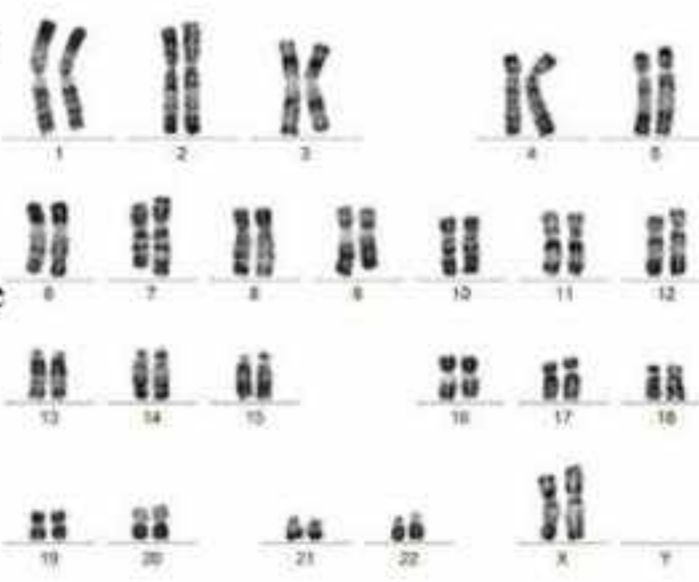
This photograph shows a plant cell that is just beginning to divide into two cells. The cells have been stained with a special dye that colours the chromosomes dark red. You cannot really see any of the other structures in the cell.

This photograph shows a chromosome from a fruit fly. Fruit flies have especially thick chromosomes, called giant chromosomes, which are much easier to see than most chromosomes. You can see that this chromosome is a long, striped thread.

Different species of organism have different numbers of chromosomes in the nuclei of their cells. Human cells have 46 chromosomes. Fruit fly cells have eight chromosomes. Mango trees have 40 chromosomes.

Scientists number the chromosomes in a cell according to how long the chromosomes are. In a human cell, the longest chromosome is chromosome 1, the next longest is chromosome 2, and so on.

We have two of each kind of chromosome. This photograph shows all the chromosomes in a human cell. It has been made by cutting and pasting pictures of the individual chromosomes. They have then been lined up in size order. They do not really line themselves up like this!



If you look very closely at this photograph, you may be able to see that each chromosome looks like a cross shape. You can see this really clearly in the photograph at the start of the next topic. This is because – just before a cell divides – each chromosome makes a copy of itself. The two copies stay joined together part-way along their length.

Activity 7.1.1

Making models of chromosomes in a cell

Work in a group of two or three for this activity.

You are going to make a set of chromosomes in a cell of a chosen species of animal.

You can use whatever materials you like to make the models of chromosomes. For example, you could use string or wool. You will also need a large sheet of paper.

First, use the internet to find out how many chromosomes your species has in its cells.

Next, draw an outline of a cell on a large sheet of paper. Do not make it a perfect circle – draw it freehand. Draw a large nucleus inside the cell.

Now make your chromosomes. Remember that there are two chromosomes of each type. So, if your animal has 32 chromosomes, you need to make two sets of 16.

Stick the chromosomes inside the nucleus of the cell.

Write a heading on the sheet of paper to say which species of animal your cell represents.

Self-assessment

How satisfied are you with your model of a cell containing chromosomes?

How does it compare with the models that other groups have made?

What would you do to improve your model, if you had different materials to use, and more time?

Questions

1. Explain why we cannot usually see the chromosomes in a cell, even using a microscope.
2. Red blood cells do not contain a nucleus. Do you think they contain any chromosomes? Explain your answer.

Genes

Each chromosome is made up of hundreds of different **genes**. The genes are arranged in a particular sequence along the chromosome. Each gene helps to control a particular characteristic in the organism. On this diagram of a short chromosome, the stripes represent different genes.

Scientists are still finding out which genes are found on each type of chromosome in humans. On chromosome 1, for example, we know that there are about 2000 different genes. Chromosome 15 is a much shorter chromosome, and it has about 600 different genes.

Discovering exactly what each of these genes do is not easy, but scientists are learning more all the time. For example, we know that two genes on chromosome 15 help to determine eye colour. Everyone has genes for eye colour in the same place on their chromosome 15s. But there are different versions of these genes, so one person could have a chromosome 15 with eye colour genes that give them blue eyes, and another could have a chromosome 15 with eye colour genes that give them brown eyes. That is why the two sisters in this photograph have different eye colours.

DNA

Chromosomes are made of a chemical substance called **DNA**. Each chromosome is one enormously long molecule of DNA.

This means that genes are also made of DNA.

A DNA molecule has a shape like a twisted ladder. This shape is called a double helix. One gene could be a length of DNA with about 2500 of these twists. We cannot see these twists when we use microscopes to look at chromosomes because DNA molecules are much too small to see.

DNA was first discovered in the 1950s. Since then, scientists have found out a great deal about how the DNA in genes helps to determine the characteristics of humans and other organisms. The DNA in a cell determines what the cell does. It contains a complete set of instructions to make a functioning cell, and a whole organism. If you continue to study science to IGCSE or O level, you will find out much more about this.

Questions

3 Explain the difference between a chromosome and a gene.

4 All fruit flies have a gene for wing shape, in the same place on their chromosome 2. But some fruit flies have normal wings, and some have very tiny wings – so small that they cannot fly. What can explain this?

Summary checklist

- ☐ I can explain that chromosomes are made of DNA.
- ☐ I can explain that each chromosome contains many genes.
- ☐ I can explain that genes help to determine an organism's characteristics.

7.2 Gametes and inheritance

In this topic you will:

- learn what a gamete is
- think about the similarities and differences between male and female gametes
- find out what happens at fertilisation
- explain what determines whether a baby is a boy or a girl.

Getting started

All cells have similar features, but most kinds of cell are specialised to perform a particular function.

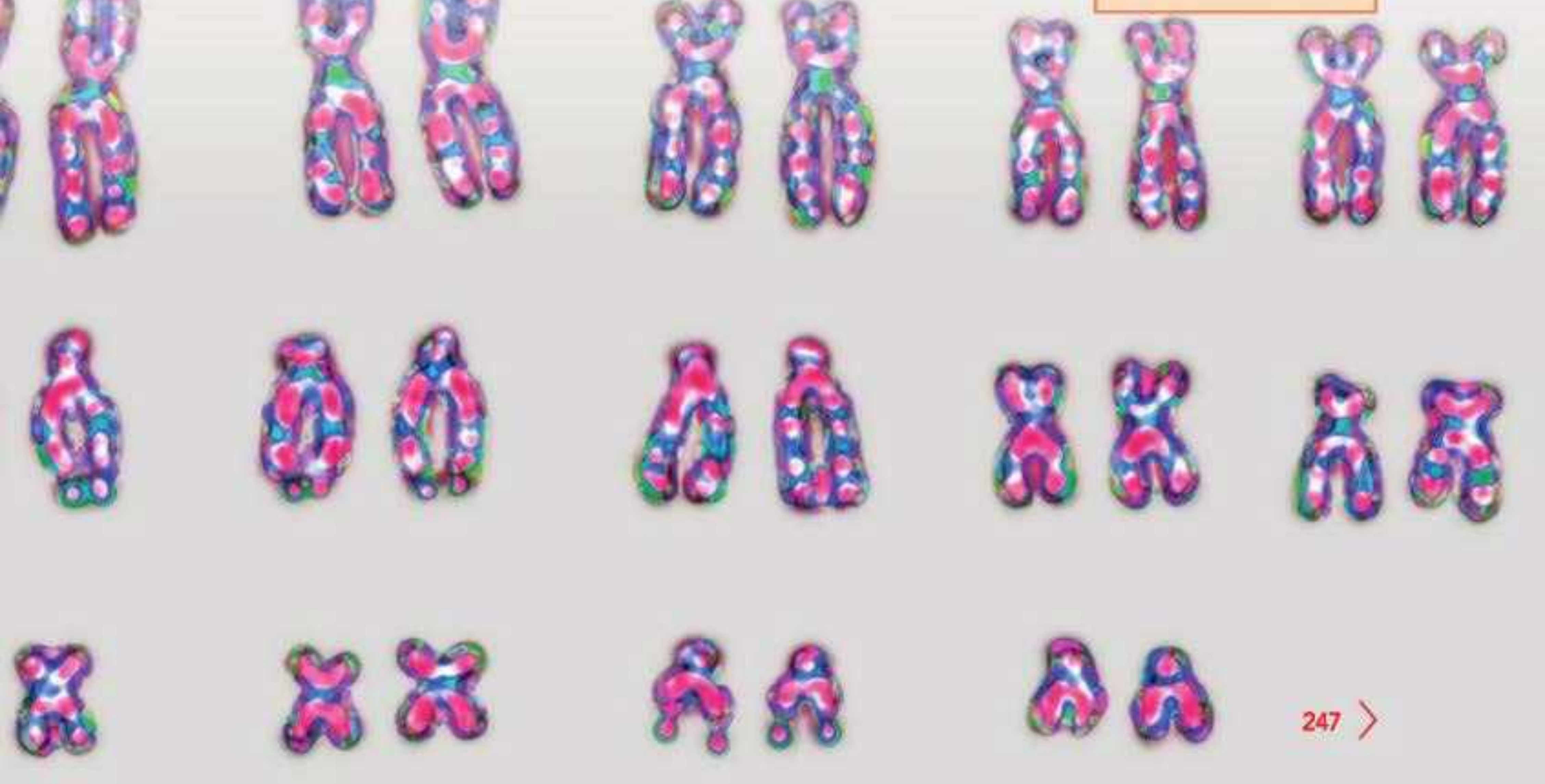
1 How many different kinds of animal cells can you think of?

2 What features do they all share?

3 Can you describe how some of them are adapted for their functions?

Key words

egg cell
fertilisation
gametes
inheritance
sex chromosomes
sex inheritance
sperm cell
X chromosomes
Y chromosomes
zygote

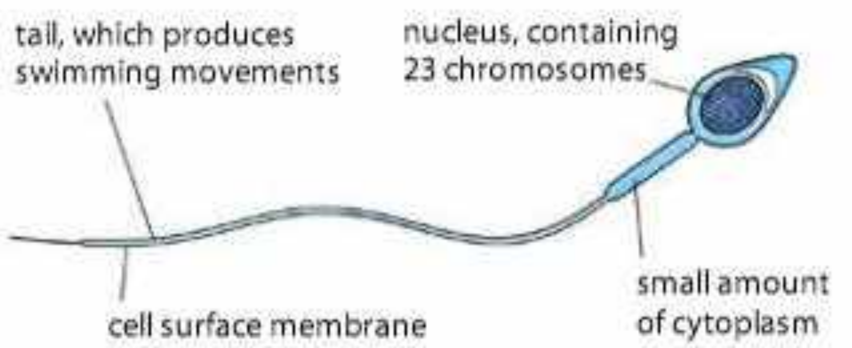


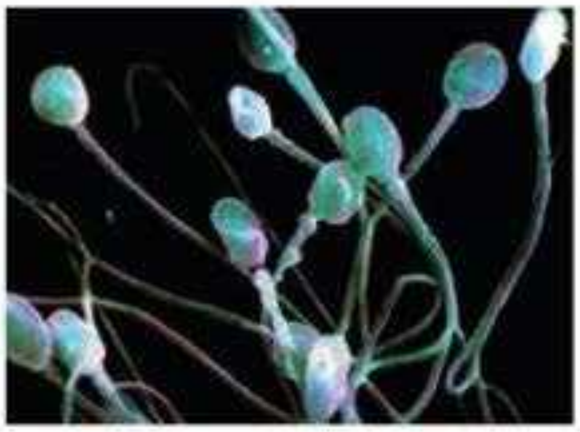
Gametes

Most cells in a human body contain 46 chromosomes. Where did these chromosomes come from? To answer that, try to think about how a new human life begins.

Every human being began life as a single cell. This cell was formed when a **sperm cell** joined with an **egg cell**. Sperm cells and egg cells are specialised cells known as **gametes**. A sperm cell is a male gamete, and an egg cell is a female gamete.

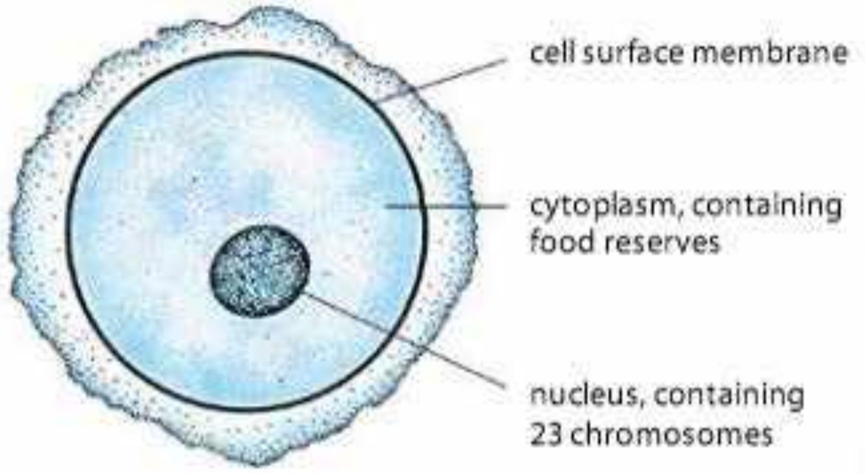
This diagram shows a human sperm cell. The photograph shows a group of sperm cells. It was taken with a special kind of powerful microscope called a scanning electron microscope.

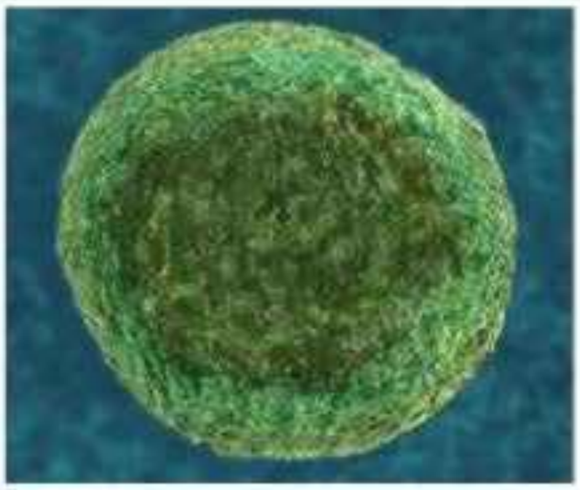




Sperm cells are very small cells. They are very active, using their tails to swim vigorously.

This diagram shows a human egg cell. The photograph, like the photograph of the sperm cells, was taken with a scanning electron microscope.





Egg cells are much bigger than sperm cells, but they are still very small. A human egg cell is about the same size as a full stop. They need to be larger than sperm cells because they contain food reserves. Another difference from sperm cells is that egg cells cannot move by themselves.

Questions

1 What is a gamete?

2 Draw a table with two columns. Write the headings 'Sperm cell' and 'Egg cell' at the top of the columns. Then make a comparison of these two cells. Try to think of at least three differences between them.

Fertilisation

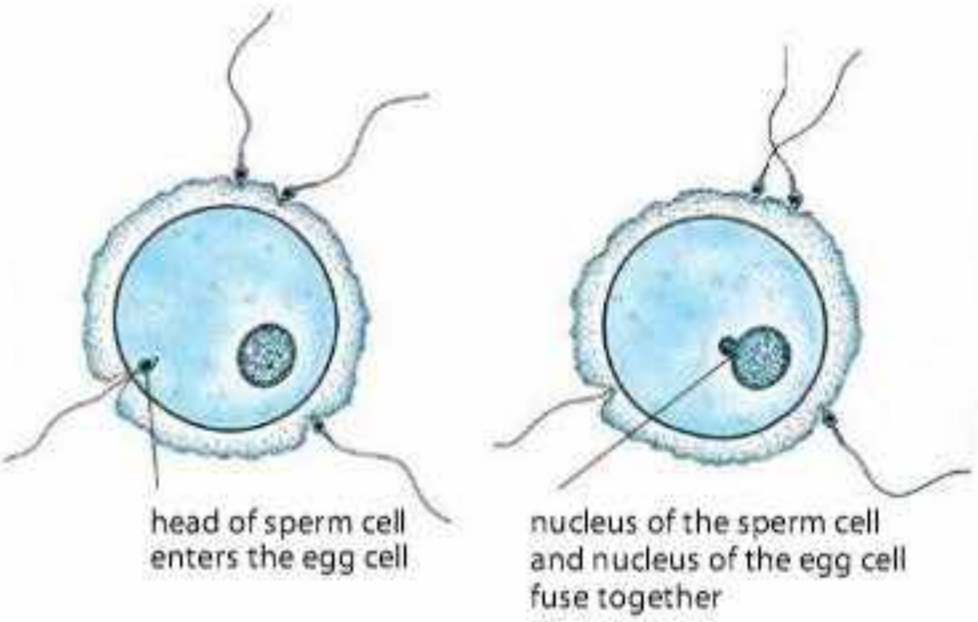
You may have noticed something odd in the labels on the diagrams of the sperm cell and the egg cell. They each have only 23 chromosomes.

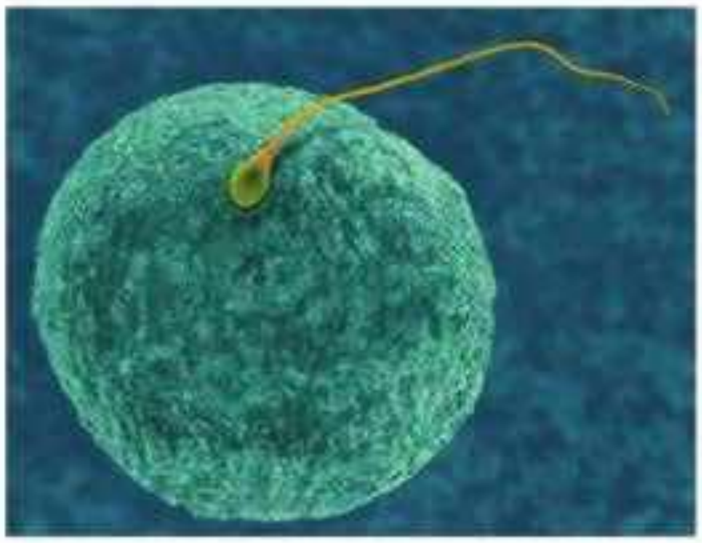
In the previous topic, we saw that human cells each have 46 chromosomes in their nucleus. They have two sets, each set containing 23 chromosomes.

But gametes have only one set of chromosomes. This means that, when a sperm cell joins with an egg cell, the new cell that is produced has two sets. It will have 46 chromosomes.

The joining of a sperm cell with an egg cell is called **fertilisation**.

The diagram and photograph show how fertilisation takes place.





The new cell that is formed when the nucleus of the sperm cell and the egg cell join together is called a **zygote**.

All humans began their life as a single cell like this. Over the next days, weeks and years, this single cell divides over and over again, eventually producing all of the millions of cells in a human body.

Boy or girl?

All of the chromosomes in the cells in a human body came from the person's mother and father. There is one set from the mother, and one set from the father. We can use this information to explain how a baby's sex is determined.

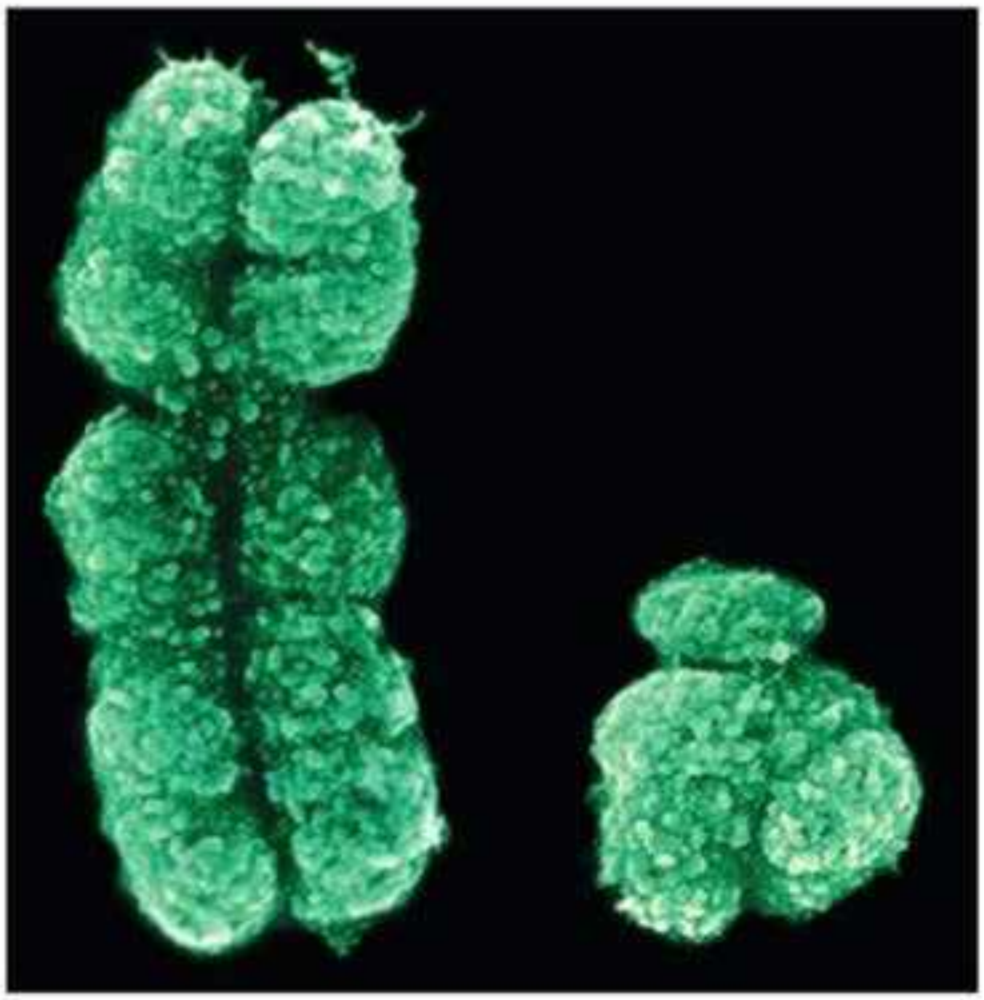
Look at the black and white photograph in the previous topic, where the two sets of chromosomes in a cell from a woman's body have been arranged in order. The last pair, at the bottom right of the photograph, are labelled X.

These two chromosomes are **sex chromosomes**. They determine whether a person is male or female. In that photograph, there are two **X chromosomes**. A person with two X chromosomes, XX, is female.

There is another kind of sex chromosome, called a **Y chromosome**.

Y chromosomes are much smaller than X chromosomes. A person with one X chromosome and one Y chromosome, XY, is male.

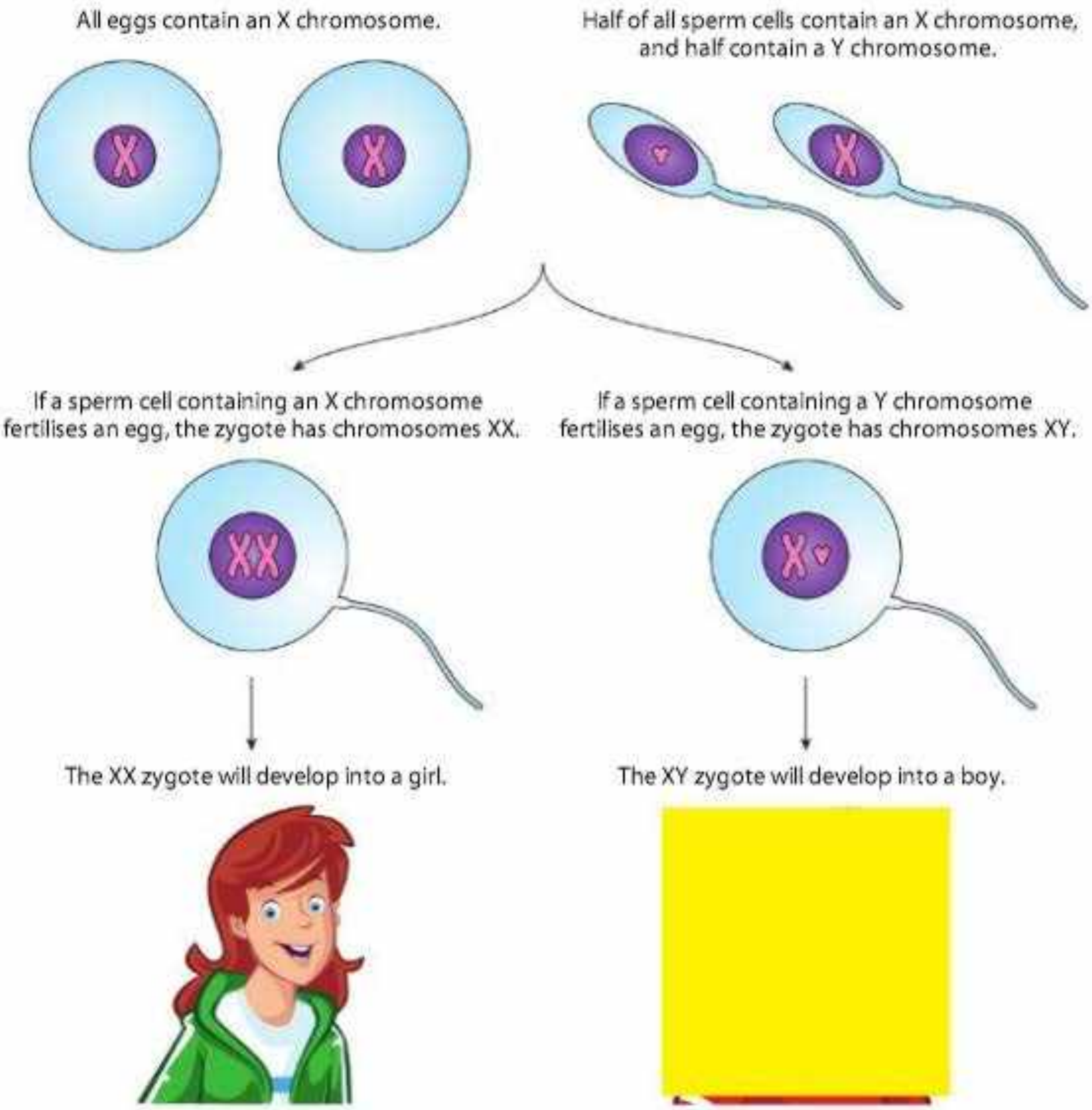
This photograph – again taken with a scanning electron microscope – shows a human X chromosome and Y chromosome.



All egg cells contain one X chromosome. Remember that gametes only have one set of chromosomes, so they only have one of each kind. However, sperm cells can have either one X chromosome or one Y chromosome.

So, each time fertilisation happens, either an X-containing sperm cell or a Y-containing sperm cell could join with an egg. If it is an X-containing sperm cell, then the zygote will have two X chromosomes, and will become a baby girl. If it is a Y-containing sperm cell, then the zygote will have one X chromosome and one Y chromosome, and will be a baby boy.

The chance of either of these events happening is about equal. This is why approximately equal numbers of boys and girls are born.



Inheritance

Inheritance means passing on DNA (as chromosomes containing genes) from parents to offspring.

A baby's sex is determined because a baby inherits X or Y chromosomes from its parents. We can use the term **sex inheritance** to describe this.

All organisms also inherit other features from their parents. You will find out more about this in the next topic.

Activity 7.2.1

Modelling sex inheritance

In this activity, you will work in pairs and use coloured pieces of string or wire to represent X chromosomes and Y chromosomes.

You will need:

- two containers – such as plastic pots, 45 short pieces of string or wire all the same size and the same colour – these represent X chromosomes, 15 short pieces of string or wire all the same size as the X chromosome strings but a different colour – these represent Y chromosomes

Method

1. Put 30 X chromosomes into one of the containers. These represent the chromosomes in 30 egg cells.
2. Put 15 X chromosomes and 15 Y chromosomes into the other container. These represent the chromosomes in 30 sperm cells.
3. One person puts their hand into the first pot – without looking – and takes out a piece of string or wire. Then they take out another piece of string or wire from the other pot.
4. Write down the chromosomes in the 'zygote' (fertilised egg) you have produced. Record the result in a table.
5. When you have used up all of the 'chromosomes', add up the total numbers of female and male zygotes that you have produced.

Question

1. From your results, what can you say about the chance of a baby being a boy or a girl?

Peer assessment

Look at how another pair have recorded their results.
Can you easily understand their results table?
Is it as good as yours, or is it better? What makes one table better than another?

Questions

3. Is it correct to say that the sex of a baby is determined by its father, not its mother? Explain your answer.
4. Explain, in your own words, why the numbers of boy and girl babies born each year is approximately equal.

Summary checklist

- [ ] I can explain what a gamete is, and describe the male and female gametes of humans.
- [ ] I can explain that fertilisation is the fusion of a male and female gamete.
- [ ] I can describe how sex is inherited in humans, in terms of X and Y chromosomes.

7.3 Variation

In this topic you will:

- learn what is meant by variation
- think about how genes help to produce variation
- investigate and record some examples of variation.

Getting started

In Stage 7, you learnt what a species is.

Think of a way to complete this sentence. Try to include some useful scientific information in your sentence.

A species is ....

Key words

genetic differences
variation

Variation within a species

Organisms that belong to different species usually look very different from one another. Horses look different from donkeys. Lions look different from tigers.

But individual organisms that belong to the same species also have differences between them. You and all of the other people in your class all belong to the same species. But you are all very different from one another.

The differences between individuals belonging to the same species are called **variation**.

Questions

1 These goats all belong to the same species. What similarities are there between them?

2 The goats show variation. What differences can you see between them?

Activity 7.3.1

Measuring variation in humans

Choose four or five features that vary among the members of your class.

Choose at least one feature that you have to measure.

Then complete a results table like this. Change the headings to match the features that you have chosen.

Draw enough rows so that you can complete results for at least eight people.

Person	Hair colour	Eye colour	Shoe size	Height in cm

Collect your results and complete your results table.

Using a bar chart to show variation

A species of plant called kidney vetch has flowers that can have any one of five different colours.

Zara studied the kidney vetch plants growing in a small area of a field. She counted the number of plants with each colour of flower.

She recorded her results like this. Each stroke represents one plant. When she gets to five, she puts the stroke for five across the first four.

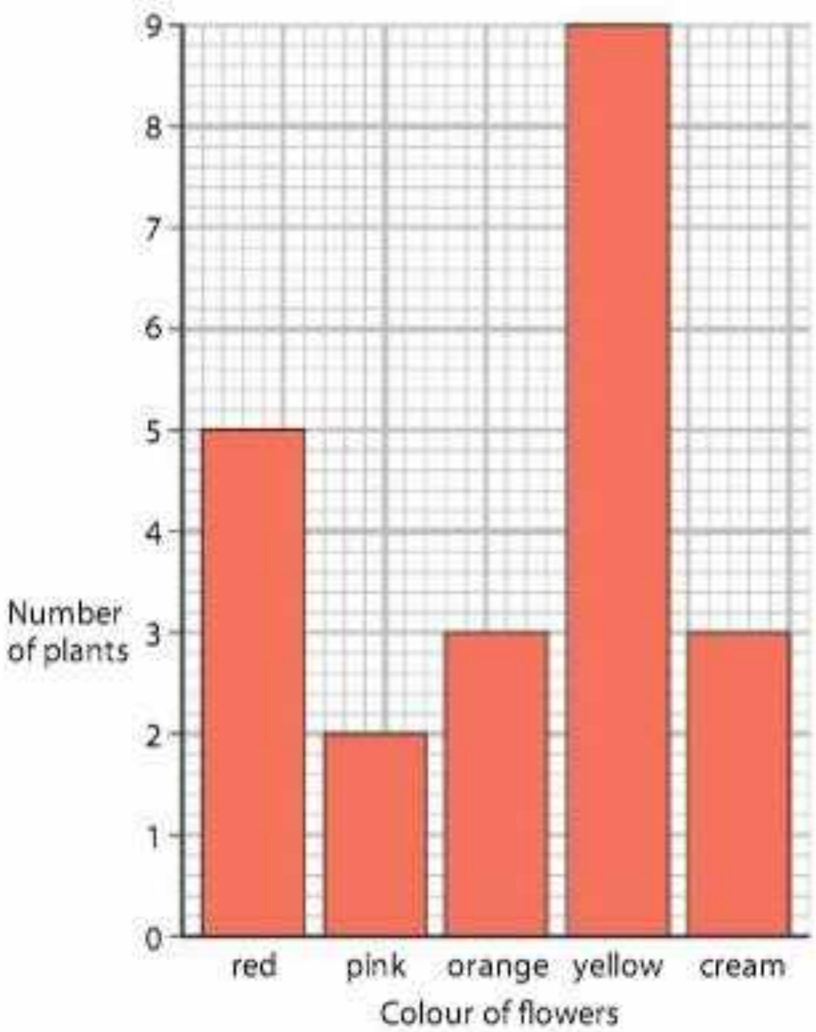
red pink orange

Colour	Red	Pink	Orange	Yellow	Cream
Tally	~~IIII~~	II	III	~~IIII~~ IIII	III
Number	5	2	3	9	3

yellow cream

When she had recorded the flower colour of each plant, she added up all the tally strokes and wrote the number in the last row.

Then she used her results to draw a bar chart, like this.



Questions

3 How many plants did Zara find?

4 Which was the most common flower colour?

5 Zara recorded her results in a table and also in a bar chart. Which of these do you think shows the results more clearly? Explain your answer.

Think like a scientist

Investigating variation in leaves

Some trees have leaves that are divided up into several smaller parts, called leaflets. You are going to investigate the variation in the number of leaflets in a leaf.

You will need:

- one or more trees belonging to the same species, with leaves divided up into leaflets.

Safety

Choose trees where you can collect leaves without having to climb onto anything.

Method

1 Collect at least 20 leaves from the same species of tree.

2 Count the numbers of leaflets on each leaf, and write them down in a list, like this:

11, 15, 12, 11, 13 ……… and so on

3 Draw and complete a tally chart like this. You will need to change the number of columns, depending on your results.

Number of leaflets					
Tally					
Number of leaves					

4 Now you are ready to draw a bar chart. Use the bar chart for the flower colour results to help you.

Questions

1 The median is the middle value for the number of leaflets. What is the median value in your results?

Continued

2 The mode is the most common value for the number of leaflets. What is the mode in your results?

3 You can find the mean by adding up all of the numbers of leaflets, and dividing by the number of leaves. What is the mean value in your results?

4 Did you find any differences between the number of leaflets on the leaves of the same individual tree? If you did, do you think that genes could have caused these differences? Explain your answer.

DNA and variation

Look again at the photograph of the goats, near the beginning of this topic. Can we tell what has caused the differences between them?

Each goat in the picture began life when a sperm cell fertilised an egg cell. A sperm cell and an egg cell each contain chromosomes, made of many genes. The genes are made of DNA.

All the sperm cells and all the egg cells of goats contain genes that affect the development of horns. There are several versions of these genes, each made of slightly different DNA. One version of the genes might produce long horns, another short horns and another one perhaps no horns at all. There could also be different genes for making curved horns or straight horns.

Different sperm cells and different egg cells probably contain different versions of these genes. They will also contain different versions of other genes – for example, for height, or coat colour or tail shape. Each gene is different because its DNA is different.

When a sperm cell and egg cell fuse together at fertilisation, the zygote that is produced has a new combination of DNA. The combination is not exactly the same as in its parents, or in its brothers and sisters.

Differences in the DNA of organisms within a species are called **genetic differences**. Genetic means 'to do with genes'.

The people in this photograph belong to three generations of the same family. Some of the DNA from the grandparents has been passed on to their children and grandchildren. You can probably see some similarities between them, because some of their DNA is the same. But everyone in the family has a slightly different combination of DNA from everyone else. There are genetic differences between them.

Environment and variation

DNA is not the only cause of variation between individuals. An organism's environment also affects it.

For example, think again about the variation in the goats. Let us for the moment just think about the two adult goats. They have different coat colours. This is determined by their DNA. Variation in coat colour is caused by genetic differences.

The size of the goat could also be affected by its DNA, but its environment will also affect size. For example, one goat might eat more than another, so it would grow fatter and have a greater body mass. This is not caused by its genes. Not all variation within a species is caused by differences in DNA.

Question

6 Look at your results for the Activity: Measuring variation in humans. For each feature that you investigated, suggest whether the differences are caused by:

- genes only
- environment only
- genes and environment.

Think like a scientist

Measuring variation in humans

You are going to investigate variation in people's wrist circumference. The data you collect are a little bit more difficult to deal with than the leaflet data. This is because they do not fit into definite categories, so you will have to determine the categories yourself.

Method

1. Measure the circumference of the wrist of every person in your class. (If your class has fewer than 20 people, you could measure some other people as well.) Write down your measurements in a list. Remember to include the unit.
2. Think about how you can fit the measurements into different categories. Each category should have the same range of measurements. Look at the table below for an idea. However, you may need to have categories that are not the same as these, depending on the measurements that you made.

Continued

Wrist circumference in cm	Tally	Number of people
8.0 – 8.9		
9.0 – 9.9		
10.0 – 10.9		
11.0 – 11.9		
12.0 – 12.9		
13.0 – 13.9		
14.0 – 14.9		

3 Now put a mark in the Tally column for each measurement that fits into that category.

4 Next, add up all the tally strokes and complete the last column in the table.

5 Now you are ready to draw a frequency diagram to display your results. Put wrist circumference on the *x*-axis, and number of people on the *y*-axis. The bars in your frequency diagram should touch one another.

Questions

1 What were the smallest and largest wrist circumferences that you measured in your investigation?

2 Which was the most common category of wrist circumference?

Peer assessment

How well do you think you have completed this task?

Did you:

- make sure that you measured the wrist circumference of each person in exactly the same way
- put the measurements into suitable categories
- label the axes of your frequency diagram correctly
- choose good scales for both axes of your graph
- draw the bars carefully and accurately?

Write down one thing that you think you did really well.

Write down one thing that you could do better next time.

Summary checklist

- [ ] I can explain what is meant by variation.
- [ ] I can describe some examples of variation affected by genes.
- [ ] I can explain that when two gametes fuse, they produce a fertilised egg with a new combination of DNA.
- [ ] I can measure and record some examples of variation, and display them in bar charts or frequency diagrams.

7.4 Natural selection

In this topic you will:

- learn about the scientific theory of natural selection
- find out about some examples of natural selection in action.

Getting started

The photograph shows a tiny frog, called a waxy monkey leaf frog.

The frogs live in a hot, humid rainforest. They are in danger from many different predators.

Suggest how the frogs are adapted to survive in their environment.

Key words

advantageous feature

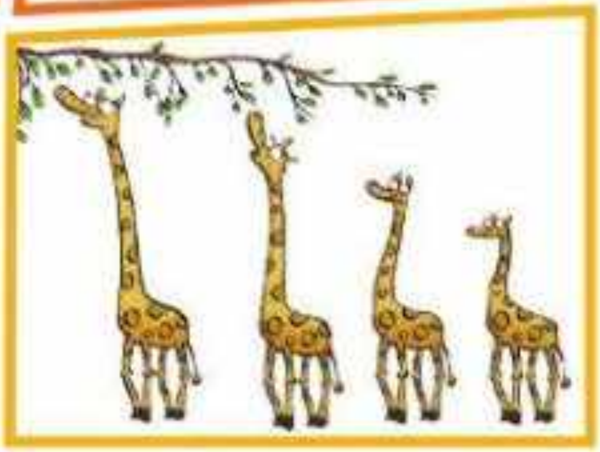
natural selection

resistant

An imaginary story

A long time ago, some animals belonging to a species of herbivore lived on the grassy plains of Africa. They ate leaves from trees. As in all species, there was genetic variation among them. Some individuals had varieties of genes that gave them long necks, and some had varieties of genes that gave them shorter necks.

In some years, the rains did not come. The animals ran short of food. When all the lower leaves had been eaten, only the long-necked animals could get food.



Most of the animals with short necks died of starvation.

When the animals reproduced, they passed on their genes to their offspring. Because only the long-necked animals had survived, it was only their genes that passed to the next generation. Most of their offspring grew up to have long necks.

This imaginary story describes how giraffes might have come to have such long necks. We do not know if this is what happened, and we can never really know. But this theory does help to explain how almost every species is so well adapted to its environment.

You can summarise the theory like this:

1 In every species, there is variation among individual organisms.

2 Some of this variation is caused by differences in their genes.

3 Some individuals have features that make it more likely that they will survive than individuals that do not have these features.

4 The individuals with these **advantageous features** are therefore more likely to reproduce, and pass on the genes that produce the advantageous features to their offspring.

5 Over many generations, the genes that produce these advantageous features get a little bit more common, and the genes that are not so useful get a little bit less common.

This process is called **natural selection**. In the imaginary giraffe example, natural selection has caused genetic changes in the giraffes over time because some varieties of genes have become more common, and some have become less common.

Activity 7.4.1

Does natural selection always produce change?

Think about these questions on your own for a few minutes. Then turn to your partner and discuss your ideas.

1 Imagine a population (group) of organisms that are all really well adapted to their environment. What organisms are you thinking of? Where do they live? How are they adapted to their environment?

2 Now think about what happens over time, if there is no change in their environment. How does natural selection affect this population?

3 Now think about a change in their environment. How does natural selection affect the population now?

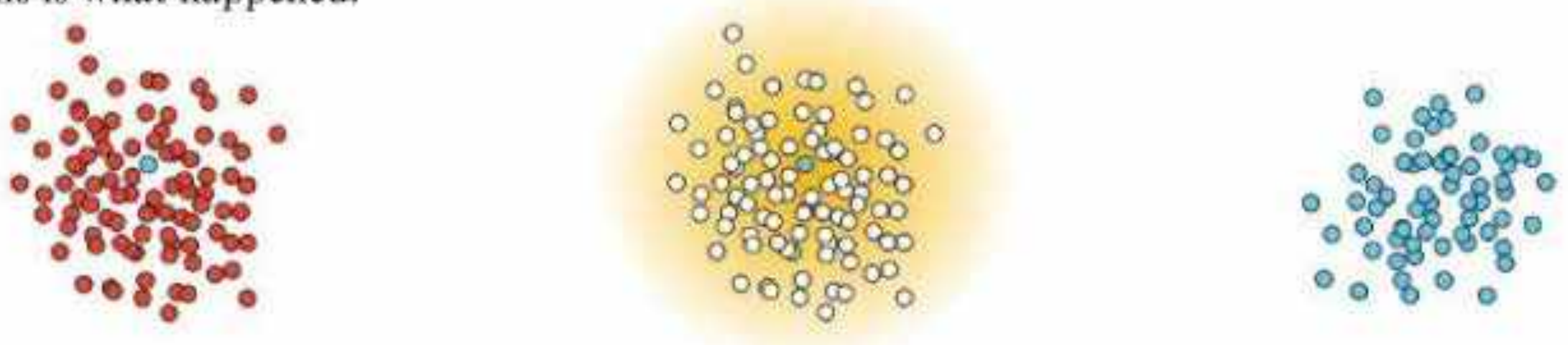
Share your ideas with a partner. Do they agree with your ideas? Do you agree with their ideas?

Bacteria and antibiotics

The giraffe story is an imaginary one. We have no evidence that any of this ever happened. But we do have very strong evidence for natural selection in other organisms.

Antibiotics are medicinal drugs that we can take to cure diseases caused by bacteria. There are many different antibiotics. But doctors are finding that some antibiotics do not work anymore. Bacteria have become **resistant** to them.

This is what happened.



In a population of bacteria, not every one is alike. By chance, one may have a gene that makes it resistant to an antibiotic.

Antibiotic is added, which kills the bacteria that are not resistant.

The resistant one can now multiply and form a population of resistant bacteria just like itself.

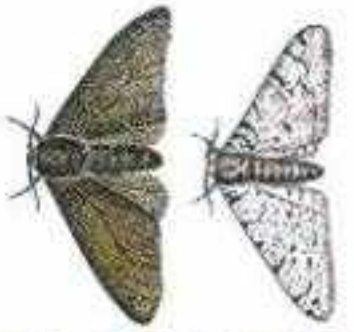
Questions

1 Explain what we mean when we say that bacteria have become resistant to an antibiotic.

2 Bacteria have genes. Explain how the development of resistance in bacteria can be explained in terms of genetic changes over time.

3 Doctors advise that we should not use antibiotics unless we really need them. We should save them for when people have serious illnesses. Suggest an explanation for this advice.

Peppered moths



Here is another example of natural selection in action.

Peppered moths live in England. Most peppered moths have pale wings, but some have a gene that gives them dark wings.

Peppered moths fly at night, and spend the daylight hours resting on tree trunks. They are hunted and eaten by birds. The pale colour of peppered moths camouflages them perfectly against lichen-covered tree bark. (Lichen is a plant-like organism that grows on rocks and trees.)

Until the year 1849, almost all peppered moths were pale. Then more and more dark ones started to appear. By 1900, almost all peppered moths near some English cities were dark ones.

What was happening? During this time, the Industrial Revolution was taking place in England. Many factories burnt coal, which polluted the air with smoke. The smoke killed lichens and made the tree trunks dark.

Scientists have done experiments that show that birds can see light moths more easily on dark tree trunks than on lichen-covered ones. And they can see dark moths more easily on lichen-covered tree trunks than on dark ones.

Now we can explain why the dark variety of the moth became more common. When the tree trunks got darker, the pale moths were not camouflaged. They were more likely than the dark ones to be eaten by birds.

The dark moths were more likely to survive and reproduce than the pale moths. They passed on their genes for their dark colour to their offspring. Over several generations of moths, more and more of the offspring inherited these advantageous genes for dark colour. Over time, the dark colour became more and more common. Each generation, more dark moths were born and fewer pale moths.

Today, pollution in England is much less. Lichens grow on tree trunks again. Today, most peppered moths are the pale variety.

Questions

4 Look back at the list of five events that summarise the theory of natural selection.

Use this list to explain how natural selection caused dark peppered moths to become more common than pale peppered moths, during the late nineteenth century in England.

How well do you think you have answered question 4? Did you:

- refer to each of the five points in the list describing how natural selection happens
- pick out events in the peppered moth story that match each of these five points
- give a really clear explanation of how genetic changes over time produced the change in the most common type of peppered moth
- use scientific terms in your explanation (e.g. gene, natural selection, variation)?

Extinction

The proportions of dark and pale peppered moths changed over time, when their environment changed. But imagine what might have happened to the peppered moths if the proportions of pale and dark moths in the population had **not** changed, when the tree trunks became darker. If the moths were still all pale, then most of them could have been eaten by birds. The population of moths might have become so small that the peppered moths all died out. The species might have become extinct.

Changes in the environment can cause a population to become extinct, if the species cannot change over time. Scientists are worried that climate change may cause a very large number of species to become extinct.

Summary checklist

- [ ] I can describe the scientific theory of natural selection.
- [ ] I can explain how natural selection can sometimes produce genetic changes in a population over time.
- [ ] I can describe some examples of natural selection in action.
- [ ] I can explain that environmental change can cause a species to become extinct.

Project: How we learnt about DNA

You are going to work in a group to produce a short report about one of the steps by which scientists discovered what we know about DNA today. Each group's report can then be used to contribute to a display to show a time line of these discoveries.

One of the first people to do scientific experiments about inheritance was Gregor Mendel. He worked in a monastery garden on his own, but today scientists researching DNA work in groups, in well-equipped laboratories. Your time line will help to show how scientific research has progressed from Mendel's time to today.

A portrait of Gregor Mendel

Research into DNA in a modern laboratory

Choose one of these steps to research:

1860s Gregor Mendel does experiments on inheritance of characteristics in pea plants.

1902 Walter Sutton and Theodor Bovari each discover that chromosomes are important in inheritance.

1920 to 1944 Frederick Griffith and Oswald Avery show that DNA is the genetic material.

1953 Rosalind Franklin, Francis Crick and James Watson work out the structure of DNA.

2001 The structure of all the DNA in human cells is worked out, through the international Human Genome Project.

You can use a mix of words, photographs (from the internet) and drawings. It would be good if everyone in the class uses the same size of paper to produce their report, so that they look good when they are all put together to produce the time line. Do not make your report too long – it should fit onto one piece of paper.

Continued

Try to include information about these questions in your report:

- Where did the people who made the discovery work?
- How did they make their discoveries?
- Did the scientists work on their own, or with others?
- How did the discoveries made earlier help your scientists to make their discoveries?
- How did the scientists share their discoveries with other scientists? Did this happen quickly, or did it take a long time?

Check your progress

7.1 Copy and complete the sentences. Choose from the list.
You can use each word once, more than once or not at all.

chromosomes DNA four genes two

The nucleus of every cell contains several long threads, called ....

In most cells, there are .... copies of each thread.

Each thread contains many ....

The threads are made of a chemical called .... **[4]**

7.2 Copy and complete the table. Put a tick in a space if you think the description is correct. Leave the space empty if you think the description is not correct. **[5]**

Description	Egg cells	Sperm cells
contain a nucleus		
are gametes		
can swim		
in humans, contain 23 chromosomes		
contain either an X chromosome or a Y chromosome		

7.3 Arun investigated variation in bean pods. (You can see a picture of a pod on the previous page.)

He picked 20 bean pods, all from the same species of bean plant. He counted the number of beans in each pod. These are the results that he wrote down.

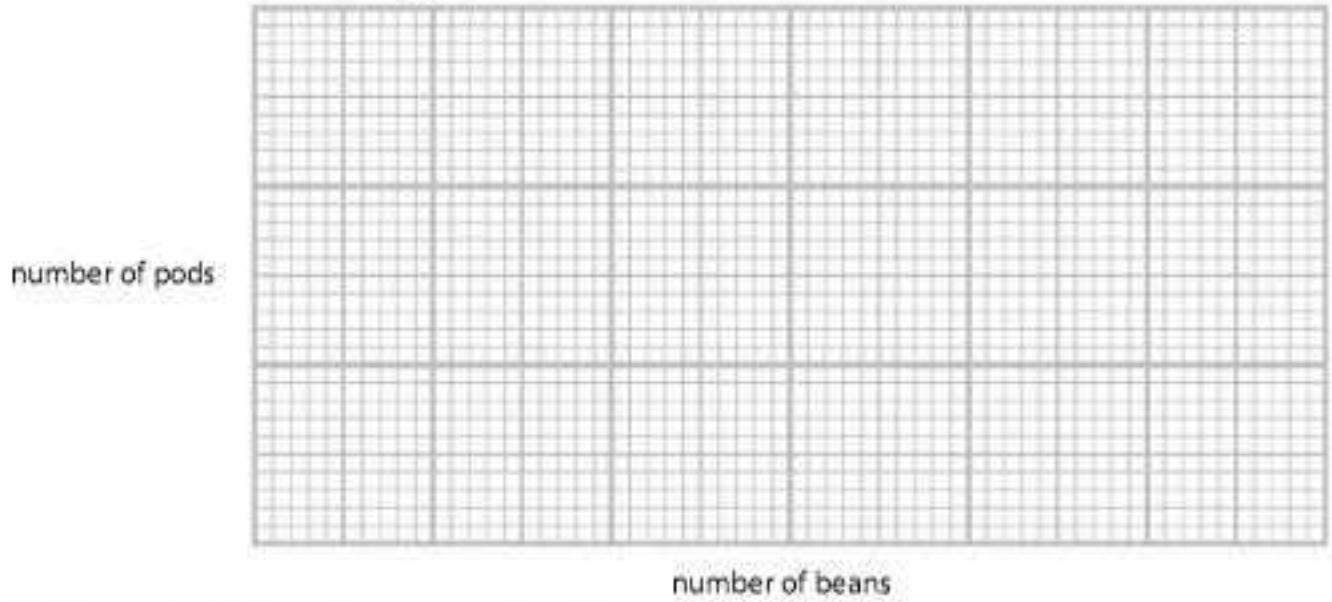
7, 3, 8, 6, 3, 4, 7, 5, 5, 8, 6, 4, 6, 7, 5, 5, 6, 5, 4, 8

a Calculate the mean number of beans in a pod.
Show how you worked out your answer. **[2]**

b Copy this results table. Use Arun's results to complete it. **[2]**

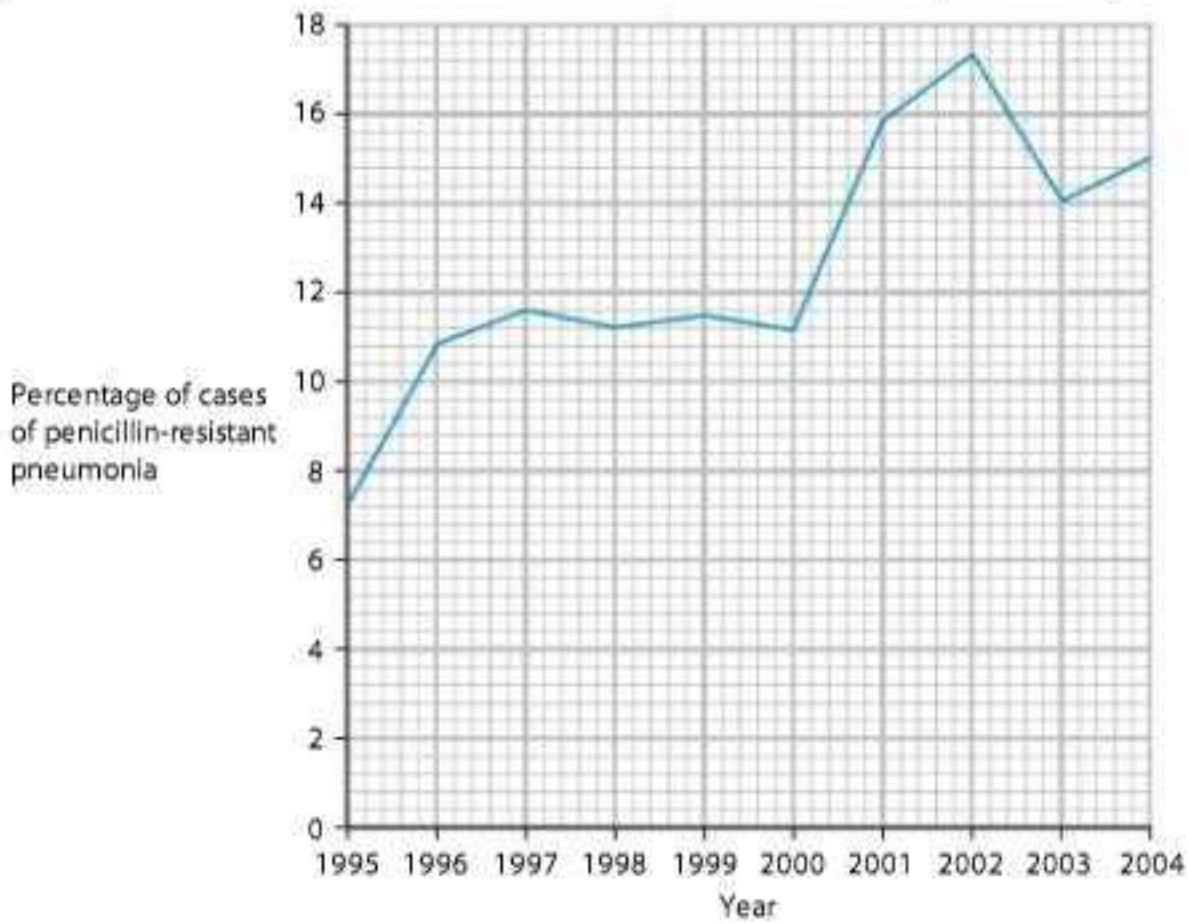
Number of beans in a pod						
Tally						
Number of pods						

c Copy these axes onto a large piece of graph paper.
Then draw a suitable graph to show Arun's results.



Add a suitable scale on each axis.
Draw touching bars to show the results. [4]

7.4 A bacterium called *Staphylococcus pneumoniae* causes a serious infection of the lungs, called pneumonia. The graph shows the percentage of cases of pneumonia in which the bacteria were resistant to penicillin (an antibiotic).



a What is an antibiotic? [1]
b Describe the trend shown in the graph. [1]
c Suggest how natural selection has caused this trend. [3]

8 Rates of reaction

8.1 Measuring the rate of reaction

In this topic you will:

- learn how the rate of reaction can change
- measure the rate of reaction
- use graphs to discuss and measure the rate of reaction
- explain why the rate of reaction changes.

Getting started

- With a partner, list as many of the ways you can of telling that a reaction has taken place.
- Can you suggest ways in which you could measure how quickly a reaction takes place?
- Share your ideas with the class.

Key words

anomalous result

collecting a gas over water

collisions

gradient

rate of reaction

Rate of reaction

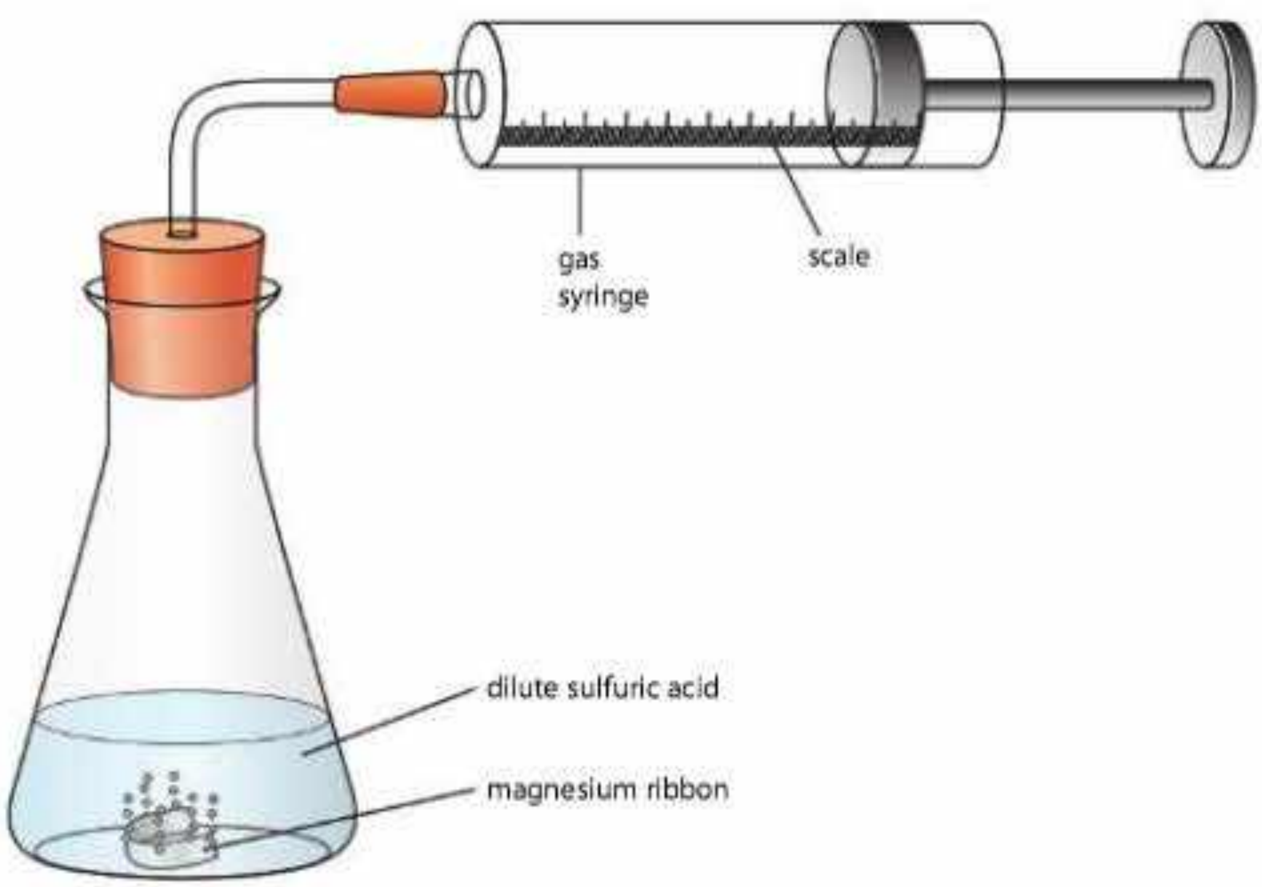
When magnesium ribbon is added to dilute sulfuric acid, you can tell a reaction is taking place because bubbles of hydrogen gas are given off. When you carried out this reaction in the laboratory, you may have noticed that at the start of the reaction a lot of bubbles were given off quickly. As the reaction came to an end, fewer bubbles were produced. Eventually, no more bubbles were produced. This shows that the reaction started quickly, then slowed, and eventually stopped.

How could you measure how quick the reaction was? This is called the **rate of reaction**.

The rate of reaction can be measured by working out how much of one of the products has been made in a given time, or how much of a reactant has been used up in a given time.

In the magnesium ribbon experiment, it is difficult to measure how quickly the reactants are used up or how quickly the magnesium sulfate is formed. The easiest way to measure the rate is to measure how quickly the hydrogen gas is produced. You can do this by measuring the volume of gas produced in a particular period of time.

To collect the gas, you can attach a syringe to the top of a flask so that no hydrogen can escape, as shown in the diagram. You can use the scale on the syringe to measure the volume of gas produced at different times during the reaction.



Questions

1 Write the word and symbol equations for the reaction of magnesium with sulfuric acid.

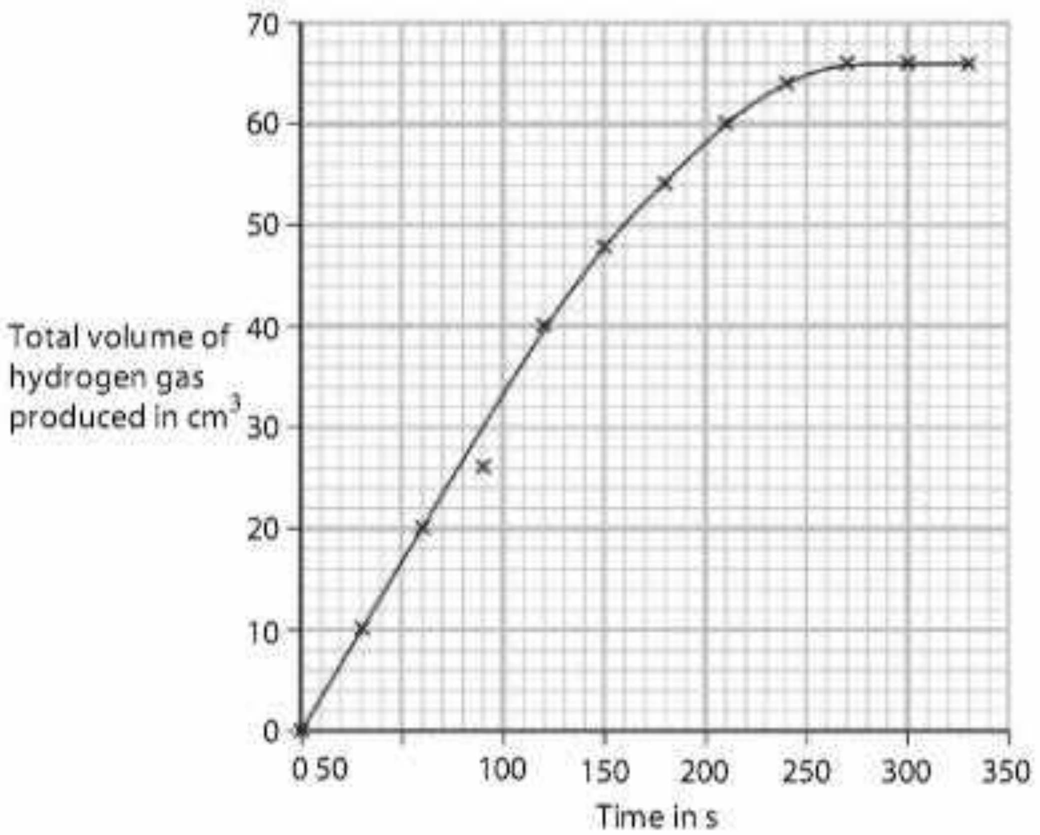
2 This three-part table shows the results obtained from an experiment using the apparatus shown above.

Time in s	Total volume of hydrogen gas produced in cm^3	Time in s	Total volume of hydrogen gas produced in cm^3	Time in s	Total volume of hydrogen gas produced in cm^3
0	0	120	40	240	64
30	10	150	48	270	66
60	20	180	54	300	66
90	26	210	60	330	66

How can you tell from the table that the reaction has finished at 270 seconds?

3 Suggest what might happen in the experiment if you used a lot more magnesium and acid, so that more than 100 cm^3 of hydrogen gas was formed. What could be done to reduce the risk of an accident if more than 100 cm^3 of hydrogen as produced?

4 When a graph of the results in the table is plotted, it is easier to see the pattern that they make. The graph shows that one of the results does not fit the pattern. This is called an **anomalous result**.



Which of the results is anomalous? Explain how you identified the anomalous result, and say what you would expect the result to be.

When you measure the rate of reaction, you find that the rate of reaction changes as the reaction proceeds. Another reaction you could look at is the one between calcium carbonate and dilute hydrochloric acid.

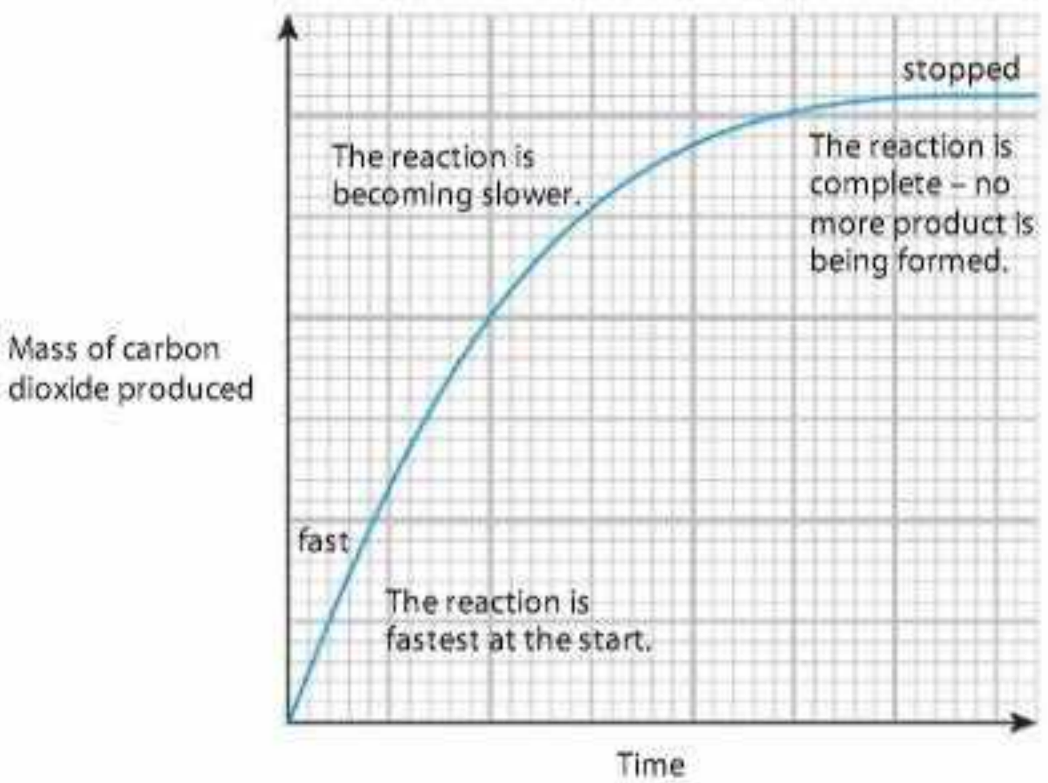
As carbon dioxide gas is lost from the flask, the mass of the flask decreases. If you measure the mass every 30 seconds, you find that the mass decreases quickly at first but, as the reaction continues, the mass decreases more and more slowly.

Using the graph

A graph of the results from investigations into the rate of reaction can be used to measure the rate of reaction at any given time. The slope or **gradient** of the line tells you how quickly the reaction is taking place.

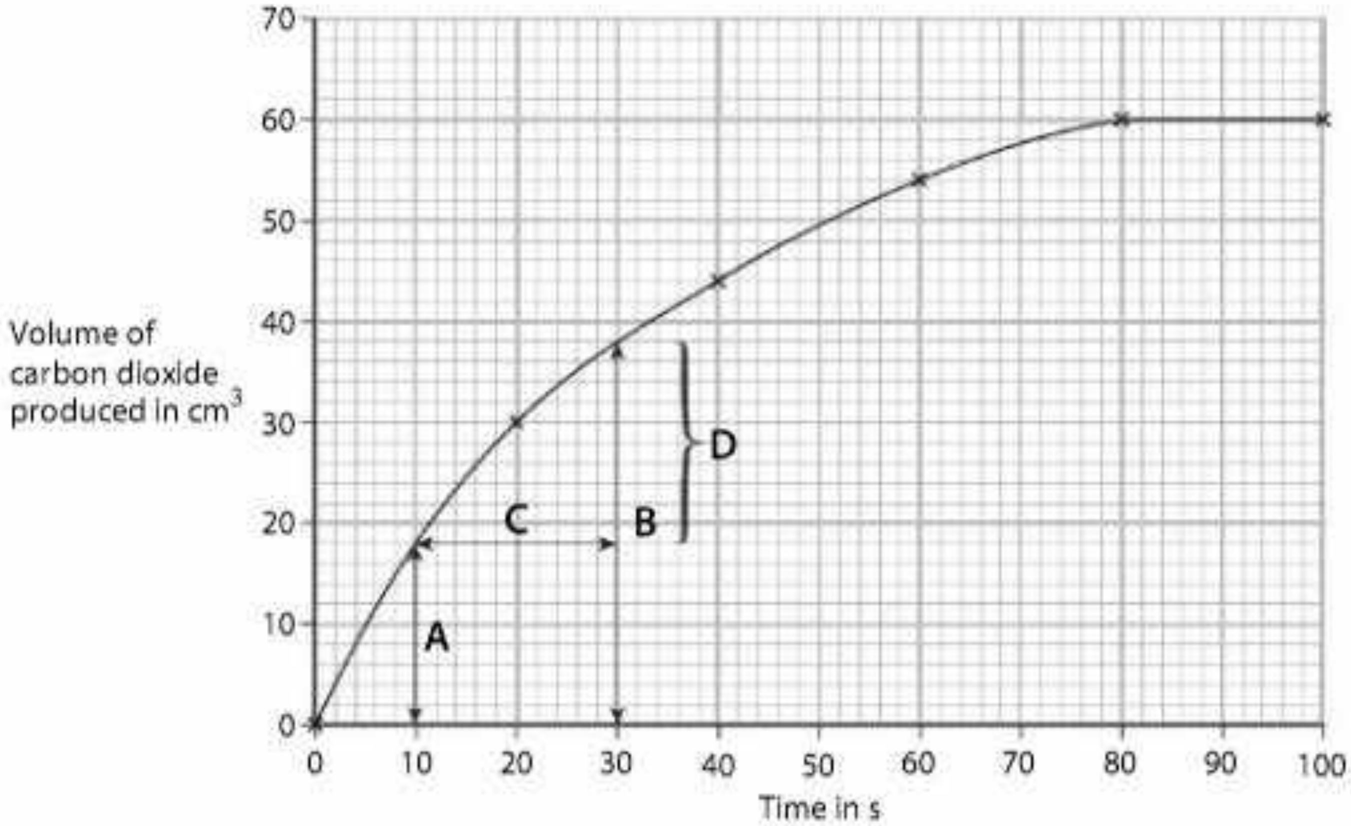
The steeper the slope, the faster the reaction.

This graph shows the results of an investigation into the rate of reaction between calcium carbonate and hydrochloric acid.



The line is steepest at the start of the reaction. This is when the reaction is fastest. As the slope of the line becomes less steep, the reaction is becoming slower. When the line levels out, it shows that no more carbon dioxide is being lost. This means that the reaction has ended.

This graph shows the rate of reaction between copper carbonate and hydrochloric acid. You can use a graph like this to measure and compare the rates of reaction at different times during the reaction. You can use the graph to find out the average volume of carbon dioxide gas given off per second in the period between 10 seconds and 30 seconds.



To do this you should draw a line at 10 seconds on the horizontal axis up to where it meets the line of the graph, labelled **A**. Then draw another line at 30 seconds up to the point here it meets the graph, labelled **B**.

Draw line **C** between **A** and **B** as shown.

The distance of **C** represents the time taken, in this case 20 seconds.

The line **D** shows you how much carbon dioxide was produced in this time, in this case 20 cm^3.

If 20 cm^3 of carbon dioxide is produced in 20 seconds. Then on average the rate of reaction over this period of time is 20 cm^3 in 20 seconds or 1 cm^3 per second.

Questions

5 Write the word equation for the reaction between copper carbonate and hydrochloric acid.

6 Use the graph above to find the average rate of reaction between 60 and 80 seconds. How does this rate of reaction compare with the rate between 10 and 30 seconds?

Activity 8.1.1

What makes a good graph?

You will need:

- poster materials and/or access to computers.

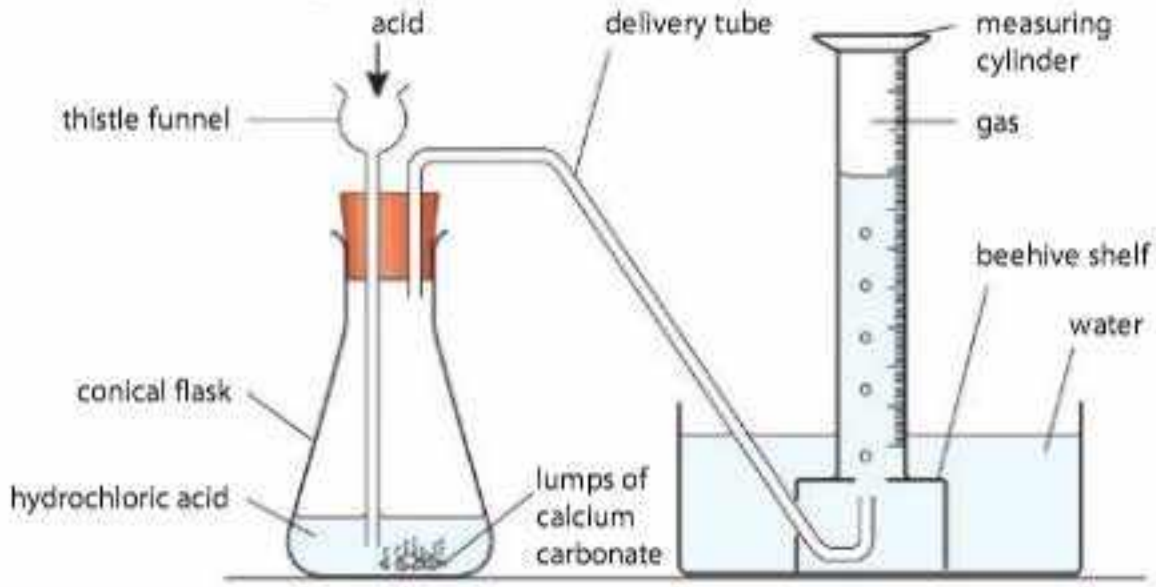
Method

1. With a partner, discuss why you may need to plot a graph of your results when you carry out an investigation.
2. Discuss the things that make a good graph; some of the things you might consider are:
   - how you know which variable to put on which axis
   - what scale to use
   - what labels you use
   - how the points are plotted
   - how you decide to join the points.
3. Make a poster, slide presentation or some other sort of presentation to illustrate how you produce the best possible graphs.
4. Present your poster or presentation to another group or the whole class.
5. Assess the presentations that other groups make to you.

Think like a scientist

Measuring the rate of reaction

In this activity, you are going to measure the rate of reaction between calcium carbonate and hydrochloric acid. You could do this in several different ways. You could do it by measuring the mass of carbon dioxide lost (using a top pan balance, as in the diagram after question 4 earlier in this topic). Or you could collect the carbon dioxide and measure the volume produced either by using a gas syringe (as shown earlier in this topic in Rate of reaction) or by using a trough of water and a measuring cylinder filled with water, as shown here. This is known as **collecting a gas over water**.



You will need:

You can work out what you will need when you decide which method you will use to measure the rate of reaction.

Answer questions 1–3 before you begin the practical task.

Method

1. Assemble your equipment and put the calcium carbonate in the flask.
2. Add the hydrochloric acid; start the timer and measure the initial mass or volume.
3. After 30 seconds, measure again. Continue to take measurements every 30 seconds until you have three consecutive readings that are the same.

Questions

1. Make a list of the equipment you will need.
2. Write a risk assessment for your investigation.
3. Prepare a table for your results.
4. Plot a graph of your results and describe how the rate of reaction changes over time.
5. What problems did you have when you carried out this reaction? How might these have affected your results?
6. How could you improve the reliability of your results?

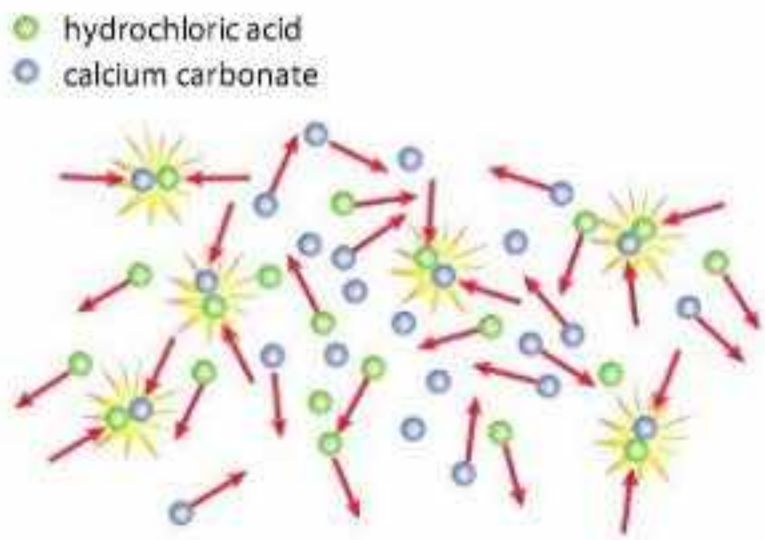
There are a number of different ways of carrying out the investigation shown on the previous page.
Will the method used have any effect on the accuracy of the results?

Why does the rate of reaction change?

We can use ideas about particle theory to answer this question.

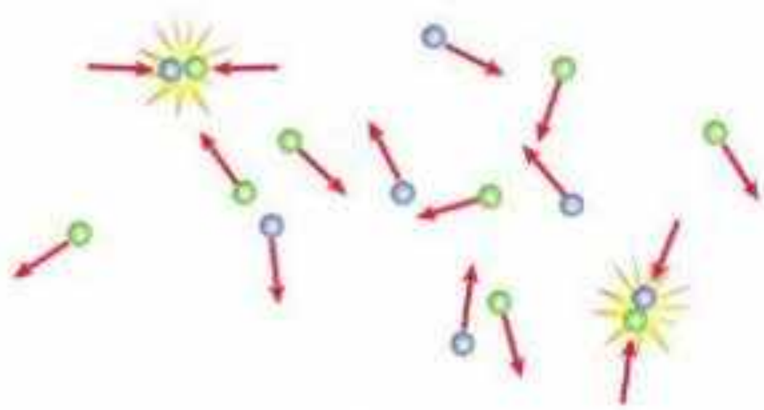
For a chemical reaction to take place, the particles of the reactants involved have to collide with one another with enough energy to react together.

At the start of the reaction there are a lot of particles that have not reacted. **Collisions** happen frequently. This means that a lot of carbon dioxide is produced in the first 30-second period.



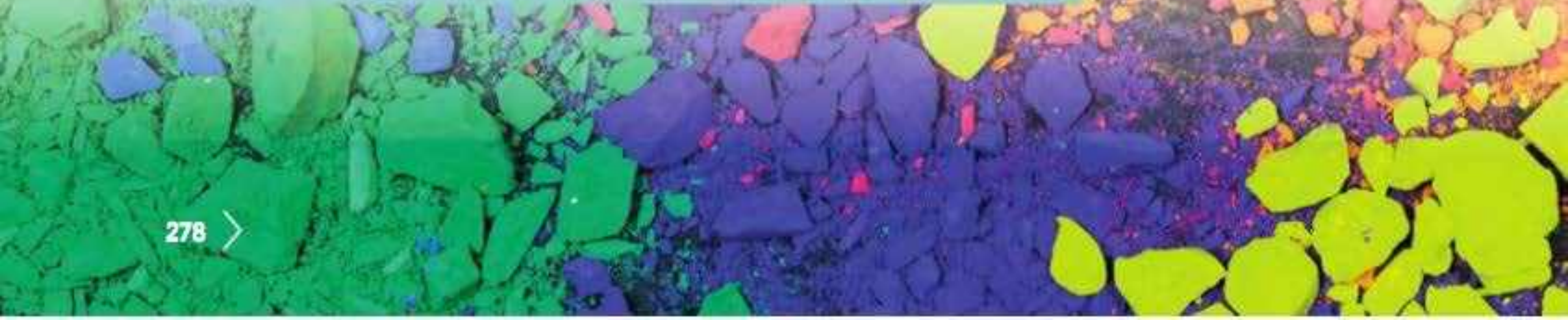
As the particles react, the number of particles that have not reacted gets lower and lower. The chance of two unreacted particles colliding with each other decreases. This means that less carbon dioxide is formed in the later 30-second periods. This means that the rate of reaction is slower.

Eventually, all the particles have reacted. There are no more collisions that result in the production of carbon dioxide gas. The reaction has finished.


Fewer particles and less frequent collisions

Summary checklist

- [ ] I know how the rate of reaction changes.
- [ ] I can carry out an investigation safely.
- [ ] I can measure the rate of reaction.
- [ ] I can use graphs to discuss and measure the rate of reaction.
- [ ] I know why the rate of reaction changes.



› 8.2 Surface area and the rate of reaction

In this topic you will:

- investigate the rate of reaction when the surface area of one of the reactants is changed
- carry out an investigation using the reaction between calcium carbonate and dilute hydrochloric acid
- consider how changing the shape of a material can affect the surface area.

Getting started

- Find the surface area of each different face of this book.
- Record the surface area for each face.
- Calculate the total surface area.
- With a partner, arrange your two books so that they are touching and have the least possible total surface area. What is this total surface area?
- Then arrange the books so that they are touching but have the largest possible total surface area. What is this total surface area?
- How does changing the arrangement of the books affect the surface area?

Key words

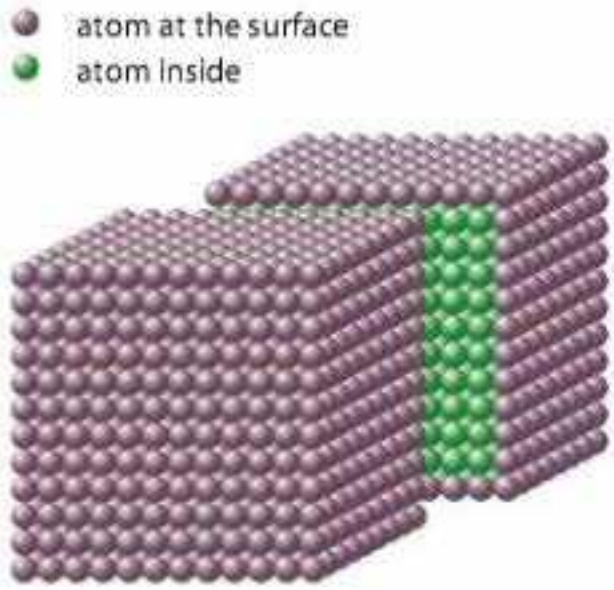
surface area

The effect of changing the surface area

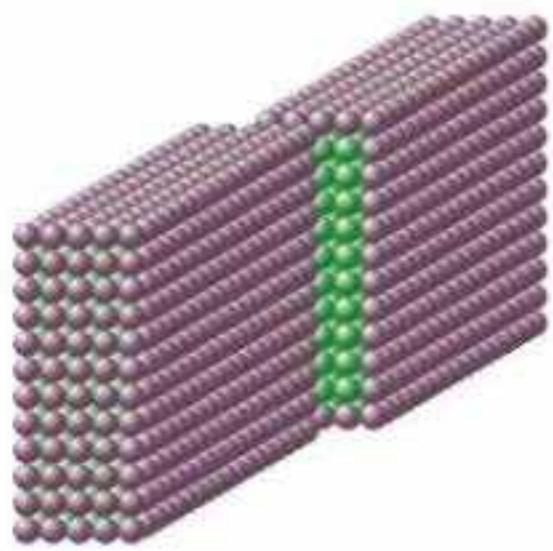
When you put magnesium ribbon in a Bunsen flame it reacts very quickly, and burns with a bright white flame to form magnesium oxide. However, if you place a large block of magnesium in the Bunsen flame it does not burn. If you place magnesium powder in the Bunsen flame it burns much faster than the ribbon.

Why does this happen?

Think about what is happening as the magnesium reacts with oxygen in the air. Only the magnesium atoms on the surface can make contact with the oxygen and react with it. In the block of magnesium, most of the atoms are inside the block, away from the oxygen. In the magnesium ribbon, more of the atoms are on the surface and react. Magnesium ribbon has a larger total **surface area** than a magnesium block of the same mass. An eqivalent mass of magnesium powder has an even larger total surface area and because it has the most atoms available to react, the reaction is even quicker.



Only the magnesium atoms on the surface of the block can react with oxygen in the air.



In magnesium ribbon, more of the atoms are on the surface and can react with the air.

Small pieces of solids always react faster than larger pieces.

Each time you cut a solid into smaller pieces, you increase the total surface area.

For example, these slices of bread have a total surface area greater than the loaf of bread.

Think like a scientist

Burning iron

You are going to compare what happens when you heat an iron nail, iron wool and iron filings in air. Remember to record your observation for each.

You will need:

- safety glasses, tongs, Bunsen burner, heatproof mat, spatula, iron nail, iron wool, iron filings.

Safety

Wear safety glasses and take care not to touch anything hot.

Method

1. Grip the nail firmly with the tongs and hold it in the flame of a Bunsen burner.
2. Hold the iron wool in tongs and hold it in the flame of a Bunsen burner.
3. Use the end of a spatula to gently sprinkle a few iron filings into a Bunsen flame.

Questions

1. Compare the reactions of these three forms of iron.
2. What effect does increasing the total surface area have on the rate of reaction?
3. Explain the reasons for the change in the rate of reaction.

Activity 8.2.1

Calculating the surface area

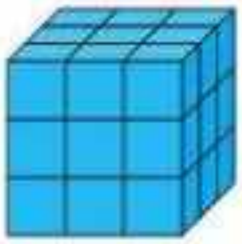
You are going to investigate how the surface area changes when you arrange cubes in different ways.

You will need:

- 27 children's construction cubes (all the same size), ruler.

Method: Part 1

Arrange the blocks to form a cube, as shown in the diagram.



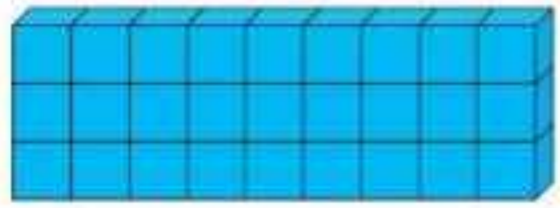
Questions

1. What is the area of one face of one of the small blocks?
2. How many faces of small blocks make up one face of the large cube?
3. What is the area of one face of the large cube?
4. What is the total surface area of the large cube?

Continued

Method: Part 2

Arrange the blocks to form a shape 3 × 9 small blocks, as shown in the diagram.



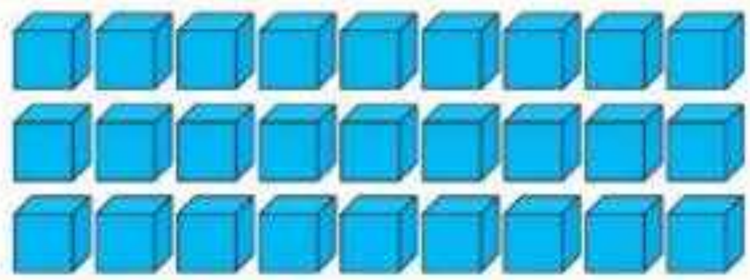
Questions

5 This shape still has 27 blocks. What is the total surface area of this shape?

6 How would this change in shape affect the rate of reaction, if the shapes were zinc metal and they reacted with acid?

Method: Part 3

Separate all the blocks from one another.



Questions

7 There are still 27 blocks. What is the total surface area of all the blocks now they have been separated?

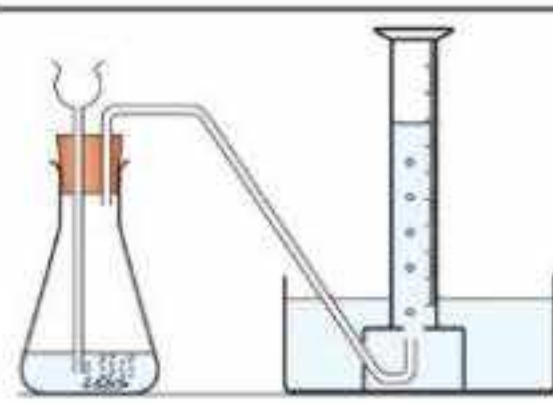
8 How would this change of shape affect the rate of reaction?

9 Explain why a change in surface area changes the rate of reaction.

Think like a scientist

Investigating the effect of surface area on the rate of reaction

In this investigation you will investigate the effect of changing the size of pieces of calcium carbonate (marble chips) in the reaction with hydrochloric acid. You could use any of the methods shown in Topic 8.1.

			
Method	Gas syringe	Top pan balance	Gas over water

Continued

You are going to do the experiment twice, using different sizes of calcium carbonate chips. Whichever method you use, use the same method for the two experiments.

The beaker on the left shows the reaction of small chips of calcium carbonate with hydrochloric acid. The beaker on the right shows the same reaction but with larger calcium carbonate chips.

Answer questions **1–6** before starting the experiment.

Questions

1 Which method will you use?

2 Which reaction do you predict will be the fastest?

3 The size of the pieces of calcium carbonate will be changed, but the total mass of the pieces will be kept the same. Why is it also important to keep the volume, type and concentration of the acid the same?

4 What are the dependent and independent variables?

5 Read through the method and then write a list of the equipment you will need.

6 Construct a results table.

Method

1 Assemble your apparatus

2 Add 5 g of large marble chips to 25 cm^3 of hydrochloric acid in a conical flask.

3 Start the timer and read the volume of gas produced or the mass of the flask and contents every 30 seconds, until you have at least three readings that are the same. Record your results carefully.

4 Repeat, but this time use 5 g of smaller chips.

5 Plot both sets of results on one graph.

Questions

7 Which line on your graph is steeper?

8 Which size of marble chip reacted more quickly?

9 What happens to the rate of reaction as the total surface area of the chips increases?

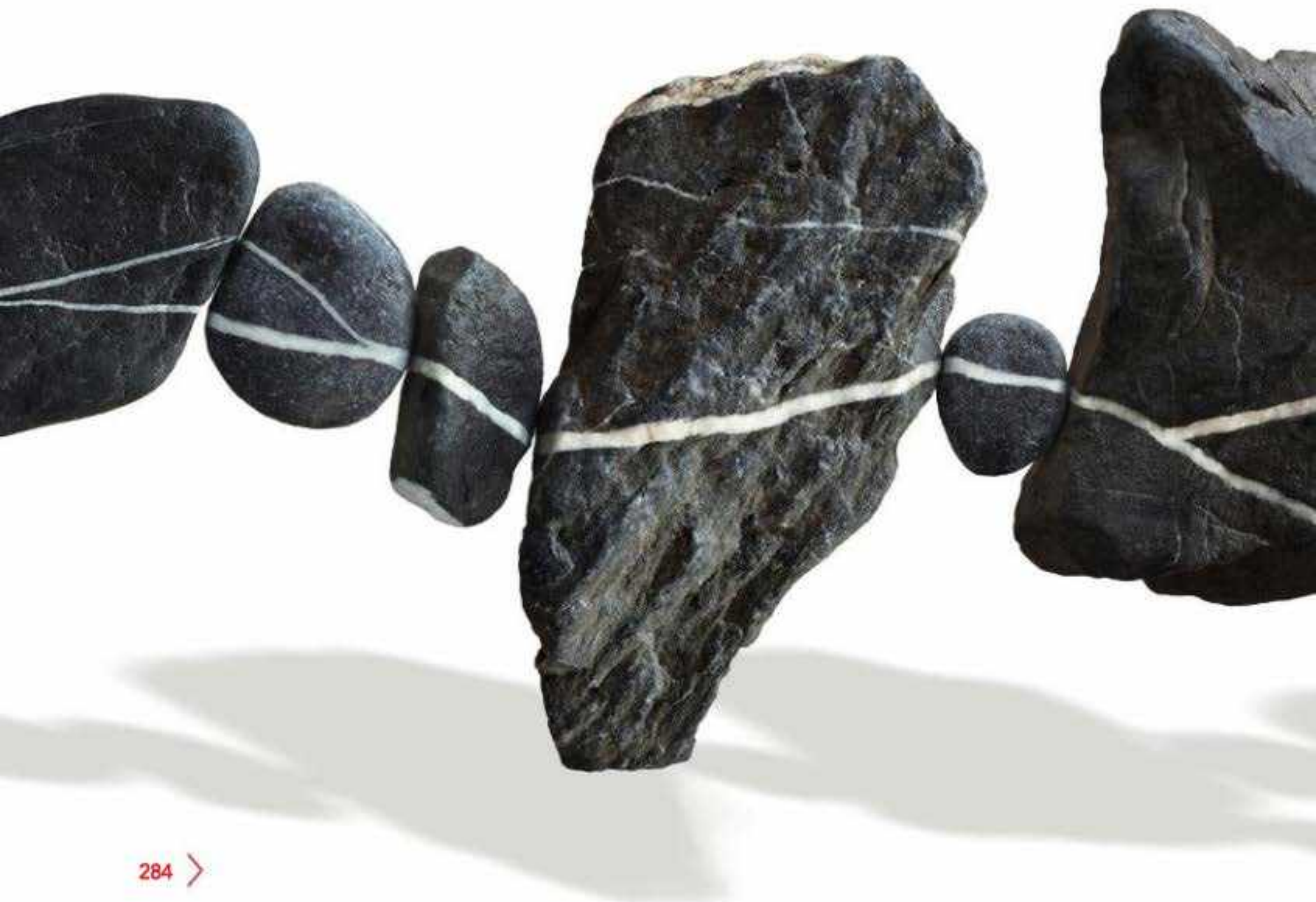
10 Was your prediction supported by your findings?

11 What do you predict would happen if you repeated the experiment using powdered calcium carbonate?

If you use the same mass of large calcium carbonate chips and small calcium carbonate chips and the same volume and type of acid each time, do you make more carbon dioxide when the reaction is quicker?

Summary checklist

- [ ] I can safely investigate the rate of reaction when the surface area of one of the reactants is changed.
- [ ] I can carry out an investigation using the reaction between calcium carbonate and dilute hydrochloric acid.
- [ ] I know how changing the shape of a material can affect the surface area.



8.3 Temperature and the rate of reaction

In this topic you will:

- investigate the effect of temperature on the rate of reaction
- carry out a trial run and preliminary work for the investigation and use the information to improve the investigation method
- select equipment
- plot a graph of results.

Getting started

- Write down what you mean by the phrase 'rate of reaction'.
- Compare your statement with a partner and discuss your answers.
- Discuss how the rate of reaction changes as the reaction progresses and write an explanation of why this happens.
- Be ready to share this with the class.

Key words

precipitate
trial run
preliminary work

Changing the temperature of reactants

If you change the temperature of the reactants in a reaction, the rate of reaction will change.

If you mix hydrochloric acid with a solution of sodium thiosulfate (a salt), the mixture becomes cloudy. This is because sulfur is produced. Sulfur is insoluble in water, so it forms a **precipitate**. The precipitate is opaque – so, when you can no longer see through the solution, you know the sulfur has been formed.

The reaction is good for investigating reaction rates, because you can easily time how long it takes for the sulfur precipitate to be formed.

And by changing the temperature of the solution, you can investigate the effect of temperature on reaction rates.

Think like a scientist

The effect of temperature on the rate of reaction

You are going to measure the rate of reaction between sodium thiosulfate and hydrochloric acid at different temperatures.

There are three parts to this: the trial run, the preliminary work and the investigation.

Part 1: The trial run

First you need to carry out a **trial run.** A trial run means you will carry out a practice experiment to make sure you can do the experiment safely and effectively. You will then be prepared and be ready to overcome any problems you find.

Safety

Make sure the room is well ventilated, because sulfur dioxide gas will be produced. Place any reacted solutions into a container with some solid sodium hydrogencarbonate for your teacher to remove later. The sodium hydrogencarbonate will react with the sulfur dioxide.

You will need:

- safety glasses, test tube with stopper, clamp stand, white card with a cross marked on it, timer or stop clock, sodium thiosulfate solution, dilute hydrochloric acid, large beaker containing solid sodium hydrogencarbonate.

Method

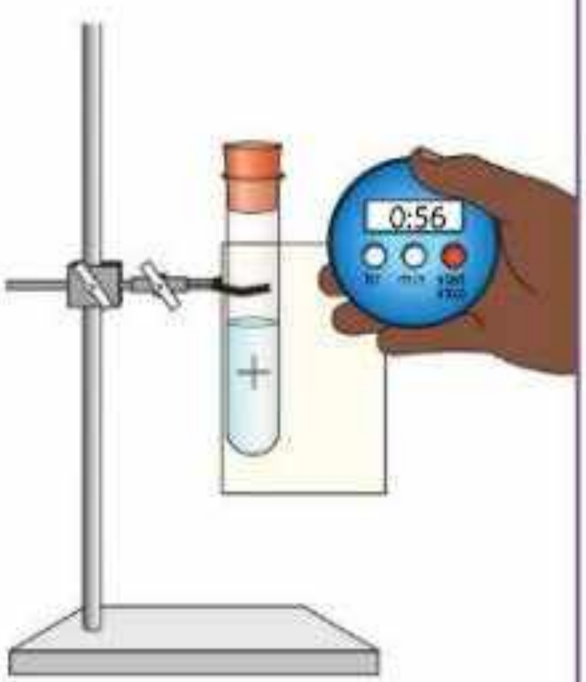
1 Place 10 cm^3 of sodium thiosulfate solution in a test tube.

2 Fix the test tube into the clamp stand and arrange the card with the black cross behind it as in the diagram.

3 Add 1 cm^3 hydrochloric acid to the test tube and put the stopper in the tube. Start the timer.

4 Time how long it takes before you can no longer see the cross.

5 When you have finished, place the contents of the test tube in the large beaker containing sodium hydrogencarbonate.



Questions

1 What information did your trial run give you?

2 Will you change the way you carry out your investigation as a result of this trial?

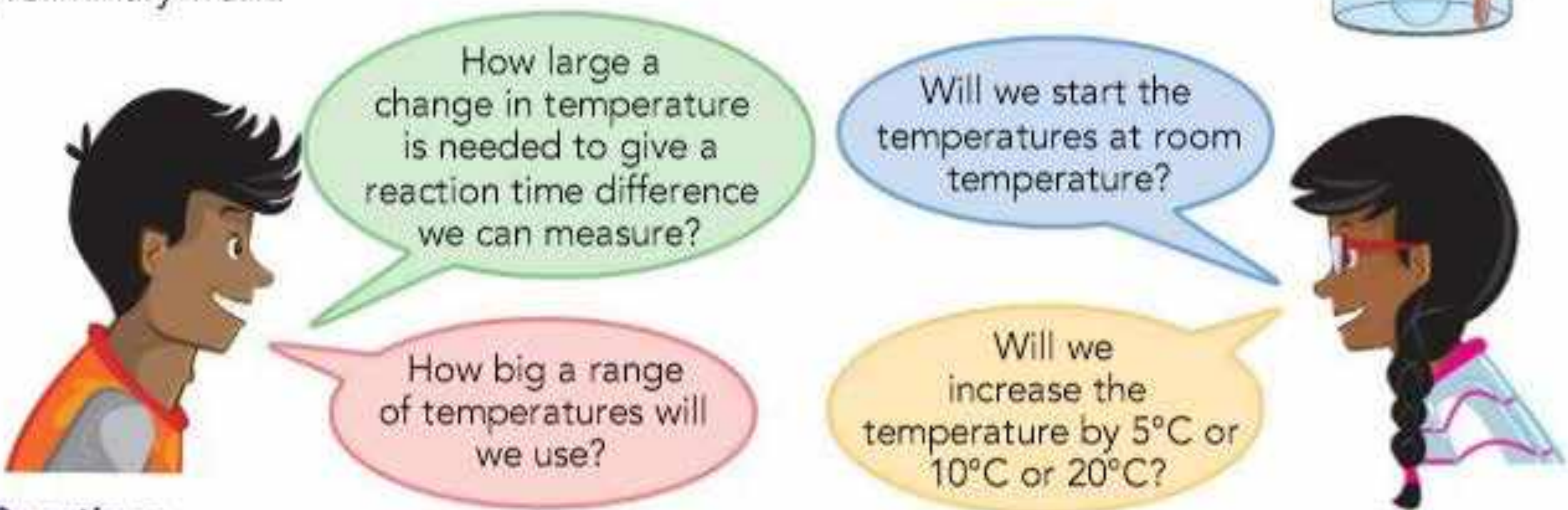
Continued

Part 2: The preliminary work

The next step is to do some **preliminary work** to decide which temperatures you will use. To change the temperature of the sodium thiosulfate solution, warm it in a suitable water bath before adding the acid. Make sure there is a stopper in the tube while it is warming.

Discuss in your group how you will do this preliminary work.

Here are some of the things you will need to consider in your preliminary work:



Questions

3 What equipment will you need for the preliminary work?

4 Describe what you have decided to do as your preliminary work.

5 How will this help you with your final investigation?

6 What can you do to try to keep your test tube at the same temperature while the reaction is taking place?

7 Write an outline plan for the preliminary work including a results table.

Once your outline plan has been checked carry out your preliminary work.

8 What did you find out that will help your final investigation?

Part 3: The investigation

Discuss in your group how you will carry out the final investigation using the information you got from the trial run and the preliminary work.

Questions

9 Write a detailed plan for your investigation. You should include a list of equipment you will need and a results table.

When your plan has been checked by your teacher, carry out your investigation.

10 How did you make sure your investigation was a fair test?

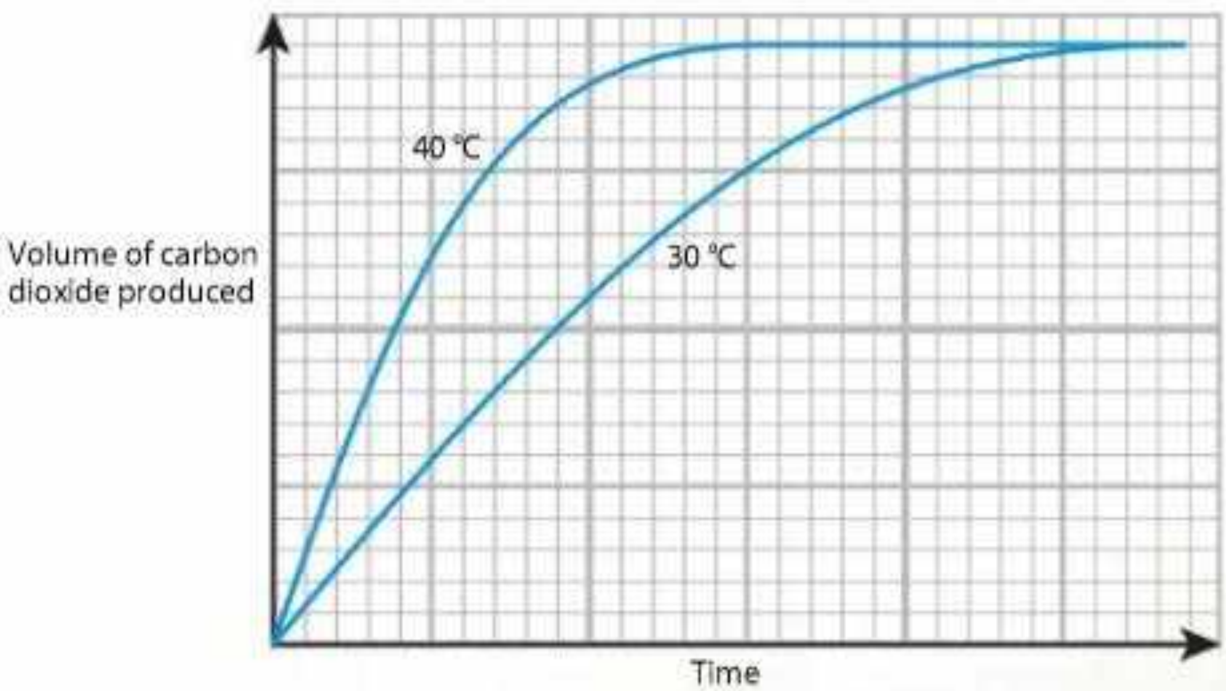
11 Plot a graph of your results.

12 Describe the relationship between the temperature and the rate of reaction.

Think how doing the trial run and preliminary work helped you to improve the investigation.

Looking at typical results

Here is a graph of some typical results for the rate of reaction between marble chips (calcium carbonate) and hydrochloric acid. This was carried out as in the previous topic.

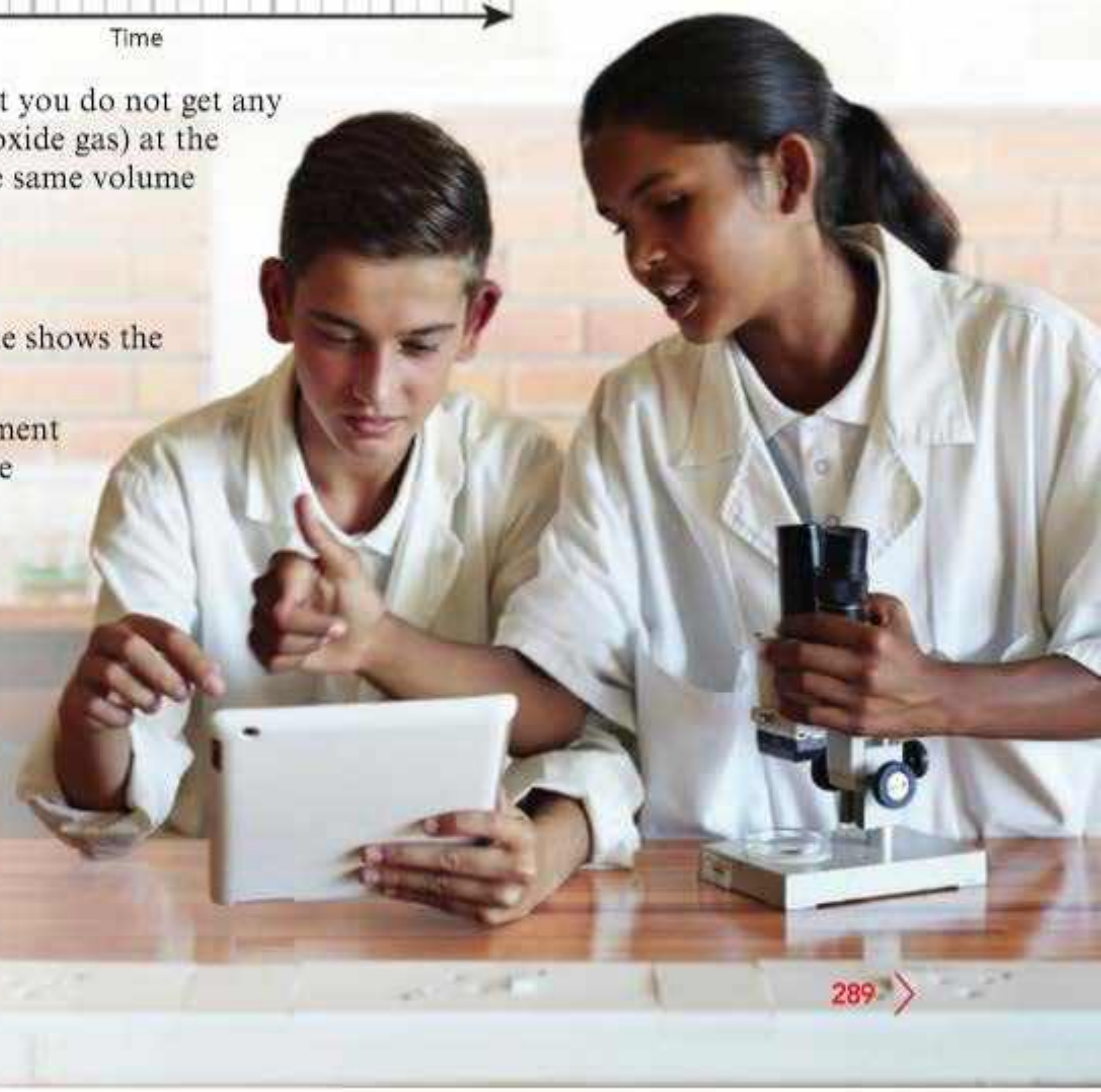


You can see from the graph that you do not get any more of the product (carbon dioxide gas) at the higher temperature. You get the same volume of gas but in less time.

Questions

1 How can you tell which line shows the faster reaction?

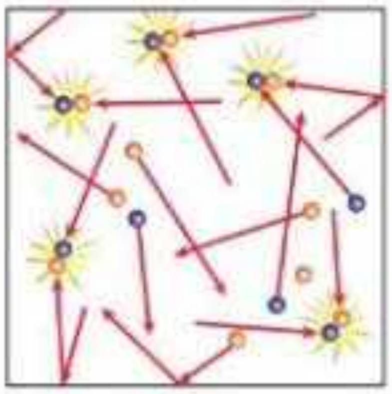
2 If you did the same experiment at 50°C what would the line on the graph be like?



Explaining the effect of temperature

Particles move all the time. When the temperature of the reaction is increased, the particles move faster. They collide more often, and with more energy.

Reaction at 30 °C



Reaction at 40 °C

The higher the temperature, the faster the rate of reaction.

Summary checklist

- ☐ I can investigate the effect of temperature on the rate of reaction, safely.
- ☐ I can carry out a trial run and preliminary work for an investigation and use the information to improve the investigation method.
- ☐ I can select equipment.
- ☐ I can plot a graph of results.
- ☐ I can explain the effect of temperature on the rate of reaction, using particle theory.

> 8.4 Concentration and the rate of reaction

In this topic you will:

- investigate the effect of concentration on the rate of reaction
- plan an investigation
- explain the effect of changes in concentration on the rate of reaction, using particle theory

Getting started

With a partner, discuss what you think would happen if you carried out an experiment with marble chips (calcium carbonate) using the same mass of chips, all materials at the same temperature but with different concentrations of acid.

Can you explain the reasons behind your ideas?

Be prepared to share your ideas with the class.

Key words

concentration

dilute

In this unit you have investigated different variables and how they affect the rate of reaction. You have also used different methods in your investigations. Now you will investigate the effect of **concentration** on the rate of reaction.

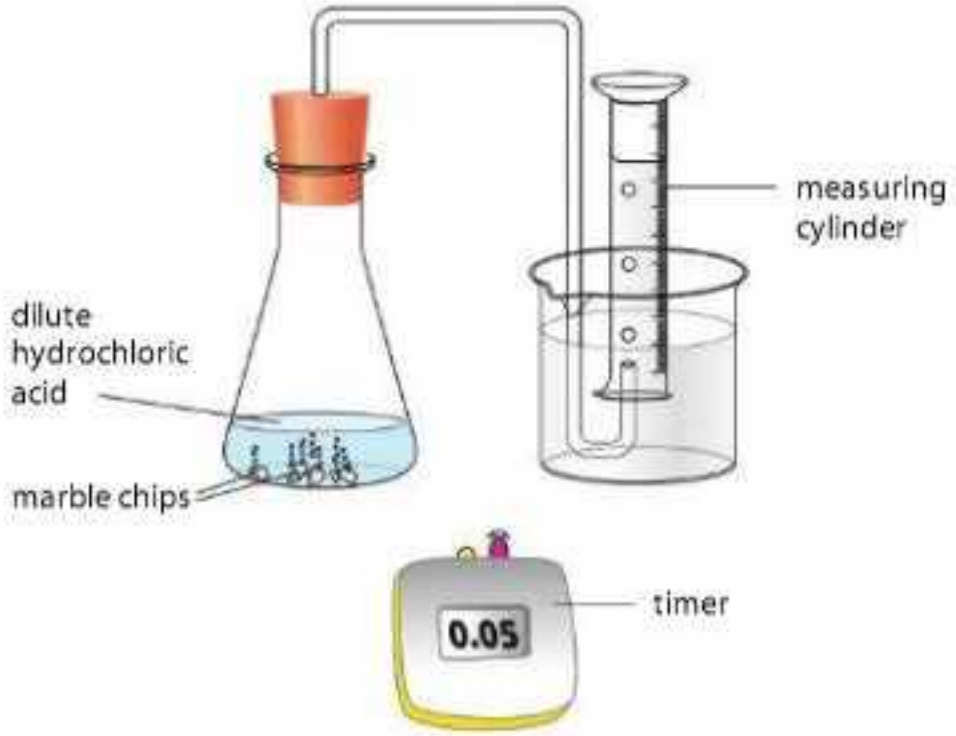
Think like a scientist

Investigating the effect of concentration on the rate of reaction

In this investigation you will change the concentration of the acid used.

Instead of measuring the volume of carbon dioxide produced every 30 seconds, you will use a slightly different method of measuring the rate of reaction.

You will time how long it takes to collect 25 cm^3 of carbon dioxide in the measuring cylinder.



Part 1: Planning the investigation

Discuss in your group how you will carry out this investigation.

- What mass of marble chips will you use?
- Which factors will you keep the same?

Some of the other things you could consider are:

- What volume of acid will you use?
- Which concentrations of acid will you use?
- What are the risks in this investigation?
- What safety precautions should you take?
- What equipment will you need?
  You will need items that are not shown in the diagram.
- Do you need to do a trial run or some preliminary work?
- If so, what do you want to find out?
- Do you need to repeat any of your readings?

Continued

Question

1 Use the results of your group discussion to write a plan for your investigation.

How does discussing ideas in a group help me to plan a better investigation?

Part 2: Carrying out the investigation

When you have shown your plan to your teacher and had it approved you may carry out the investigation.

Safety

Make sure you follow the safety precautions in your plan.

You will need:

- safety glasses, top pan balance, timer, measuring cylinders (to collect the gas and to measure the volume of acid used), beakers and a marking pen to label the different concentrations of acid, conical flask fitted with a bung and delivery tube, large container for holding the water when collecting the gas over water, marble chips, dilute hydrochloric acid, water.

Method

1 Make up your concentrations of acid. You can do this by diluting the acid you have been given. Make up 50 cm^3 each time. Use the table below to help you.

Solution	Acid in cm^3	Water in cm^3	
A	10	40	least concentrated
B	20	30	↓
C	30	20	
D	40	10	
E	50	0	most concentrated

2 Set up the apparatus as shown in the previous diagram.

3 Weigh out the marble chips and place them in the flask.

4 Add the acid and time how long it takes to collect 25 cm^3 of carbon dioxide. Record the acid used and the timing.

5 Repeat with different concentrations of acid.

Continued

Questions

2 How did you ensure this was a fair test?

3 How did you ensure the results were reliable?

4 Present your results in a suitable table.

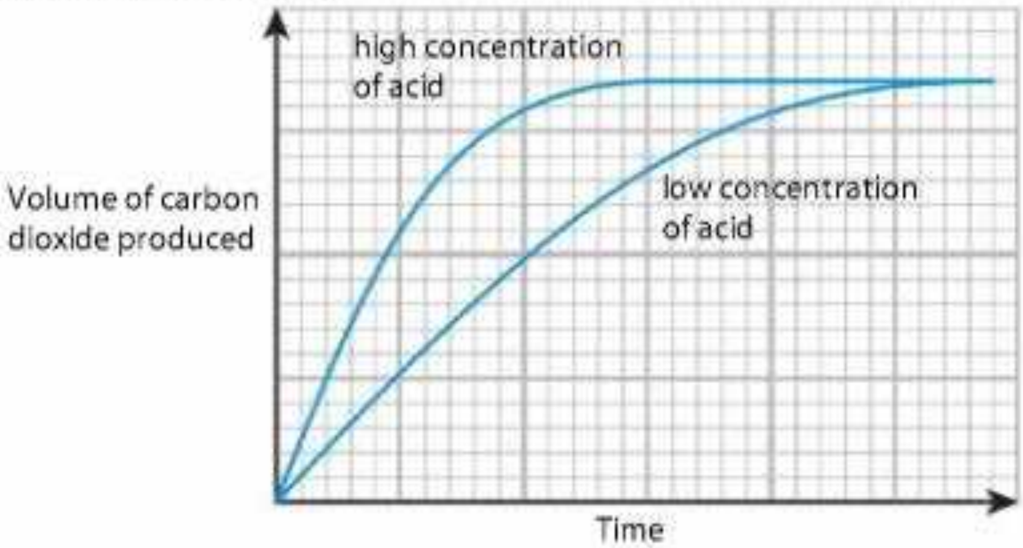
5 Plot a graph of your results.

6 Which concentration of acid gave the fastest results?

7 Describe the pattern in your results.

Typical results

The graph below shows some typical results for the rate of reaction between marble chips and **dilute** hydrochloric acid. These results have been obtained from an experiment in which the volume of carbon dioxide has been measured every 10 seconds. Not like the experiment you have just carried out.



You can see from the graph that you do not get any more product (carbon dioxide gas) at the higher concentration. You get the same volume of gas, but more quickly.

Questions

1 How can you tell which line on the graph shows the faster reaction?

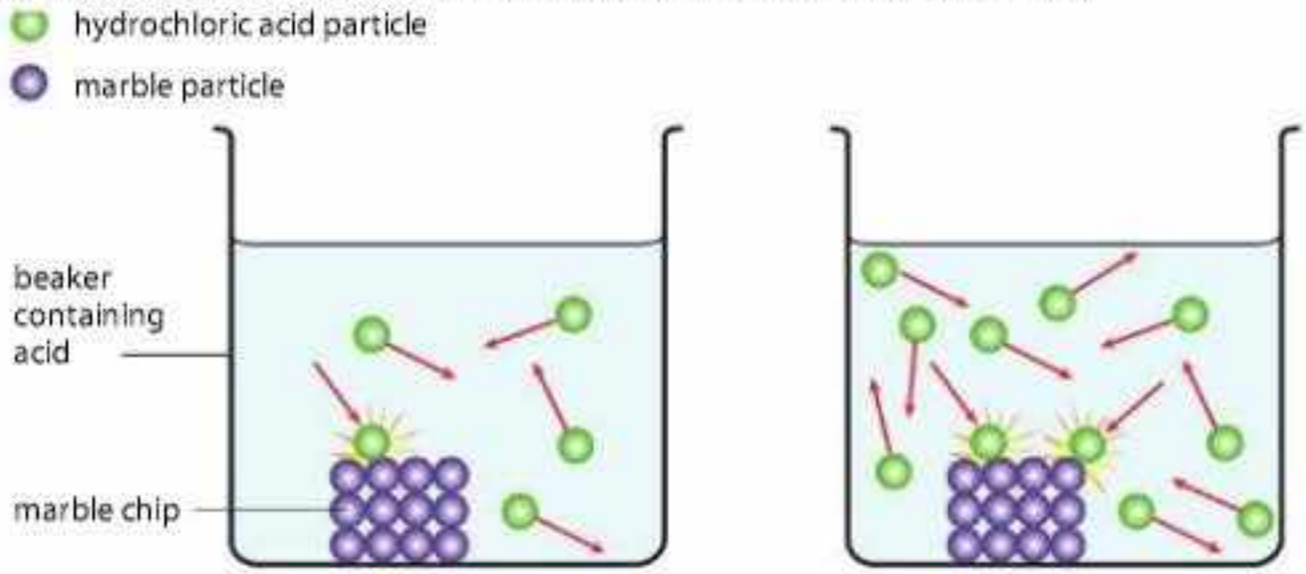
2 If you did the same experiment with an even less concentrated acid what would the line on the graph be like?

Does plotting the results on a graph make it easier to see the pattern?

Explaining the effect of concentration

Once again, we can use particle theory to help explain these results.

The higher the concentration of hydrochloric acid, the more hydrochloric acid particles there are in a given amount of space. This means that there will be more frequent collisions between hydrochloric acid particles and calcium carbonate particles.



Reaction in dilute acid

Reaction in acid that is twice as concentrated

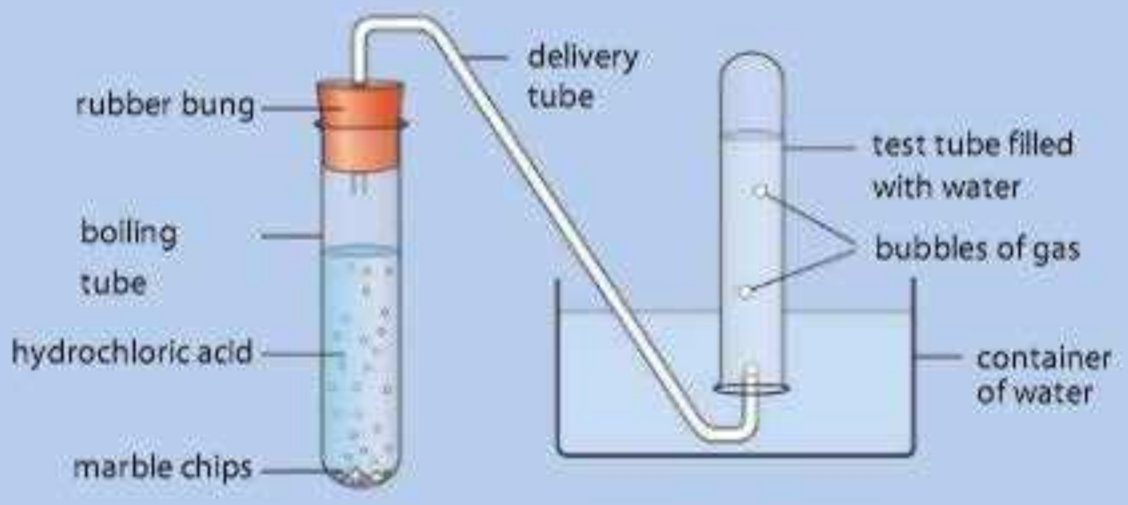
Summary checklist

- [ ] I can plan an investigation.
- [ ] I can investigate the effect of concentration on the rate of reaction, safely.
- [ ] I can explain the effect of changes in concentration on the rate of reaction using particle theory.

Project: Gas for sale

In this unit you have looked at various ways to increase the rate of reaction. In this task you are going to imagine that you are manufacturing carbon dioxide gas to sell to the drinks industry. The carbon dioxide puts the 'fizz' into soda. The aim is to make as much soda as possible.

You will use the reaction of marble chips with hydrochloric acid to produce the carbon dioxide gas. You have a 'budget' of $20 and each item you need to use has to be 'paid' for. You can sell the test tubes of carbon dioxide that you produce and the winners are the group that makes the most money. You will have a fixed time in which you can make your product.



In your group, decide how much equipment you will buy. Use the price list to help you. You can sell your test tubes of carbon dioxide for $5.

Remember that the gas will be tested to check it really is carbon dioxide.

You can use your income to buy more chemicals (and test tubes and bungs) to make more gas.

Your group needs to produce a report that covers how you carried out the task, your profit and how you could improve production of carbon dioxide. Some of the things you could consider including are the list of your purchases and prices and the sales of your product. You could also discuss the practical issues that may result in you not making as much profit as you could have done and how you overcame any of those difficulties. Mention any risk assessment that you made and how you overcame any risks.

A price list is given on the next page.

Continued

Price list

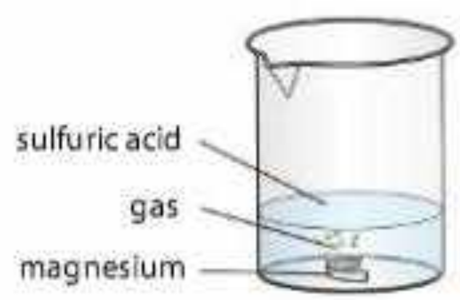
Item	Cost
test tube	50c
rubber bung	50c
boiling tube	$1
bung with delivery tube	$1
plastic bowl	$1
5g marble chips	$1
10 cm^3 hydrochloric acid	$5
hire of pestle and mortar	$1
heating apparatus	$1
safety glasses	$1

Check your Progress

8.1 The chemical name for marble is calcium carbonate. In the experiment shown below, equal masses of marble lumps, small marble chips and powdered marble were placed into equal volumes of dilute hydrochloric acid.

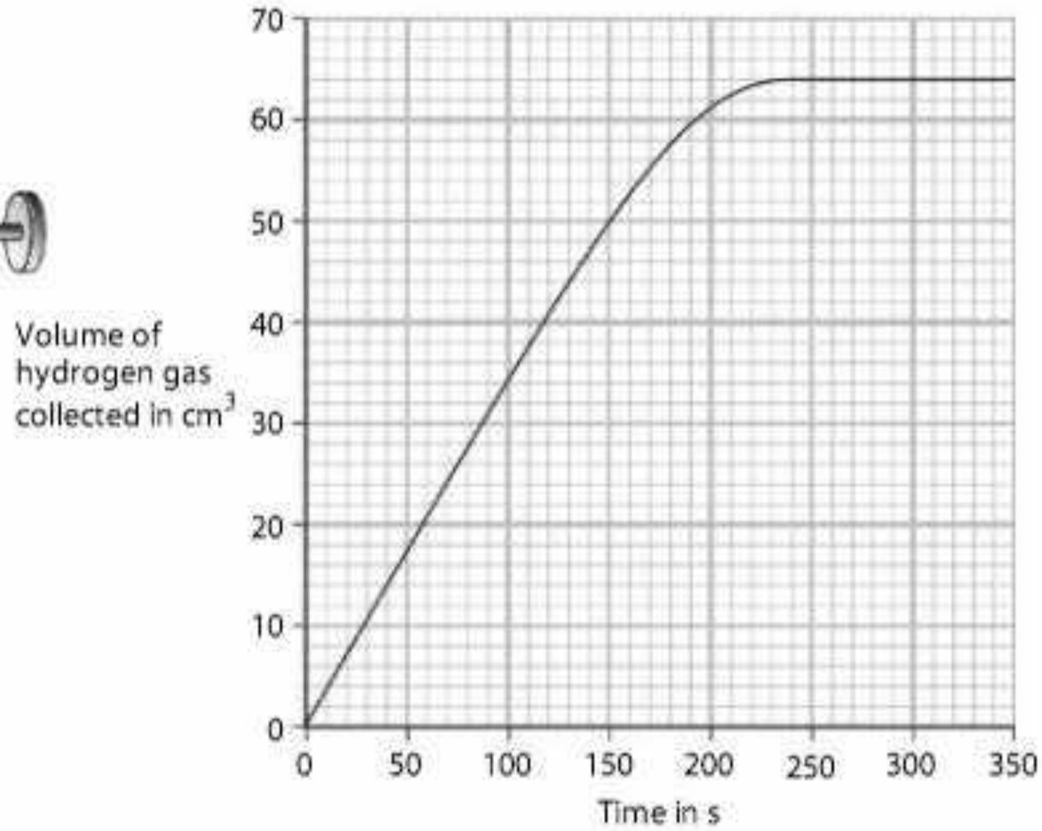
- **a** In which beaker will the reaction be faster? **[1]**
- **b** Explain why you think this. **[3]**
- **c** When the reaction between the calcium carbonate and dilute acid occurs, carbon dioxide gas is given off. How would you test for this gas and how would you know that the gas is carbon dioxide? **[2]**
- **d** What is the name of the salt formed in this reaction? **[1]**

8.2 Arun was investigating the reaction below. He placed 4 g of magnesium ribbon into a beaker of dilute sulfuric acid. He timed how long it took for the magnesium to 'disappear'. It took 45 seconds.



- **a** Write the word equation for the reaction between magnesium and sulfuric acid. **[2]**
- **b** How could he test for the gas given off in this reaction? (Remember to give the result he would get if the test showed that the gas was the one he was testing for.) **[2]**
- **c** Which of the following would result in the magnesium ribbon 'disappearing' in less than 45 seconds?
  - warming the acid
  - using 8 g magnesium ribbon
  - stirring the mixture
  - adding water to the acid **[2]**

8.3 Zara investigates the rate of reaction between magnesium and dilute hydrochloric acid. She measures how much gas is given off every 30 seconds. The graph shows her results.



- **a** How long does it take to collect 30 cm^3 of the gas? **[1]**
- **b** How long does it take for the reaction to finish? **[1]**
- **c** Describe how the rate of reaction changes over the period that the reaction is taking place. **[3]**
- **d** Predict what would happen to the rate of reaction if Zara increased the temperature of the acid. **[1]**
- **e** Explain your answer to part **d** using particle theory. **[3]**

9 Electricity

9.1 Parallel circuits

In this topic you will:

- find out the difference between series and parallel circuits
- find out how current flows in a parallel circuit.

Getting started

Work in pairs to answer these questions.

1 a Draw a circuit diagram with a cell, a lamp and a buzzer in series (all connected end-to-end).

b Name the component used to measure current in circuits.

c The current flowing through the lamp is 2 A. What is the current flowing through the buzzer? Assume the lamp and buzzer are both working properly.

d What will happen to the lamp if the buzzer breaks?

e What will happen to the buzzer if the lamp breaks?

Key words

branches

connected in parallel

connected in series

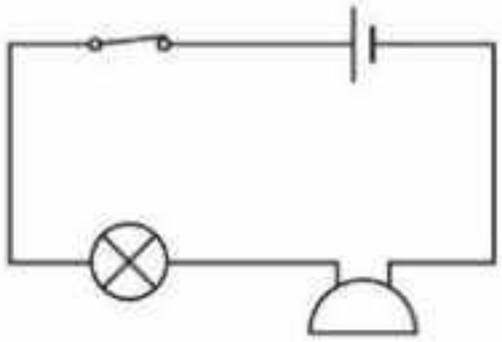
parallel circuit

Series circuits

The circuits you used at Stage 7 were all series circuits. Series means all the components are connected end-to-end or one after the other. We sometimes say the components are **connected in series**.

In a series circuit, there is only one path for the current to flow. This means the current is the same all the way around a series circuit. In a series circuit, all of the current flowing out of one component flows into the next component.

The circuit in this diagram is a series circuit.



If the switch in this circuit is opened, both the lamp and the buzzer will stop operating. They both stop operating at the same time because the current in the whole circuit stops flowing when the switch is opened.

If we want to operate the lamp and the buzzer separately from the same cell, then we need a parallel circuit.

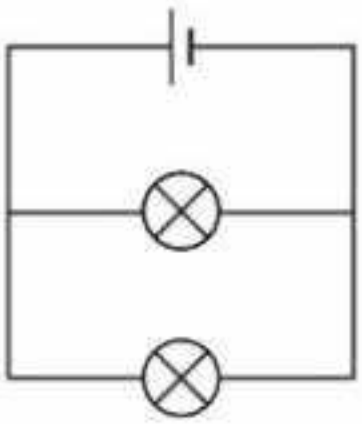
Parallel circuits

In a **parallel circuit**, there is more than one path for the current to flow.

The paths where the current can flow are called **branches**.

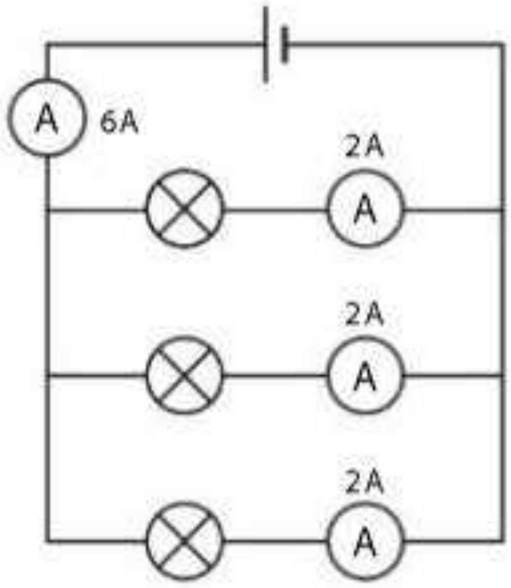
The name parallel comes from the circuit diagram because the branches are drawn using parallel lines. The components in each of the branches are sometimes said to be **connected in parallel**.

Look at the parallel circuit in the diagram to the right. Current from the cell flows to the branch in the circuit. At the branch, the current is divided. If the two lamps are the same, the current will be divided equally between them.



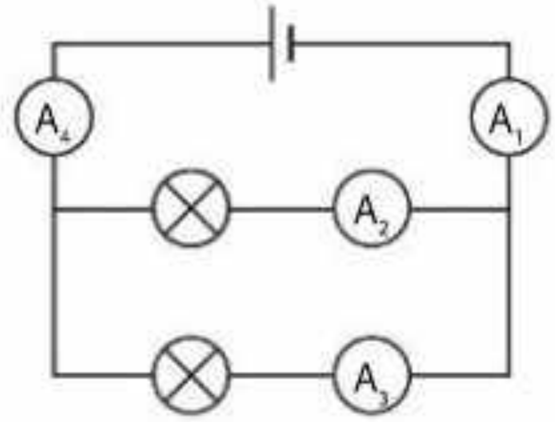
When the current comes to the other side where the branches join again, the current combines (adds together) again.

The parallel circuit in this diagram below has ammeters to show how the current is shared between the branches.



The rule for parallel circuits is:

> the current through the cell is equal to the total of the current in all the branches.

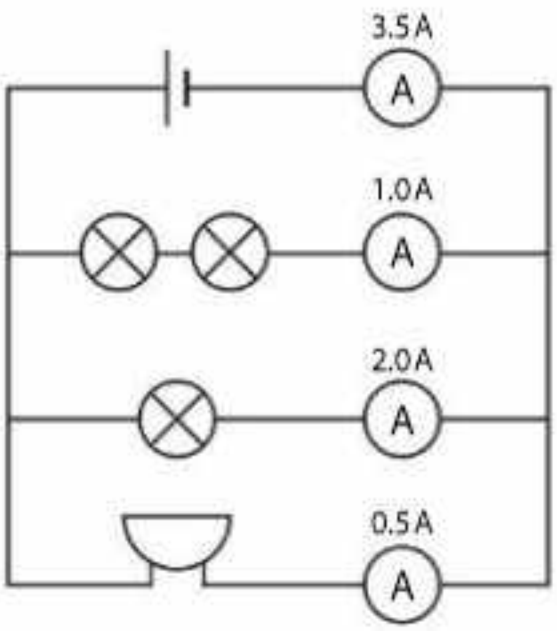


This circuit diagram can be used to summarise the rule for parallel circuits.

In this first circuit on the right, the readings on ammeters A_1 and A_4 are equal.

The readings on ammeters A_2 and A_3 will add up to the reading on A_1 (and A_4).

This rule still works even when the current in the branches is different.

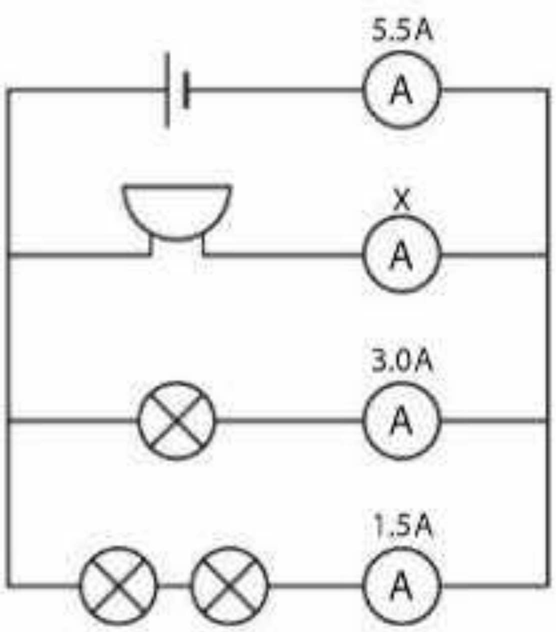


Look at this second circuit on the right. The circuit has three parallel branches, each with a different current.

The current through the cell is equal to the total of the currents through each of the branches.

So, 1.0 A + 2.0 A + 0.5 A = 3.5 A.

If we know the current through the cell, but do not know the current through one of the branches, we can calculate the missing current. Look at this circuit below. We can calculate the missing current through the buzzer.



The total current is 5.5 A, so the currents through each of the branches must add up to 5.5 A.

Call the missing current X.

$$X + 3.0 + 1.5 = 5.5$$
$$X + 4.5 = 5.5$$
$$X = 5.5 - 4.5$$
$$X = 1.0$$

So, the missing current though the buzzer is 1.0 A.

As with all calculations, do not forget the unit with your answer!

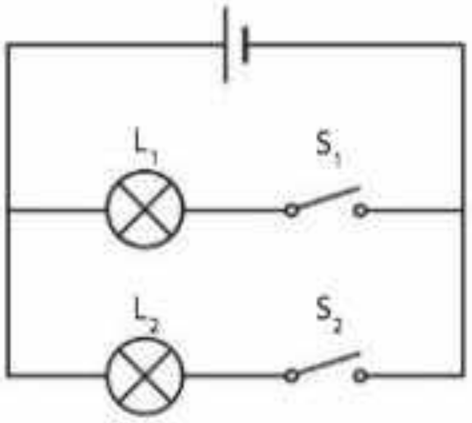
Advantages of parallel circuits

In a parallel circuit, the current through a branch can keep flowing, even if the current stops flowing in the other branches.

This means:

- components in the same circuit can be switched on and off independently
- if a component in one branch stops working, the other branches are not affected.

Look at the parallel circuit in the diagram on the right.



The circuit has two branches. Each branch has a lamp and a switch.

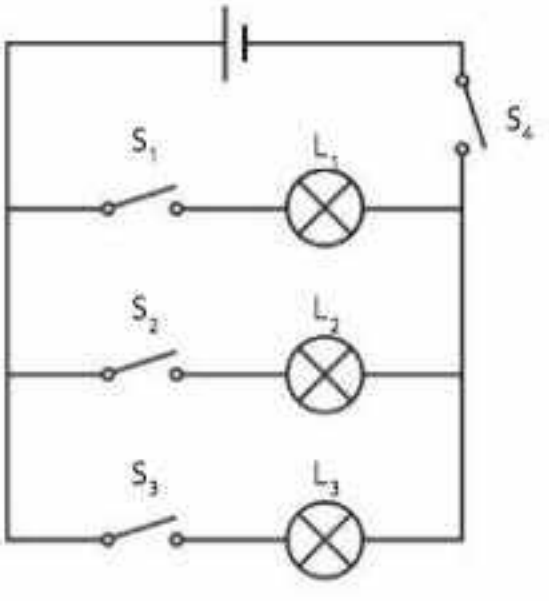
When switch S_1 is closed, then lamp L_1 will light. This will not affect lamp L_2 because L_2 is on a different branch.

When switch S_2 is closed, then lamp L_2 will light. This will not affect lamp L_1 because L_1 is on a different branch.

If both lamps are switched on and lamp L_1 stops working, then lamp L_2 will not be affected.

Components in a parallel circuit can be switched on and off separately by having switches on each branch. The components can also be all switched on or off together if the switch is between the cell and the branches.

Look at this second circuit diagram on the right. For any lamp to light in this circuit, switch S_4 must be closed.



Switches S_1, S_2 and S_3 can then be used to control each lamp separately.

If all the lamps are on, then opening S_4 will cause all of the lamps to go off.

If all the lamps are off, but switches S_1, S_2 and S_3 are closed, then closing S_4 will cause all lamps to light together.

Car headlamps (left) are connected in parallel so they can be switched on and off together. The string of lamps (right) are connected in parallel so, if one lamp fails, the others will still light. The lamps can also be switched on and off together.

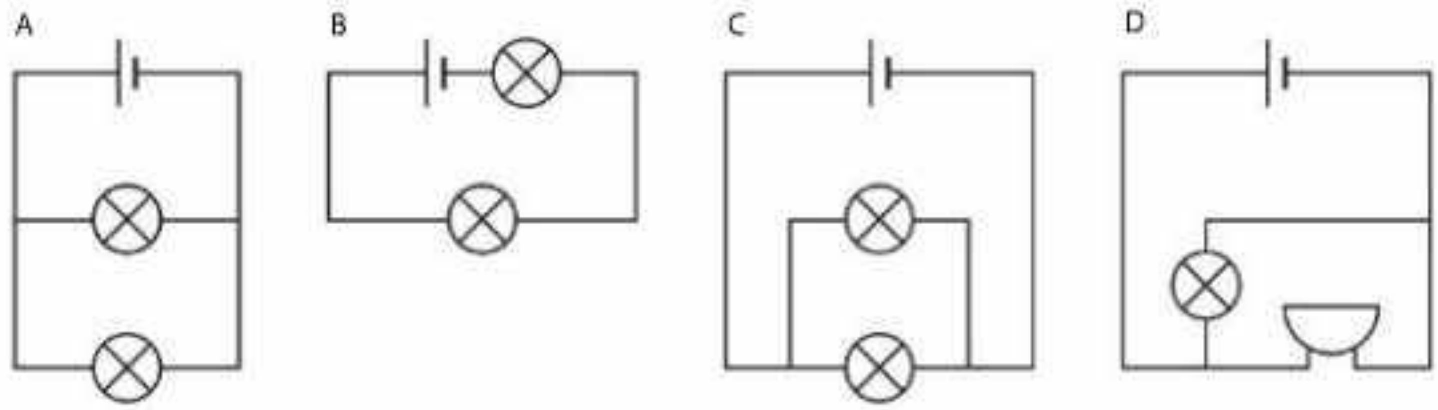
Questions

1 Which of these describes the current through the cell in a parallel circuit? Write **one** letter.

- **A** The current through the cell is equal to the current in the first branch.
- **B** The current through the cell is equal to the current in the last branch.
- **C** The current through the cell is the total of the current in each branch.
- **D** The current through the cell does not depend on the current in the branches.

2 Which of these are parallel circuits?

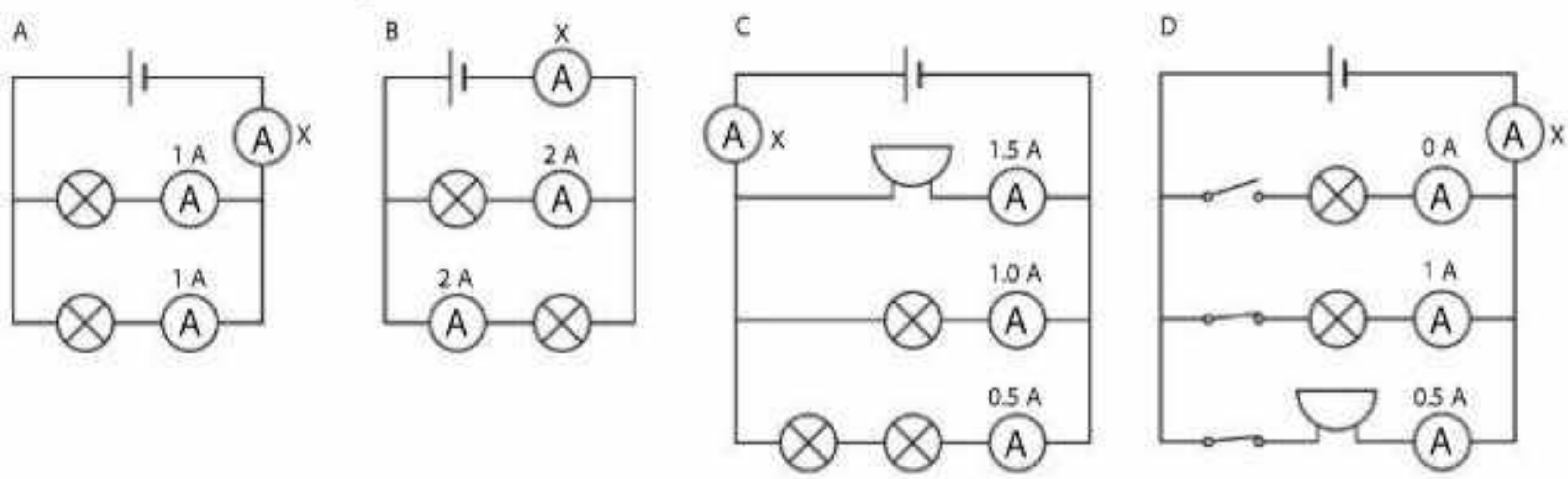
Write the letter or letters that are correct.



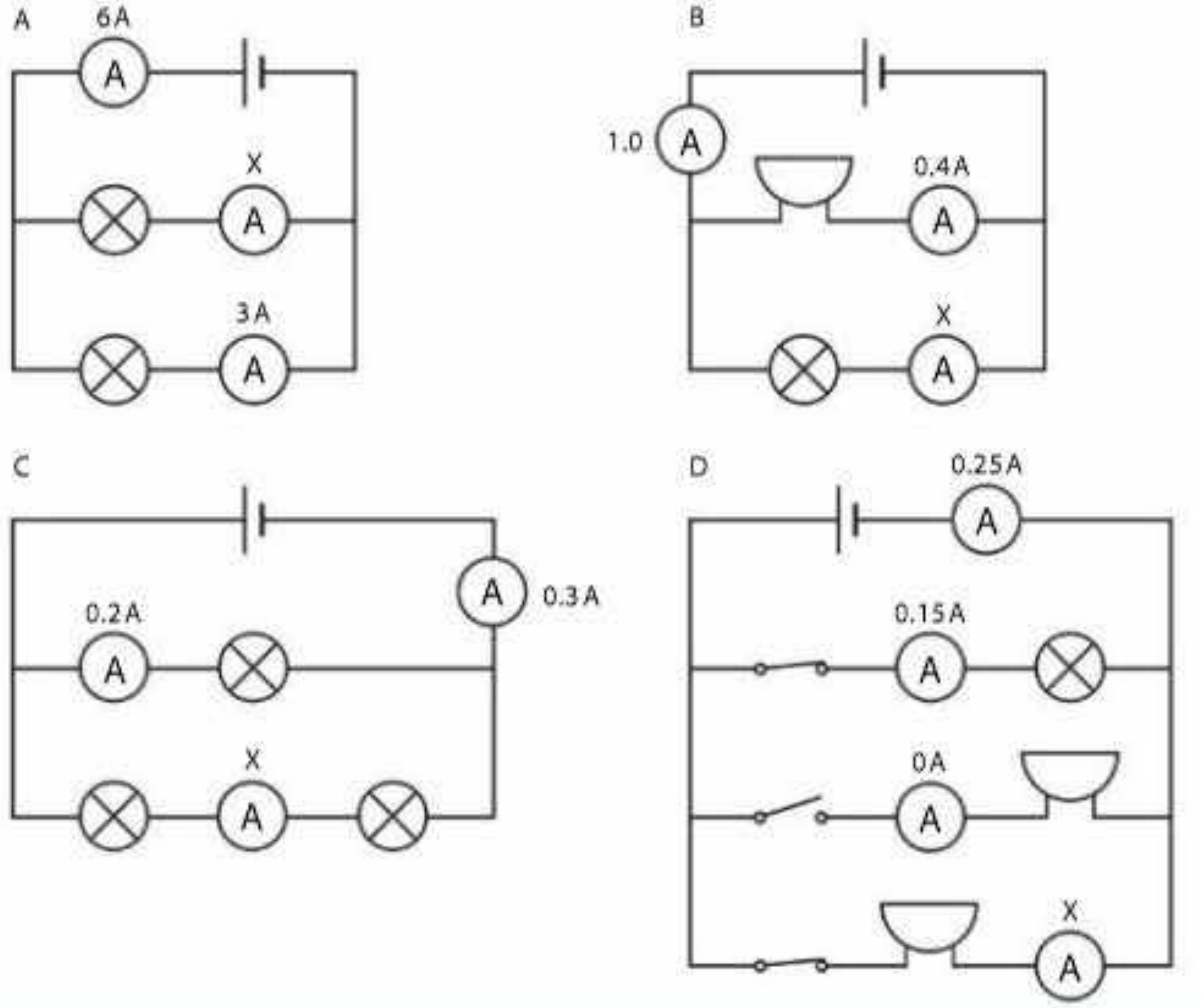
3 A circuit is to be designed with a cell and four identical lamps.

- **a** Draw a circuit diagram with
  - **i** four lamps connected in series with a cell
  - **ii** four lamps, each connected in parallel with a cell.
- **b** Describe **two** advantages of connecting the four lamps in parallel rather than in series.
- **c** The four identical lamps are connected in parallel. When all four lamps are working, the current through the cell is 2.0 A. Calculate the current through each lamp.

4 Calculate the missing current, X, in each of these circuits.



5 Calculate the missing current, X, in each of these circuits.



Activity 9.1.1

Measuring current in parallel circuits

In this activity, you will measure the current at various positions in a parallel circuit.

Work in groups of two or three.

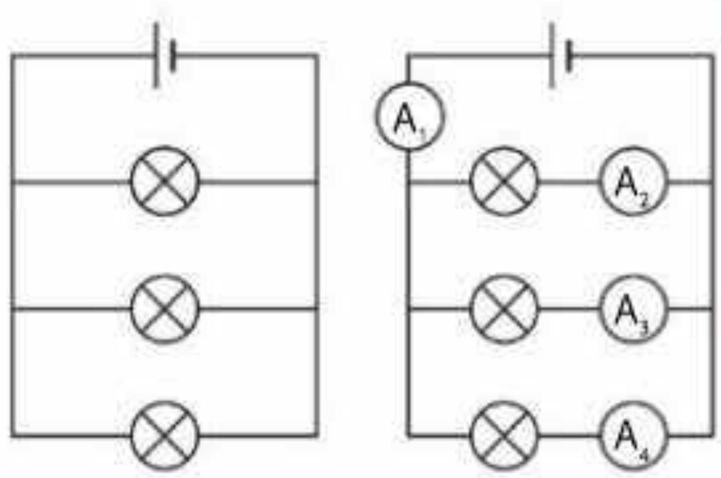
You will need:

- three lamps, the correct number of cells to operate one of these lamps, wires, ammeter.

Method

1 Set up a circuit as shown in the first diagram. Do not include the ammeter at this stage.

2 When you are sure that all the lamps are working correctly, you can include the ammeter.



Continued

3 You will put the ammeter into the circuit four times and in a different place each time. These four positions, A_1, A_2, A_3 and A_4, are shown in the second diagram.

4 Measure the current at each position, A_1, A_2, A_3 and A_4.

Questions

1 Record your results in a suitable table.

2 Explain what your results show about current in a parallel circuit.

Think like a scientist

Making predictions about current

In this investigation, you will make predictions about current and then test your predictions.

Work in groups of two or three.

You will need:

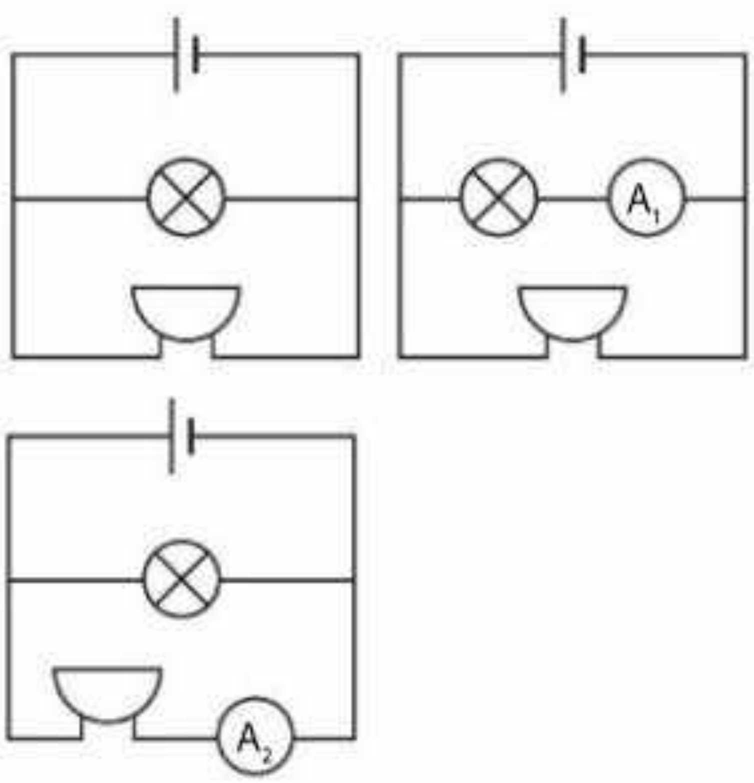
- three lamps, one buzzer, other electrical components (optional), the correct number of cells to operate these components, wires, ammeter.

Method

1 Set up a circuit as shown in the first diagram.

2 When you know the circuit is working correctly, put the ammeter in the position shown in the second diagram.

3 Remove the ammeter and put it in the position shown in the third diagram.



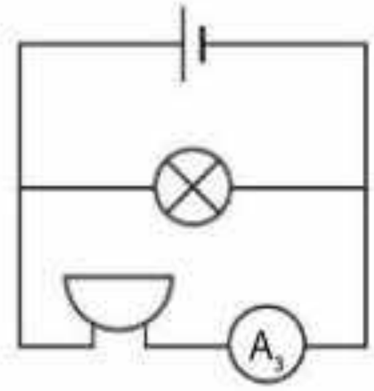
Continued

Questions

1 Record the currents A_1 and A_2 that you measured.

2 Use your values of A_1 and A_2 to predict the current flowing through the cell. Call this current A_3.

3 Check your prediction by putting the ammeter in the position shown in the next diagram.



4 Build other parallel circuits and measure the current in each of the branches. Use these currents to predict the current through the cell. Check your prediction each time.

5 Draw circuit diagrams for each circuit you build, and label the ammeters.

6 Build some other parallel circuits.
This time measure the current through the cell and all but one of the branches.
Use these currents to predict the current through the other branch.
Check your prediction each time.

7 Draw circuit diagrams for each circuit you build, and label the ammeters.

Peer assessment

For each of these statements, decide on how confident you are. Give yourself 5 if you are very confident and 1 if you are not confident at all.

I know:

- how to build parallel circuits from circuit diagrams
- how to measure the current at different positions in a parallel circuit
- how to correctly predict a missing current value in a parallel circuit.

Summary checklist

- ☐ I know how current divides in a parallel circuit
- ☐ I can calculate missing current values in parallel circuits.
- ☐ I can measure the current in a parallel circuit.
- ☐ I can describe the advantages of parallel circuits compared to series circuits for some applications.

9.2 Current and voltage in parallel circuits

In this topic you will:

- compare current and voltage in series and parallel circuits
- describe the effects of adding cells and lamps on current and voltage in circuits.

Getting started

Work in pairs to discuss answers to these questions.

1. Name the particles that flow inside wires when current flows.
2. What happens to the speed of these particles as current increases.
3. State the unit of current.

Key words

battery
mains
rating
supply
voltage
voltmeter
volts

What is voltage?

Voltage is linked to the electrical energy in a circuit. Voltage is measured in units called volts. The symbol for **volts** is V.

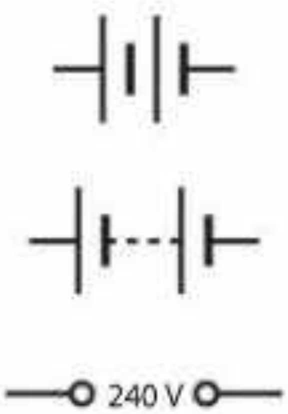
Voltage is related to the electrical energy supplied to a circuit by the cell, battery or power supply. Voltage is linked to energy, but it is not the same as energy.

Most cells supply 1.5 V. A **battery** is two or more cells connected in series. Batteries commonly supply 6 V, 9 V or 12 V. Each of the cells or batteries in this picture has a different voltage.

The sockets found on the walls of buildings supply a **mains** voltage. Mains in this context means an electrical supply that comes from a power station or generator of some kind. In most countries the mains voltage is between 220 and 240 V. In some countries, the mains voltage is 110 or 120 V. The next picture shows some mains sockets from different countries.

Sometimes, we refer to the source of energy in a circuit as the **supply**. The supply could be a cell, a battery, a power supply or the mains.

This diagram shows circuit symbols for a battery made from two cells, a battery made from many cells, and a 240 V mains supply.



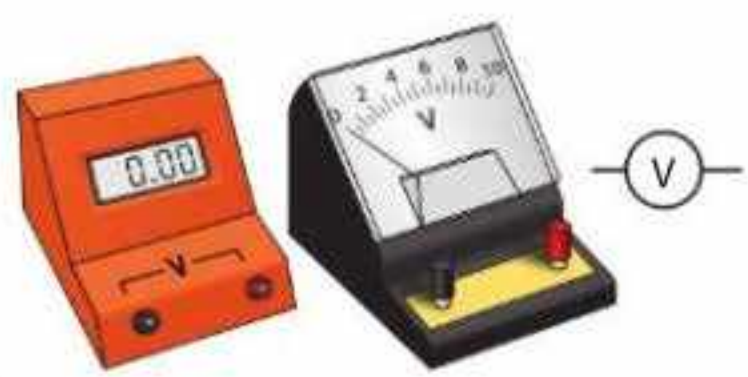
Voltage is also linked to the energy changed by components in a circuit. For example, lamps change electrical energy into light and thermal energy. Most components have a voltage **rating**.

The lamps used in schools for electrical experiments are often rated at 3 V or 6 V. The rating tells us the maximum voltage that can be used.

Measuring voltage

Voltage is measured using a **voltmeter**.

This picture shows a digital voltmeter, an analogue voltmeter and the circuit symbol for a voltmeter.

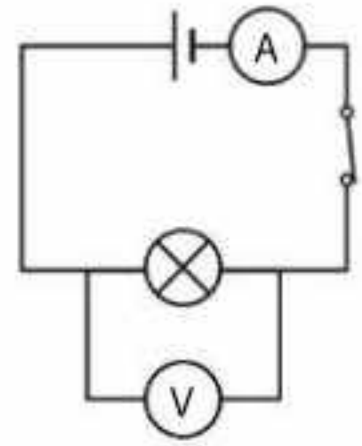


A voltmeter is connected in a different way to an ammeter.

An ammeter measures the current flowing through a component, so the ammeter is connected in series with the component.

The voltmeter measures the energy difference either side of a component, so the voltmeter is connected in **parallel** with the **component**.

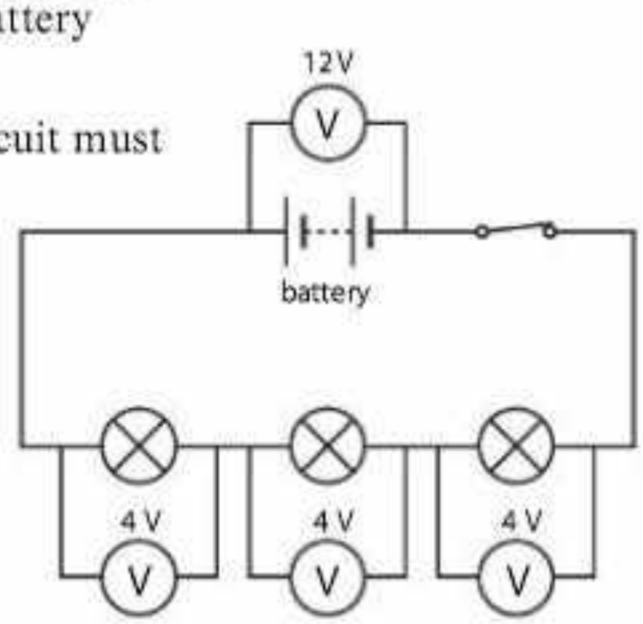
Look at the drawing of the circuit and circuit diagram. The ammeter is connected in series with the lamp and the voltmeter is connected in parallel with the lamp.



Voltage in a series circuit

Energy is always conserved, so the energy changed by the components in a circuit must be equal to the energy supplied by the cell, battery or power supply.

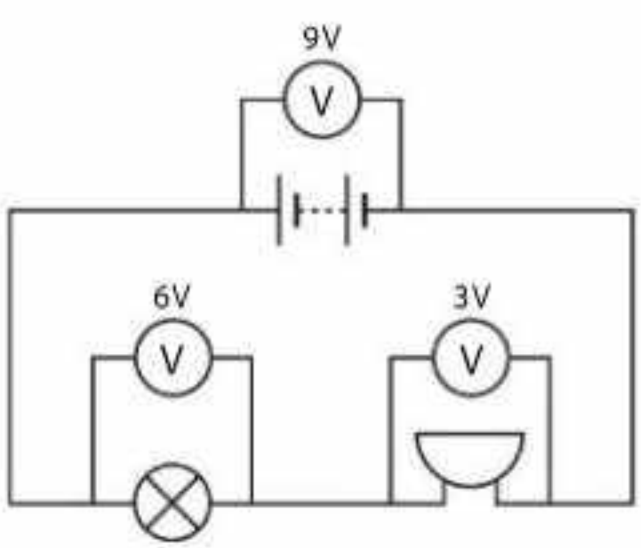
That means the voltages across each component in a series circuit must add up to the voltage of the supply.



Look at the circuit in this diagram. All three lamps are identical. They change the same quantity of energy, so have the same voltage. The voltage across all the lamps adds up to the voltage from the battery.

Look at this next circuit, where the components are not the same.

In this circuit, the lamp is changing more energy than the buzzer, so the voltage across the lamp is higher than the buzzer. The voltages across the lamp and buzzer add up to the voltage of the battery.



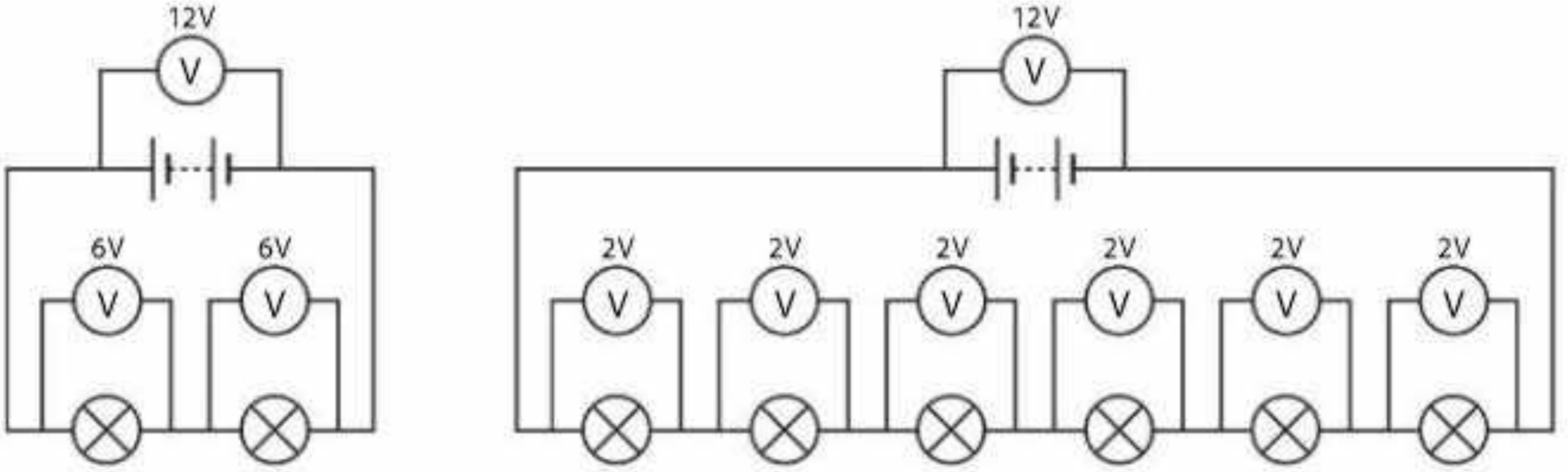
The voltages across all the components in a series circuit add up to the voltage of the supply.

We discovered at Stage 7 that the current is the same all the way around a series circuit. This is because the circuit has no branches and the current can only flow in one path. The voltage in a series circuit can be different across different components.

Adding more components in a series circuit

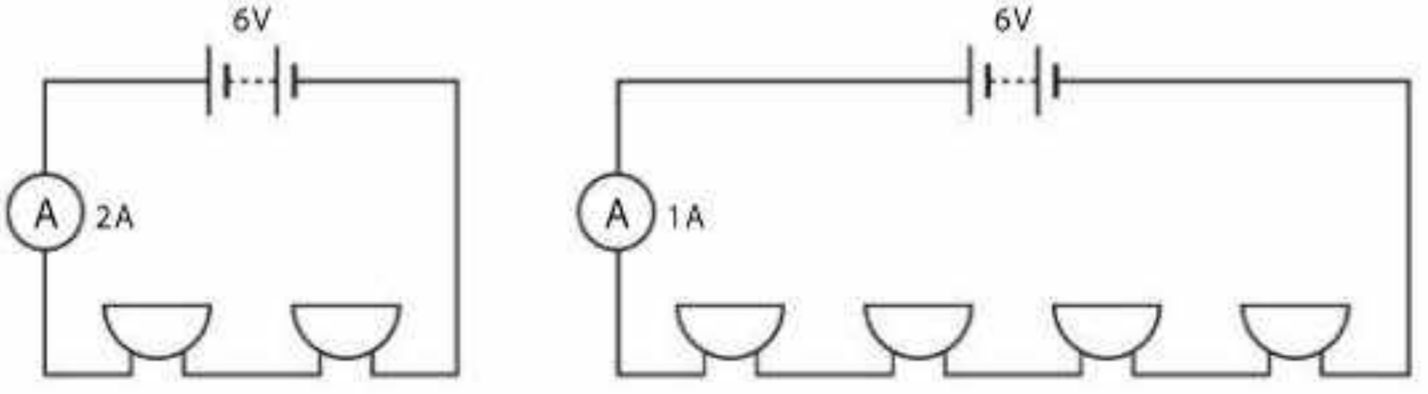
The voltage from the supply in a series circuit is shared between each of the components. That means adding components such as lamps or buzzers will cause each component to get a smaller share of the voltage.

Compare these two series circuits. Both have the same type of battery and both have identical lamps.



Adding more components in a series circuit will decrease the current. As components are added, it becomes more difficult for the power supply to push the electrons around the circuit.

Compare these two series circuits. The one with more components has a smaller current.



Adding more cells in a series circuit increases the voltage of the supply.

One 1.5 V cell gives a supply voltage of 1.5 V.

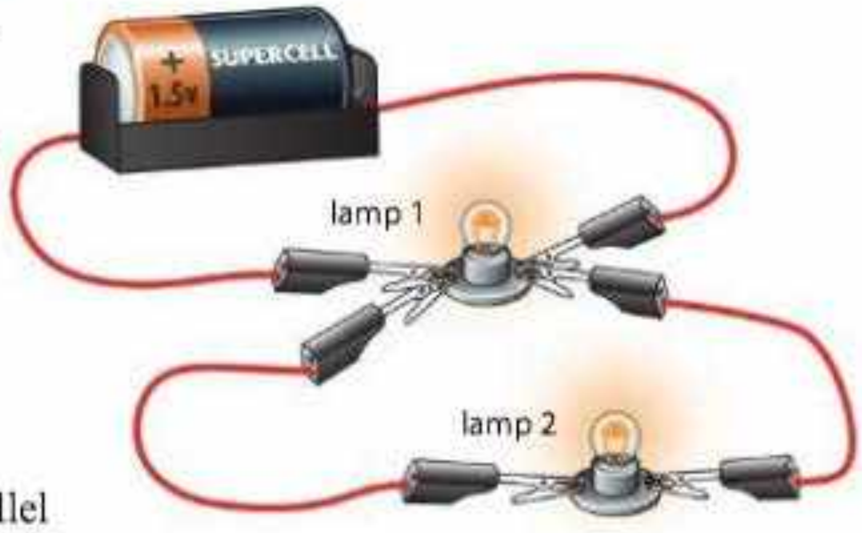
Two 1.5 V cells gives a supply voltage of 2×1.5 V = 3 V.

A 12 V battery contains eight cells each of 1.5 V making 8×1.5 V = 12 V.

Increasing the number of cells in the same series circuit will:

- increase the current in the circuit
- increase the voltage across each component.

Voltage in a parallel circuit



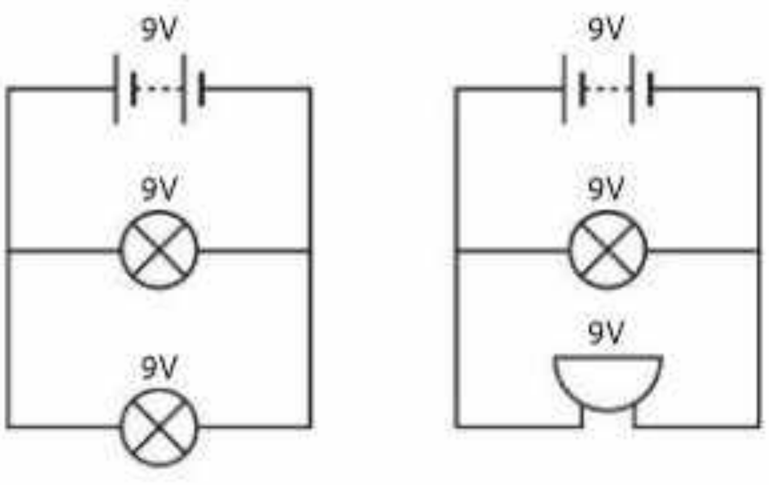
Look carefully at the drawing of a parallel circuit.

Lamp 1 is connected directly across the terminals of the 1.5 V cell. The voltage across lamp 1 is 1.5 V.

If you follow the wires from lamp 2, you can get to the terminals of the cell *without* going through lamp 1. That means we can think of lamp 2 also being connected directly across the terminals of the cell. That means the voltage across lamp 2 is also 1.5 V.

The voltages across each of the branches of a parallel circuit are equal to the voltage of the supply.

Look at these circuit diagrams.



The voltage of the battery in both circuits is 9 V.

In the left circuit, the voltage across each lamp is also 9 V.

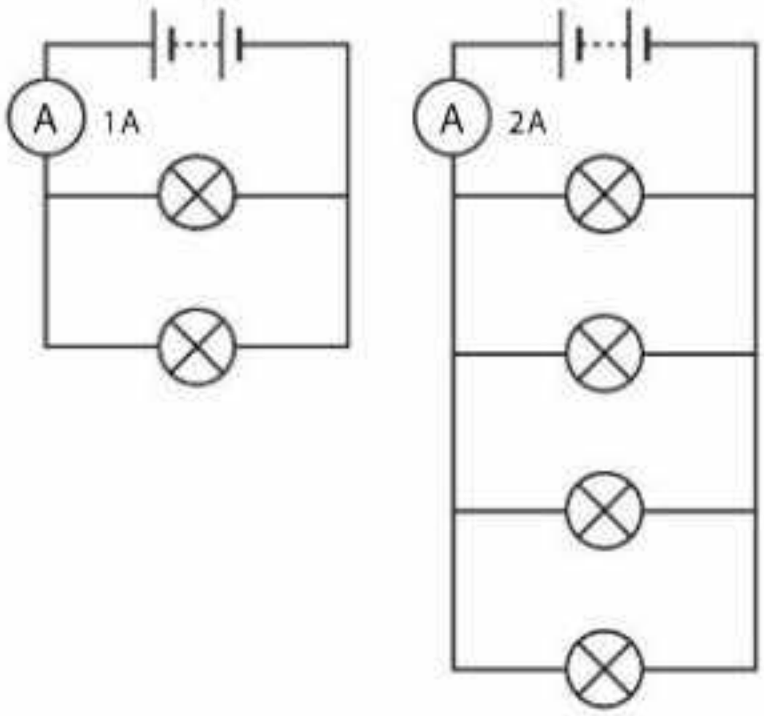
Look at the right circuit and you will see that the voltage across the branches of a parallel circuit is the same whether or not the components are the same. The lamp and the buzzer are different, but the voltage across the branches is still the same (9 V).

Topic 9.1 explained that the current can be different in the branches of a parallel circuit. This is because the current can flow in different paths. The voltage in all branches of a parallel circuit is the same.

Adding more components in a parallel circuit

Adding more branches to a parallel circuit gives more paths for the current to flow through. The more paths there are for current to flow through, the easier it becomes. That means the current though the cell increases.

Compare these two parallel circuits. Each has the same type of battery and the lamps are identical.



Adding more components to any one branch of a parallel circuit will decrease the current in that branch. Remember that the voltage across any branch will be the same, so adding more components in the branch makes it harder for current to flow in that branch.

Adding cells to a parallel circuit increases the supply voltage so it also:

- increases the voltage across each branch
- increases the current through the cell
- increases the current through each branch.

Questions

1 Copy and complete the sentences using words from the list.

series **parallel** **current** **voltage**

An ammeter is used to measure the ……………… through a component.

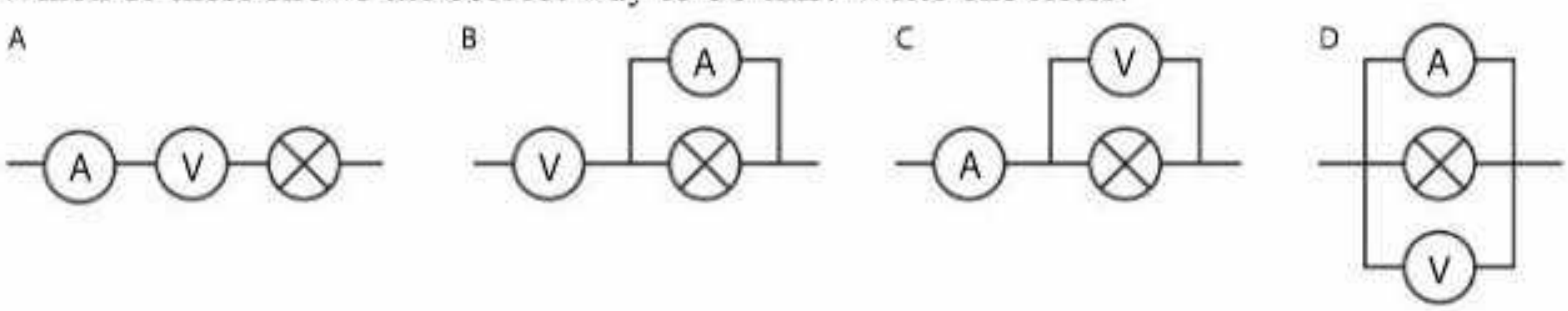
An ammeter should be connected in …………….. with the component.

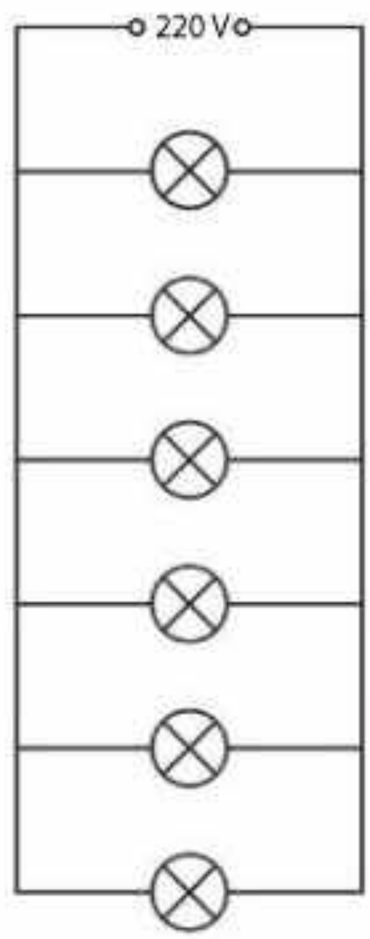
A voltmeter is used to measure the …………….. across a component.

A voltmeter should be connected in ……………… with the component.

2 Sofia wants to measure the current through a lamp and the voltage across the lamp.

Which of these shows the correct way to do this? Write **one** letter.





3 A school classroom has six identical lamps. Each of the lamps is connected in parallel across a 220 V mains supply, as shown in the diagram.

a State the voltage across one of the lamps in the diagram.

b The classroom has one light switch. The light switch is used to switch all of the lamps on or off together. Copy the diagram and include the switch in the correct position.

c The current from the mains supply to all six lamps is 2.4 A.

i Calculate the current through one of the lamps.

ii Two more lamps, identical to the other six, are added, each in a new separate branch of the parallel circuit.

State what will happen to the total current from the mains supply when the new lamps are added.

4 Marcus has a box containing ten identical lamps rated at 2.0 V. He also has a 12 V battery.

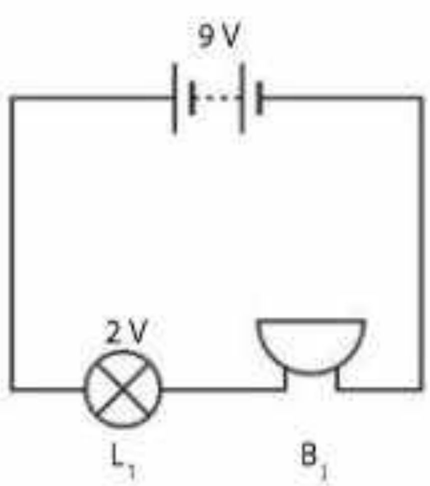
a Explain why Marcus cannot connect these lamps, each individually in parallel across the battery.

b Marcus connects the lamps in series with the 12 V battery.

i Calculate the number of these lamps that can be connected in series to operate properly.

ii Draw the circuit diagram for these lamps connected in series with the battery.

iii Add a voltmeter to your circuit diagram to show how the voltage across **one** lamp could be measured.



5 Zara has a series circuit with a 9 V battery, a lamp and a buzzer as shown in the diagram.

The voltage across the lamp L_1 is 2 V.

a Calculate the voltage across the buzzer, B_1.

b Zara adds another lamp, L_2, in series with the other components.

i State what happens to the voltage across L_1 when the new lamp is added.

ii State what happens to the current in the circuit when the new lamp is added.

6 Arun has a series circuit with a 6 V battery, two identical buzzers and two identical lamps.

The voltage across one buzzer is 1 V.

a Calculate the voltage across one lamp.

b Arun adds another 6 V battery in series with the first battery. All the components continue to work properly.

i State the voltage across one of the buzzers when the second battery is added.

ii State the effect on the current in the circuit of adding the second battery.

Activity 9.2.1

Measuring voltage in a series circuit

In this activity, you will measure the voltage across different components in a series circuit.

You will need:

- power supply, battery or cells, voltmeter, two or three lamps, another component – such as a buzzer, switch, wires, connectors.

Safety

Do not exceed the voltage rating for any component. Your teacher will show you how many of each component to connect. Switch off before adding or removing any components.

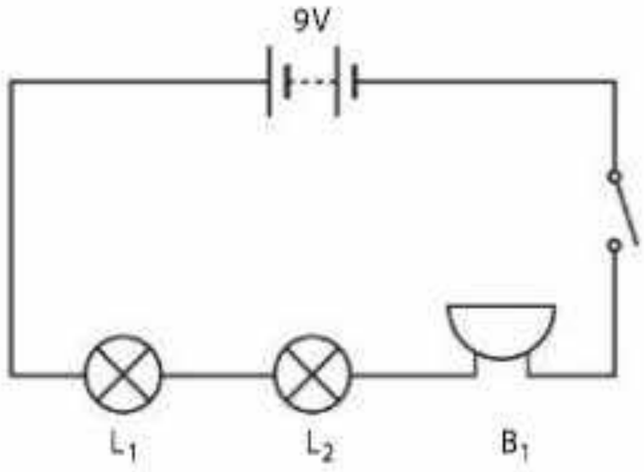
Always ask your teacher before connecting any new component into your circuit.

Method

1 Set up a series circuit as shown in the diagram.

2 Connect the voltmeter across the battery. Measure and record this voltage. Do not worry if the voltmeter reading is not the same as the value printed on the battery or the setting of the power supply. Use your voltage measurement.

3 Connect the voltmeter separately across each of the components. Measure and record these voltages.



Questions

1 Draw the circuit diagram that you used. Label each of the components, for example, L_1 and L_2 for two lamps.

2 Draw the circuit diagram again and include the voltmeter in position across one of the components to show how voltage is measured.

3 Draw a suitable table for your voltage measurements and write the results into the table.

4 Explain what your results show about voltages in series circuits.

5 If you have time and access to other components, you could make other series circuits. Can you confirm that a similar trend in results can be observed in these?

Think like a scientist

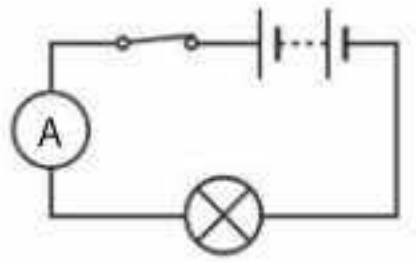
Measuring current in a parallel circuit

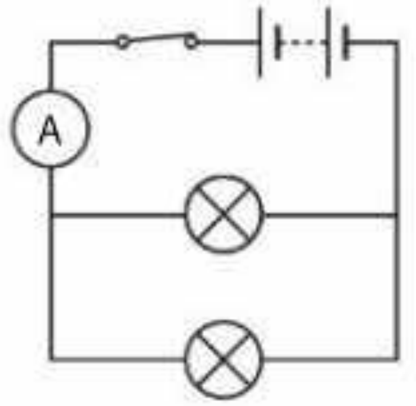
In this investigation, you will investigate how the current through a battery depends on the number of identical branches in a parallel circuit.

You will need:

- four or six identical lamps, battery or suitable power supply to light up to six lamps in parallel, switch, ammeter, leads, connectors.

Method





1 Set up the circuit as shown in the first diagram.
2 Measure and record the current with one lamp.
3 Add another lamp in parallel with the first lamp as shown in the second diagram.
4 Measure and record the current with two lamps.
5 Continue adding lamps in parallel, one at a time. Do not change the position of the ammeter. Measure and record the current through the battery each time.
6 Repeat each measurement two further times. Decide whether any more repeats are needed.
7 Calculate the average result for each set of measurements.

Questions

1 Record your results in a table.
2 Plot a line graph of your results. Put the number of lamps on the *x*-axis and the current on the *y*-axis. Draw the most appropriate line.
3 a Describe the trend in the results.
  b What happens to the current when the number of lamps in parallel doubles?
  c Explain this trend. Use ideas about how current flows around a circuit.
4 Use your results to predict the current through the battery if you had eight lamps in parallel.

Summary checklist

- [ ] I can measure current and voltage in series and parallel circuits.
- [ ] I know how adding more cells or more lamps affects current and voltage in series circuits.
- [ ] I know how adding more cells or more lamps affects current and voltage in parallel circuits.

9.3 Resistance

In this topic you will:

- discover how resistance affects current in a circuit
- calculate resistance from voltage and current.

Getting started

1 Describe how current flows in a conductor.
2 Describe the difference between a conductor and an insulator in terms of current flow.
3 What does the word resistance mean in everyday language?

Key words

filament
ohms
Ohm's law
resistor
resistance

Resistance

Resistance is a measure of how easy or difficult it is for electrons to move though a material.

Conductors, such as copper, have very low resistance.

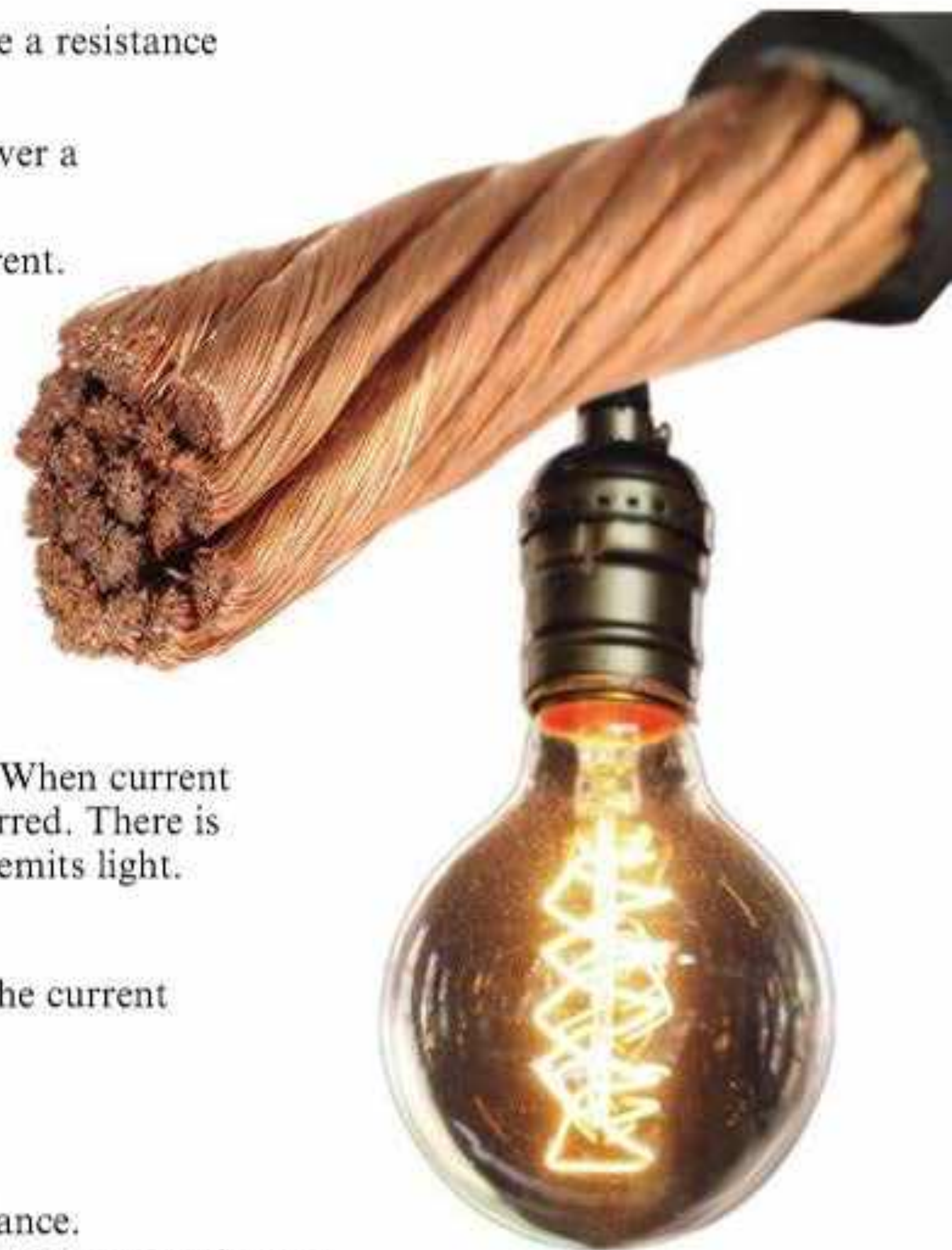
Insulators, such as most plastics, have very high resistance.

Resistance is measured in units called **ohms**. Ohms have the symbol Ω which is the Greek letter omega.

A 100 m length of copper wire, for example, can have a resistance of 0.5–1.0 Ω.

A 1 cm length of some plastics have a resistance of over a 1 000 000 000 000 Ω .

Resistance slows the flow of electrons, so lowers current.



Copper wire is designed to have very low resistance so the wires in a circuit affect the current as little as possible.

The resistance of insulators – such as the plastic around this copper wire – is so high that they do not allow current to flow at all under most circumstances.

Some conductors are designed to have a high resistance. Inside some lamps, there is a small wire called a **filament**. The filament has a high resistance. When current flows through the filament, thermal energy is transferred. There is so much thermal energy that the filament glows and emits light.

As resistance makes it difficult for current to flow:

> the greater the resistance in a circuit, the smaller the current in the circuit.

Ohm's law

Georg Simon Ohm was a scientist who studied resistance. Ohm discovered there was a link between voltage, current and resistance in wires. The link between voltage, current and resistance applies to many electrical components and not only to wires.

Ohm's law states that:

$$\text{voltage} = \text{current} \times \text{resistance}$$

These are often given letter symbols:

V = voltage, in volts

I = current, in amps

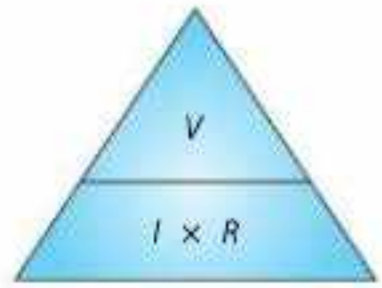
R = resistance, in ohms.

The letter I is used for current because in the French language, current was originally called *intensité du courant*.

So, we can write Ohm's law as:

$V = I \times R$ or just $V = IR$

We can put Ohm's law into a formula triangle like this:



Worked example

Question

A current of 2 A flows through a buzzer. The voltage across the buzzer is 10 V.

Calculate the resistance of the buzzer.

Answer

Using Ohm's law, the equation can be rearranged to

$$R = \frac{V}{I}$$

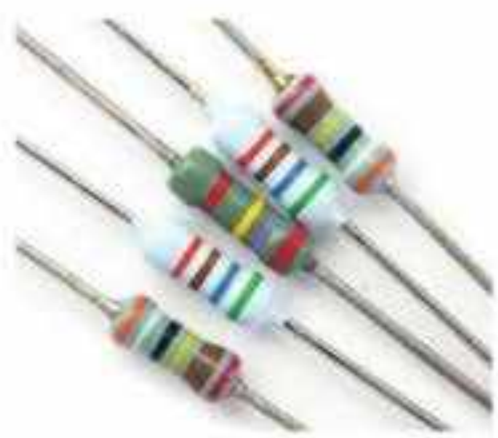
$V = 10$ and $I = 2$, so

$$R = \frac{10}{2} = 5\,\Omega$$

Resistors

A **resistor** is a type of electrical component designed to have a known resistance.

The picture shows some resistors.



Many resistors, such as those in the picture, have coloured bands. The colours form a code to show the resistance value in ohms.

This is the circuit symbol for a resistor:

The value of the resistor is usually written with the circuit symbol. When the value of the resistor is not important, or when you have to calculate the value, the letter R is usually written beside the symbol.

Questions

1 Copy and complete the sentences using words from the list.

Each word can be used once, more than once or not at all.

low high easy difficult

Copper wires have a very .... resistance.

That makes it very .... for current to flow in copper wires.

A resistor of 10 000Ω has a .... resistance.

2 **a** Write the unit of resistance.

b Write the equation for Ohm's law.

c State what the letter *I* represents in the equation for Ohm's law.

3 Calculate the values of these resistors. Show your working and give the unit with each answer.

a Resistor R_1: The voltage across R_1 is 6 V and the current through R_1 is 3 A.

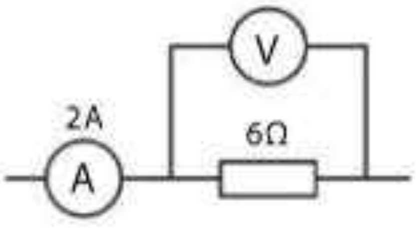
b Resistor R_2: The voltage across R_2 is 9 V and the current through R_2 is 2 A.

c Resistor R_3: The voltage across R_3 is 1.5 V and the current through R_3 is 0.5 A.

4 The diagrams in this question show parts of circuits.

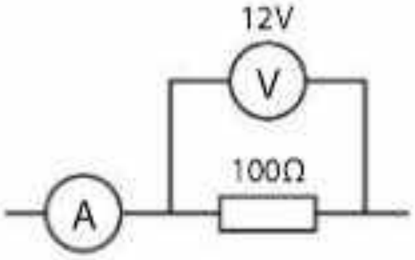
a This circuit contains a 6Ω resistor. The current through the resistor is 2 A.

Calculate the voltage across this resistor. Show your working and give the unit with your answer.



b This circuit contains a 100Ω resistor. The voltage across the resistor is 12 V.

Calculate the current through this resistor. Show your working and give the unit with your answer.



Activity 9.3.1

Working out resistance

In this activity, you will work out the resistance of different components.

Work in groups of two or three.

You will need:

- cell or battery, range of different components (such as a lamp, a buzzer and a resistor), ammeter, voltmeter, switch, wires, connectors.

Safety

Ask your teacher to check your circuits. Switch off before changing components.

Method

1 Connect each component in turn to the cell or battery.

2 Measure the current through the component and the voltage across the component.

Questions

1 Draw a circuit diagram to show how this is done for one of your components.

2 Record your voltage and current results for each component in a table.

3 a Use the results to calculate the resistance of each component. Show your working.

  b Add another column to the table for the resistance values. Remember to include the unit in the column header.

4 State which of your components had

  a the highest resistance

  b the lowest resistance.

Think like a scientist

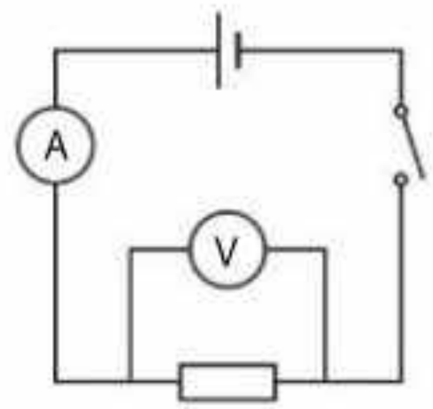
Current and voltage in a resistor

In this investigation, you will investigate how the current through a resistor depends on the voltage across the resistor.

You will need:

- minimum of four 1.5 V cells, resistor of about 10 Ω, ammeter, voltmeter, switch, wires, connectors.

Method



1. Set up the circuit with one cell as shown in the diagram.
2. Measure and record the current and voltage with one cell.
3. Add another cell in series with the first.
4. Measure and record the current and voltage with two cells.
5. Repeat with three, then four cells.

Questions

1. Record your results in a table.
2. Plot a line graph of your results. Put voltage on the *x*-axis and current on the *y*-axis. Draw the most appropriate line.
3. a Describe the trend in the results.
   b Explain why the current changes in the way that you observe.
4. Sketch how the graph would be different if the experiment were repeated with
   a a resistor with a higher resistance
   b a resistor with a lower resistance.

   If you have time, you could repeat this experiment with another resistor to test your prediction.

Summary checklist

- [ ] I know how resistance affects current in a circuit.
- [ ] I know the equation linking voltage, current and resistance (Ohm's law).
- [ ] I can use Ohm's law to calculate resistance from voltage and current.

9.4 Practical circuits

In this topic you will:

- draw circuit diagrams that include symbols for cells, switches, resistors, variable resistors, ammeters, voltmeters, lamps and buzzers
- make circuits that include some or all of these components.

Getting started

Work in pairs.

1 Draw the circuit symbol for each of these: cell, switch, resistor, ammeter, voltmeter, lamp and buzzer.

2 Beside each circuit symbol, write the function of each component.

3 Describe, in words or with a diagram, how to connect

a a voltmeter to measure the voltage across a lamp

b an ammeter to measure the current through a resistor.

Key words

dimmer
fixed resistor
variable resistor
volume

Variable resistors

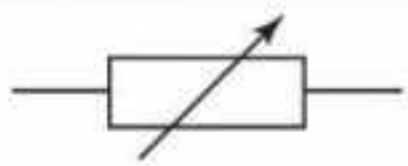
In many circuits, it is useful to be able to change the resistance. For example, in a **dimmer** switch for a lamp, or in the **volume** control of a music player. In this case, the word volume means loudness of sound.

The component that is used to change resistance is called a **variable resistor**.

These light switches (called dimmer switches) contain variable resistors that can be turned to control the brightness of lamps in a room.

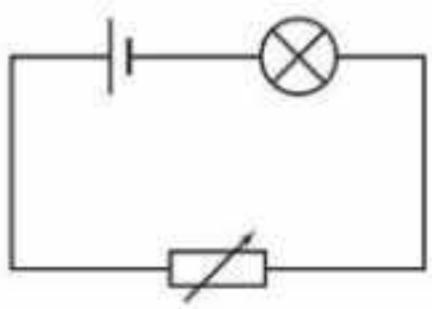
Sliding controls at the bottom of this sound recording equipment are variable resistors for adjusting volume.

The circuit symbol for a variable resistor is similar to that for a **fixed resistor**, but with an arrow through the symbol.



The term fixed resistor is sometimes used for the type of resistors you learnt about in Topic 9.3, to avoid confusion with variable resistors.

This diagram shows how a variable resistor is used to control the brightness of a lamp.



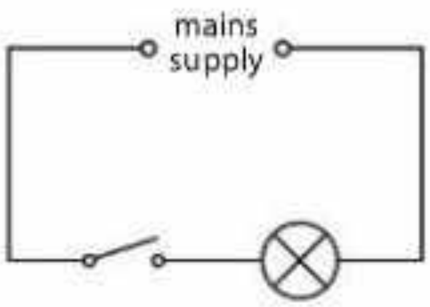
As the resistance of the variable resistor is increased, the current in the circuit decreases. A smaller current flowing through the lamp makes the lamp dimmer.

As the resistance of the variable resistor is decreased, the current in the circuit increases. A larger current flowing through the lamp makes the lamp brighter.

Everyday circuits

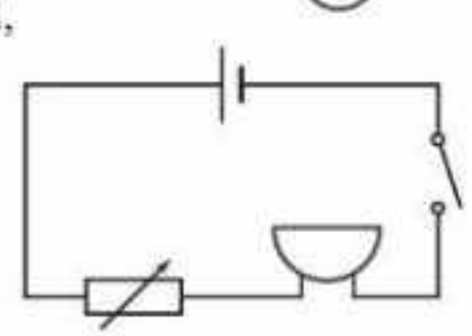
Electric circuits are used in many homes, schools, cars, bicycles, phones, music systems, watches, computers and lots more things that we use every day.

Scientists are always designing new circuits, many of which make life easier for us. Here we will look at some examples.



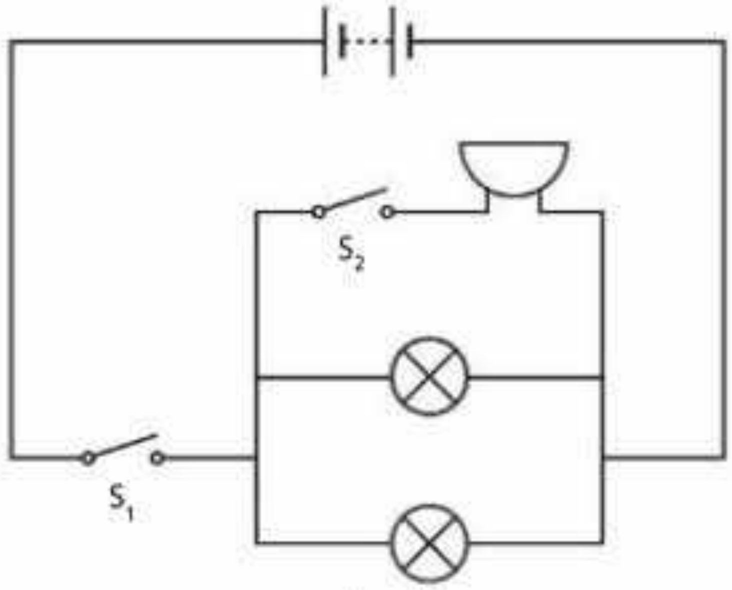
When opening the door of a refrigerator (fridge), a light comes on inside. The circuit for this is shown in the diagram.

The switch is opened and closed by the movement of the fridge door. When the door is open, the switch is closed and when the door is closed, the switch is open.



Some equipment is fitted with buzzer to make a warning sound if something is done incorrectly. Often, the loudness of the sound can be adjusted. This circuit shows how this is done.

Some cars have a buzzer that makes a sound when the driver opens the door while the headlamps are switched on. The door of the car controls the switch for the buzzer, but the buzzer should only operate when the headlamps are on.

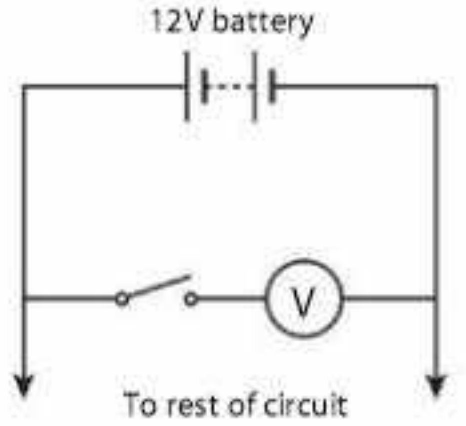


The headlamps are connected in parallel, so they can be switched on and off together. The buzzer is part of the same branch of the parallel circuit, as shown in the diagram.

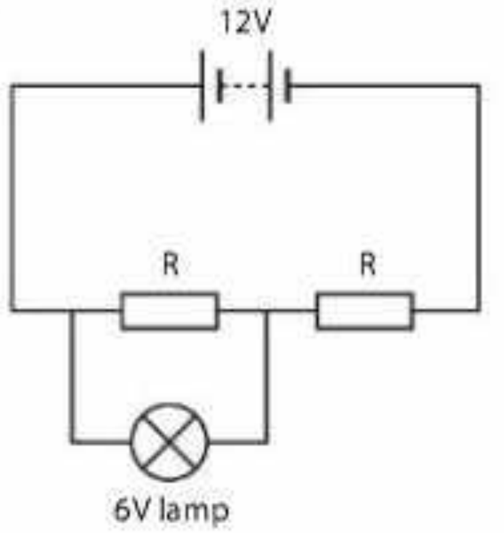
Switch S_1 controls the headlamps. Switch S_2 is controlled by the door. When the door is open, the switch is closed and when the door is closed, the switch is open. Current cannot flow to switch S_2 unless switch S_1 for the headlamps is closed. That means a buzzer will sound when you open the door while the headlamps are on.

Equipment that uses 12 V batteries include cars, trucks and some boats. These batteries need to be recharged from time to time. Sometimes, a battery voltage indicator is fitted so the voltage of the battery can be measured.

The circuit diagram shows how a switch can be used to display the battery voltage. A voltmeter is connected in parallel across the battery, and a switch is included in this branch of the parallel circuit.



Sometimes a lamp with a low voltage rating is required in a circuit with a battery of higher voltage. For example, a 6 V lamp can be operated using a 12 V battery. Resistors are used to produce different voltages. If two resistors of equal resistance are connected in series with a battery, then the battery voltage will be shared equally across each resistor. A 6 V lamp can then be safely connected in parallel with one of the resistors, as shown. The lamp will receive a 6 V supply and work properly.



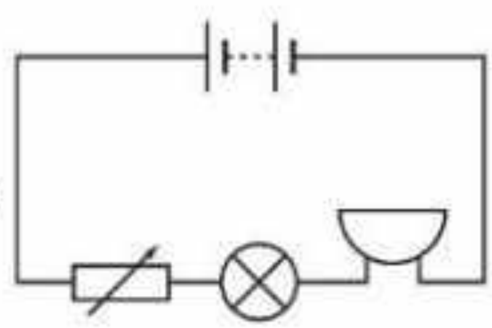
Questions

1 Draw the circuit symbol for

a a fixed resistor

b a variable resistor.

2 Look at the circuit diagram.



What can this circuit be used for? Write **one** letter.

A Changing the loudness of the buzzer, keeping the brightness of the lamp constant.

B Changing the brightness of the lamp, keeping the sound from the buzzer constant.

C Changing the loudness of the buzzer and brightness of the lamp at the same time.

D Changing the loudness of the buzzer and brightness of the lamp separately.

3 A circuit will use one cell and two lamps.

One switch must turn both lamps on and off at the same time.

The brightness of each lamp must be controlled separately.

Draw a circuit diagram for this circuit.

4 A circuit has two cells, a lamp and a buzzer in series.

a Draw a circuit diagram to show how the current through the buzzer and the voltage across the buzzer could be measured at the same time.

b Draw **one** circuit diagram to show how:

- the lamp and the buzzer can be switched on and off separately
- the brightness of the lamp can be changed without affecting the sound from the buzzer.

Think like a scientist

Designing and building circuits

In this activity, you will draw circuit diagrams and then build the circuits.

Work in pairs.

You will need:

- cells, lamps, buzzers, variable resistor, voltmeter, ammeter, selection of fixed resistors, wires, connectors.

Method

1 Write a risk assessment for building electric circuits.

2 Draw circuit diagrams for the following circuits.

Circuit 1 • two lamps can be switched on and off separately • the current through one of the lamps can be measured	**Circuit 2** • two lamps can be switched on and off together using one switch • the brightness of one of the lamps can be varied
Circuit 3 • a fixed resistor and a variable resistor in series • the voltage across the variable resistor can be measured	**Circuit 4** • one lamp can be switched on and off • a buzzer can only be switched on at the same time the lamp is on • the brightness of the lamp can be varied without affecting the sound from the buzzer

3 Ask your teacher to check your risk assessment and circuit diagrams, and then build each of the circuits.

Continued

Questions

1 Did all your circuits work as you expected? Describe any observations that you did not expect.

2 Describe any improvements you could make to your circuits. You can suggest the use of different equipment. You should describe this equipment, rather than suggesting 'better' equipment.

Summary checklist

- ☐ I can draw the circuit symbol for a variable resistor.
- ☐ I know how variable resistors are used in circuits.
- ☐ I can compare circuit diagrams that contain cells, switches, fixed resistors, variable resistors, ammeters, voltmeters, lamps and buzzers.
- ☐ I can build circuits that contain cells, switches, fixed resistors, variable resistors, ammeters, voltmeters, lamps and buzzers.

Project: Circuits for schools and houses

Background

In schools and houses that have electricity, many things work from the same electricity supply. This supply is usually a mains supply from a power station or a generator.

Your task

You will make a model of a school or a house.

You will use cells, a battery or a power supply as an analogy for the mains supply.

Next, you will design a circuit to operate lamps and other electrical equipment in the building.

Remember that lamps in each room must be switched on and off separately.

Include other equipment. For example, a school may have a buzzer that sounds at the start and end of lessons. A house or school may have an alarm that makes a sound when an outside door is opened. There will also be an electricity meter that shows how much electrical current is flowing at any time. There may also be an emergency switch that turns off the electricity to all the equipment at once.

Include anything else that you have the equipment to make.

Work in pairs.

Your pair will need:

- cardboard boxes to make the rooms
- scissors to cut the boxes
- glue or adhesive tape to join the boxes
- cells, battery or power supply
- switches
- lamps
- buzzers
- ammeter
- other components
- wires and connectors.

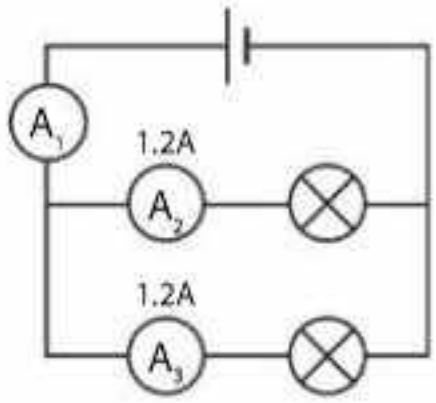
By the end of the project you should be able to:

- demonstrate how all the equipment in the school or house works
- show one fully labelled circuit diagram for all the equipment.

Check your progress

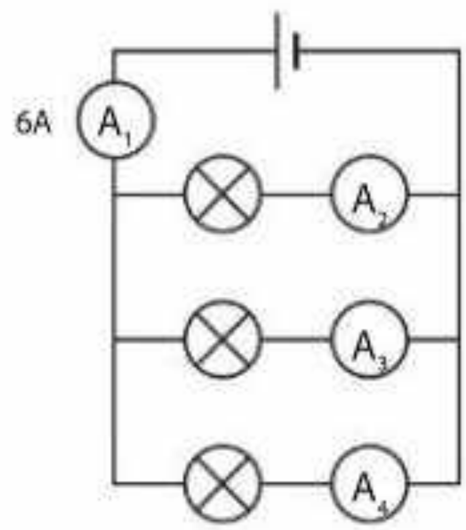
9.1 These circuits show identical lamps connected in parallel.
The readings on some of the ammeters are given.

a



Calculate the reading on ammeter A_1 **[1]**

b



i Calculate the reading on ammeter A_4. **[1]**

ii Write an equation linking the readings on all four ammeters in this circuit. **[1]**

9.2 A circuit has a lamp and a resistor in series.

Describe how to connect:

a an ammeter to measure the current through both components **[1]**

b a voltmeter to measure the voltage across the resistor. **[1]**

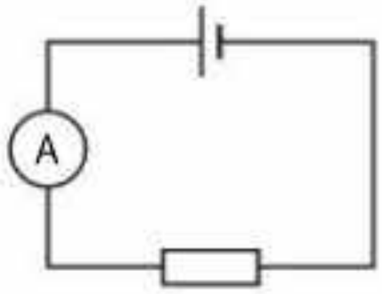
9.3 A circuit has two identical lamps in series.
Describe the effect of adding another identical lamp in series:

a on the brightness of the lamps **[1]**

b on the current in the circuit **[1]**

c on the voltage across one of the lamps. **[1]**

9.4 A circuit has a resistor in series with an ammeter and a cell.



State the effect on the current through the cell when making these changes separately:

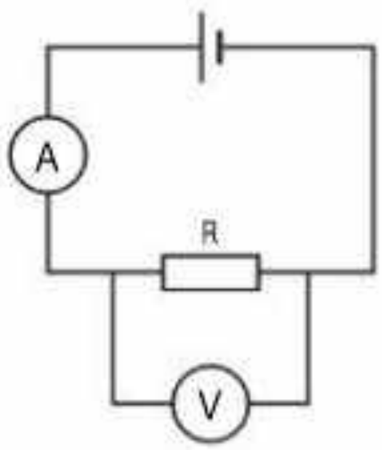
a adding another cell in series with the first cell **[1]**

b adding another resistor in parallel with the first resistor. **[1]**

9.5 a Write an equation to calculate resistance from voltage and current. **[1]**

b State the unit of resistance. **[1]**

9.6 This circuit contains a resistor, an ammeter and a voltmeter.



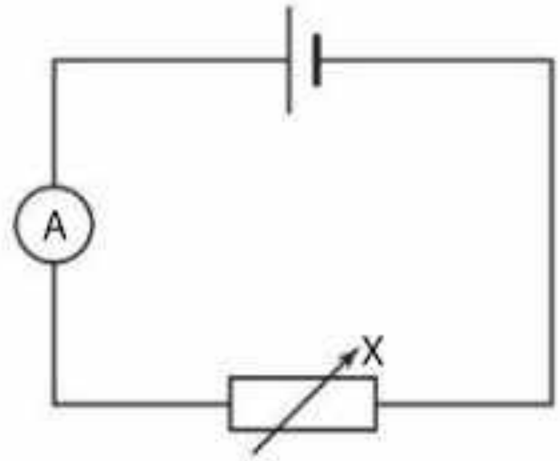
In each of these questions, show your working and give the unit with your answer. Calculate:

a the value of R when the voltage is 12 V and the current is 2 A **[3]**

b the reading on the voltmeter when the current is 0.5 A and R is 1Ω **[3]**

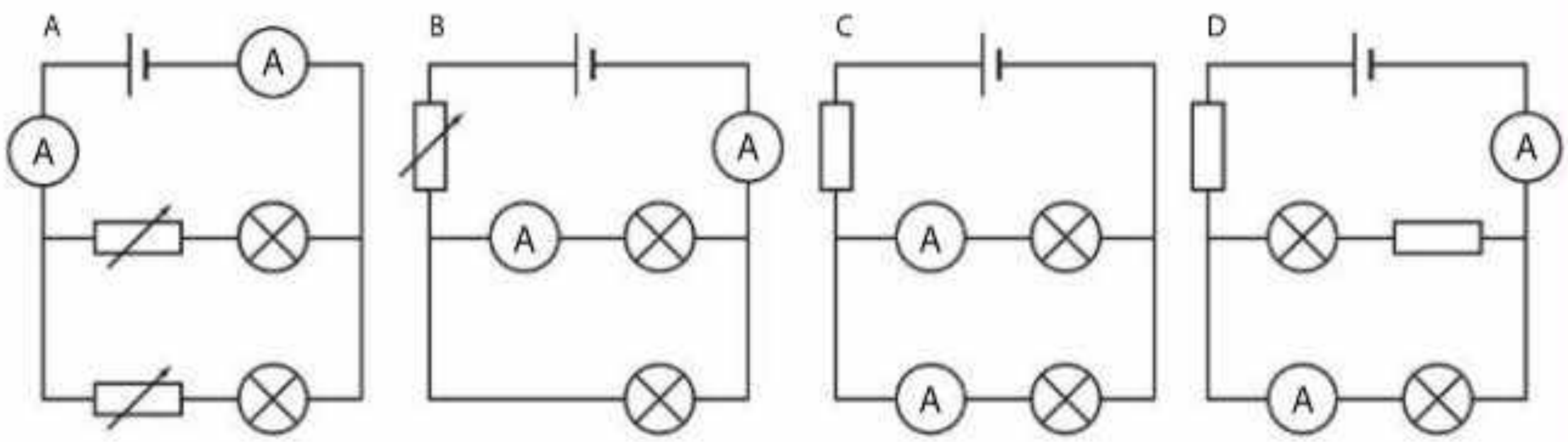
c the reading on the ammeter when the voltage is 6 V and R is Ω **[3]**

9.7 Look at the circuit diagram.



- **a** Name the component labelled **X**. [1]
- **b** Explain what happens to the reading on the ammeter when the value of X is increased. [2]

9.8 Look at the four circuit diagrams, A–D.



- **a** Which **two** circuits have two ammeters that show the same current? [2]
- **b** Which circuit can control the brightness of two lamps by adjusting one component? [1]
- **c** Which circuit can control the brightness of two lamps separately? [1]

9.9 Draw a single circuit diagram for a circuit where:

- two lamps and a buzzer can each be switched on and off separately
- the current through one lamp can be measured
- the brightness of the other lamp can be changed. [4]

Science Skills

Working with equations

In science, we often use equations to show how two or more quantities are related. You need to be able to use equations. Sometimes you will have to rearrange an equation before you can calculate the quantity you are interested in.

Here is an equation from Topic 3.1:

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

This equation tells us how we can calculate the density of a substance. We need to know two quantities:

- the mass of a sample of the substance
- the volume of the sample.

Then we calculate the density of the substance by dividing mass by volume.

Remembering an equation

You may be able to memorise an equation simply by repeating it to yourself. It may be easier if you change the names of the quantities into letters or other symbols, like this:

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

$$\mathrm{D} = \frac{m}{V}$$

Another way is to think about the meaning of the quantity. Density tells us how to compare two materials – which is heavier, when their volumes are the same? So we compare the masses of 1 $\mathrm{cm^3}$ or 1 $\mathrm{m^3}$.

An alternative is to think about units. The unit of density is $\mathrm{g/cm^3}$, or $\mathrm{kg/m^3}$. This should remind you to divide the mass (in g or kg) by the volume (in $\mathrm{cm^3}$ or $\mathrm{m^3}$).

Rearranging an equation

The equation above, for density, has density as its subject (the quantity on its own, on the left). But sometimes, we might want to calculate one of the other quantities. For example:

The density of mercury = 13.5 $\mathrm{g/cm^3}$. What is the mass of 4 $\mathrm{cm^3}$ of mercury?

We need to rearrange the equation to make mass m its subject. To do this, multiply both sides by volume V:

$$D \times V = m$$

So

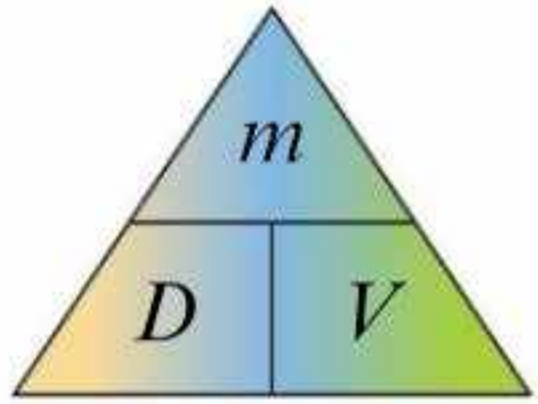
$$\begin{aligned} m &= D \times V \\ &= 13.5 \times 4 \\ &= 54\ \mathrm{g} \end{aligned}$$

It can help if you think about units. We want to know the mass (in g). We can find this if we multiply the density (in g/cm^3) by the volume (in cm^3).

$$m = 13.5\ \text{g/cm}^3 \times 4\ \text{cm}^3$$
$$= 54.0\ \text{g}$$

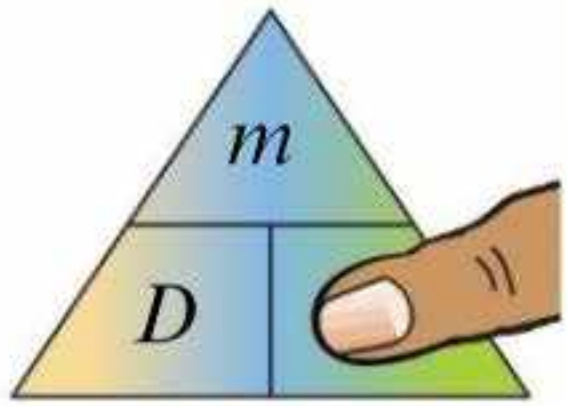
(The cm^3 units cancel out.)

Notice how calculations should be set out, with only one equals sign on each line. If you do this, you should make fewer mistakes!



Another method is to use a 'formula triangle'. The three quantities in the equation are put into a triangle, as shown. Mass m is at the top.

To find the equation which has volume V as its subject, cover the V in the triangle.



You will see that this leaves $\frac{m}{D}$

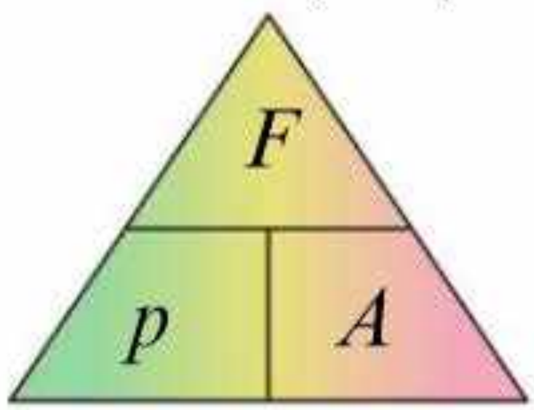
$$\text{volume} = \frac{\text{mass}}{\text{density}}$$

$$V = \frac{m}{D}$$

It is better to rearrange the equation before you put the numbers in.

Question

1 The diagram below shows the formula triangle for pressure.



- **a** Use the pressure formula triangle to find the equation with area A as its subject.
- **b** Calculate the force on an area of 3 m^2 when a pressure of 50 N/m^2 acts on it.

2 Here is the equation for the moment of a force:

moment = force × distance from pivot

- **a** Rearrange the equation to make force the subject.
- **b** Calculate the force which must be applied at a distance of 10 m from a pivot to give a moment of 500 N m.

Why is planning so important?

Careful planning of an investigation is important to make sure the investigation does what it is supposed to.

One example where planning was not done properly was a space mission in 1998. The Mars Climate Orbiter was a 640 kg space probe with no people on board, and it looked similar to the one in the picture. The mission was intended to investigate the climate on Mars.

The probe was launched from Earth in 1998 and arrived at the planet Mars in 1999. It was planned to orbit Mars and collect results about the climate. Results would be transmitted back to scientists on Earth.

Soon after going into orbit around Mars, the probe crashed and was destroyed before any results had been collected.

What happened?

An enquiry discovered that the two teams of scientists who designed the probe had not carried out their planning together. One group used standard international scientific (SI) units, such as newtons and metres. The other group had used American units, such as pounds and feet. The calculations from the computer that controlled the probe gave quantities in SI units, but the engine took these as being in American units! That meant the force produced by the engine was less than a quarter of what it was supposed to be.

In 1999, the cost of this mission was almost 330 million US dollars – a very expensive mistake!

An investigation that 'failed' – but won a Nobel Prize

In the year 1887, people already knew that the Earth travels at almost 110 000 km/h around the Sun. They also knew that light travels very fast.

In 1887, an American scientist called Michelson made a prediction: light would seem to travel faster in the opposite direction to Earth's movement, and slower in the same direction. This is similar to throwing an object out of a moving car. If you throw the object backwards, it will seem to go away from you faster than if you throw it forward. Note that this is an analogy and you should never throw anything out of a moving car!

Michelson worked with a colleague called Morley and designed an investigation to test his prediction, using a light ray and some mirrors to reflect the ray.

The picture shows Michelson checking some of the equipment.

The investigation was repeated many times but each time, the results failed to support the prediction. The results showed that the speed of light was the same in all directions.

However, rather than being a true failure, these results were the first to show that the speed of light is constant in air. This 'failed' investigation won Michelson a Nobel Prize in physics.

This example shows that significant discoveries can be made even when the results are unexpected. It is how we make the conclusions from the results that is important.

Glossary and index

advantageous feature	A feature of an organism that increases its chances of surviving and reproducing.	263
alignment	The orientation of objects or the way things are lined up according to some external influence.	236
alkali metals	Metals in Group 1 of the Periodic Table that produce alkalis when they react with water.	54
amplitude	The maximum distance moved by a particle in a wave as measured from the position of the particle when there is no wave; the height of a wave, or graph of a wave, from the mid-point to the top.	207
anomalous result	A measurement or reading that does not fit in with the pattern of the other results; such a result is not necessarily wrong, but it should be checked.	273
atomic number	The number of protons in an atom.	49
bases	Metal oxides are known as bases.	193
battery	Two or more electrical cells connected in series.	309
bladder	Organ where urine is stored.	157
branches	Parts of a parallel circuit where the current divides.	301
carbon cycle	The pathway by which carbon atoms cycle between organisms and the environment.	31
carbonate	A salt that is made from carbonic acid	180
chemical bonds	Ways in which elements are joined together to form compounds.	61
chloride	A salt that is made from hydrochloric acid	180
chlorophyll	A green pigment found inside chloroplasts in some plant cells, which captures energy from light.	9
chromosomes	Long threads of DNA, found in the nucleus of a cell.	244
citrate	A salt that is made from citric acid.	181
colder	Used to describe an object at lower temperature.	113
collecting a gas over water	A way of collecting a gas given off in a reaction.	277
collision	What happens when two or more objects bump into each other.	278
collision theory	One of the theories for the formation of the Moon; sometimes called the giant impact hypothesis.	225

concentration	A measure of how many particles of a substance are in a fixed volume of a solution.	292
conduction	Method of thermal energy transfer where more vigorously vibrating particles cause neighbouring particles to vibrate by colliding; conduction works best where particles are close together in solids and liquids.	120
connected in parallel	Components that are attached across each other, so that the terminals of one component are connected to the terminals of the other.	301
connected in series	Components that are joined so that all the current flowing out of one component flows into the next.	301
conserved	In this context, conserved means the total quantity of something is kept the same.	107
continental coasts	The outlines of the continents that form the boundary between land and sea or ocean.	235
convection	Method of thermal energy transfer where more vigorously vibrating particles cause expansion and decrease in density in a liquid or gas; the less dense material then rises because it floats, setting up a convection current.	122
convection current	Method by which all of a liquid or gas becomes heated through convection; particles flow through the material due to differences in density.	122
covalent bond	A link formed when atoms share electrons to form a molecule.	68
created	To be made from nothing or from something different.	107
crucible	A piece of laboratory equipment; a container that is heated directly at high temperatures.	199
crystallisation	The process of turning into crystals.	184
crystallise	To form crystals.	189
density	Property of an object or material, calculated as density $= \frac{\text{mass}}{\text{volume}}$ and usually has the units g/cm^3 or kg/m^3.	85
destroyed	Cease to exist	108
dimmer	In circuits, a control used to adjust the brightness of a lamp, usually a variable resistor.	326
dilute	Adding water to a solution dilutes it; there are fewer particles of the solute in a fixed volume of the solution.	294
displacement reaction	A reaction in which a more reactive metal 'pushes out' a less reactive one from a compound.	172
DNA	A chemical made up of long molecules with a shape like a twisted ladder.	246

dot and cross diagram	A way of showing atoms sharing electrons to form a covalent bond.	68
egg cell	A female gamete.	248
electron shells	The layers of electrons arranged around the nucleus of an atom.	50
electronic structure	The arrangement of electrons in the shells or levels around the nucleus of an atom.	51
electrostatic forces	Forces of attraction between particles with opposite electrical charges.	51
emit	Give out radiation or energy.	123
endothermic reaction	A chemical reaction in which energy is transferred from the environment.	201
energy levels	The layers or shells of electrons around the nucleus of an atom are referred to as being at different energy levels.	50
erodes	Wears away.	188
excretion	Getting rid of waste materials that have been inside the body.	156
excretory system	The organ system that includes the kidneys, ureters, bladder and urethra.	156
exothermic reaction	Chemical reaction in which energy is transferred to the environment.	201
expand	Become larger.	120
fertilisation	The fusing together of a male and female gamete.	249
fertiliser	A substance containing minerals, which is added to soil to help plants to grow well.	20
fetal	To do with a fetus.	161
fetus	A young animal developing inside the uterus.	160
filament	The high resistance wire used in some lamps and in some radiant heaters.	320
fixed resistor	A component whose resistance should be constant under specified conditions.	326
formula	Uses chemical symbols to show how many atoms of different elements are present in a particle of an element or compound (the plural is formulae).	181
fossil record	The collection of remains of dead animals and plants from millions of years ago that provide evidence of what conditions were like in those times.	235
frequency	The number of complete vibrations of an object in 1 second.	209
gametes	Sex cells; two gametes fuse together to produce a zygote.	248
genes	Parts of a chromosome that determine a feature of an organism.	245

genetic differences	Differences between individuals that are caused by differences between their genes.	257
gradient	The steepness of a slope, including on a graph.	274
graphite	A form of carbon used as the 'lead' in pencils.	74
halogens	The elements found in Group 7 of the Periodic Table.	57
highest energy level	The outermost shell of electrons in an atom has the highest energy level.	61
hollow	An object that has a space filled with air on the inside.	85
hotter	Used to describe an object at a higher temperature.	113
inheritance	Passing on genes from parents to offspring.	251
interference	The effect produced when two or more waves meet.	217
intermolecular forces	The forces between molecules.	72
ion	An atom that has lost or gained one or more electrons and has an electric charge.	62
ionic bond	A link formed between two or more ions to form a compound.	63
ionic compounds	A compound formed when the ions of a metal and a non-metal react together.	65
irregular	Of a three-dimensional shape, having a volume that cannot be calculated using a simple equation.	86
jigsaw	A type of puzzle where a complete picture is made by fitting smaller interlocking pieces of the picture together.	235
kidneys	Organs that filter the blood, removing urea and other unwanted substances from it and forming urine.	156
lattice	A regular, repeated, three-dimensional arrangement of atoms, ions or molecules in a metal or other crystalline solid.	72
layers	As in a form of material where one sheet of material is placed on top of another.	74
light intensity	The strength or quantity of light.	12
limestone	A sedimentary rock made from calcium carbonate.	188
loudness	The intensity of a sound; very quiet sounds are difficult to hear, whereas very loud sounds can be painful and damaging to the ears.	207
macromolecules	Giant molecules.	73
mains	The power supply from wall sockets; 220 – 240 V in most countries or 110 – 120 V in others.	309
mass extinction	The loss of large numbers of species.	37
mass number	The number of protons and neutrons in an atom added together.	49
meteorite	A meteor that has landed on the surface of the Earth.	38

meteoroids	Objects in space that are smaller than an asteroid.	38
meteors	Meteoroids as they are moving through the Earth's atmosphere.	38
molecule	A particle formed when atoms are bonded together with covalent bonds.	68
molten	In a liquid state.	176
natural selection	The increased chance of survival of individuals that have particular advantageous features; these individuals therefore have a greater chance of survival and passing on their genes to the next generation.	263
nebulae	Clouds of dust and gas in space (the singular is nebula).	230
neutralisation	To change an acid or alkaline solution to one that has a pH of 7.	190
nitrate	A salt that is made from nitric acid.	180
noble gases	The elements found in Group 8 of the Periodic Table.	58
northern hemisphere	The part of the Earth that is north of the equator.	230
Ohm's law	The relationship where resistance $= \frac{\text{voltage}}{\text{current}}$	320
ohms	The unit of resistance, symbol Ω.	320
ores	Rocks or minerals that contain a metal compound.	177
oscilloscope	Electronic equipment used to display a waveform on a screen.	208
outermost electron shell	The electron shell furthest from the nucleus of an atom.	61
parallel circuit	Circuit with branches where current can flow through more than one route.	301
peak	The top of a wave graph where the line is at its highest; also known as a crest.	207
Periodic Table	A table of all the elements placed in order of their atomic number.	49
photosynthesis	The way that plants make glucose and oxygen from carbon dioxide and water, using energy from light.	9
pitch	The highness or lowness of a musical note.	208
porous	A solid that has tiny holes allowing water to soak through.	132
precipitate	An insoluble solid formed when two soluble substances react.	286
preliminary work	Some practical work you do before an investigation to find out how you will carry it out. For example, you might find out the range or interval of the independent variable that you will use.	288

radiation	Method of thermal energy transfer that uses waves and does not depend on particles; occurs through a vacuum, through gases and through transparent solids.	123
random	Not predictable or not following any pattern.	131
rate of reaction	How quickly or slowly a reaction happens.	272
rating	The maximum current or voltage that can be safely used without damaging a component.	309
reactivity	How quickly or slowly a chemical reacts.	169
reactivity series	A list of metals in order of how reactive they are; the most reactive are at the top of the list and the least reactive at the bottom.	169
regular	Of a three-dimensional shape, such as a cube or cuboid, having a volume that can be calculated using a simple equation.	86
reinforce	In this context, where interference results in an increase in amplitude.	218
renal	To do with kidneys.	156
resistance	In an electrical circuit, anything that tends to slow the flow of current.	320
resistant	Of bacteria, able to survive in the presence of an antibiotic.	263
resistor	An electrical component designed to have a known resisistance.	321
root hairs	Specialised cells on the outer surface of a root, which absorb water and mineral ions from the soil.	143
salt	A compound formed when a metal reacts with an acid, for example, magnesium chloride.	180
sex chromosomes	Chromosomes that determine the sex of an organism; in humans, a female has two X chromosomes, while a male has one X chromosome and one Y chromosome.	250
sex inheritance	The way in which X and Y chromosomes are inherited.	251
slush	Partly-melted snow.	35
solid	In this context, an object that has no space filled with air on the inside.	85
southern hemisphere	The part of the Earth that is south of the equator.	230
sperm cell	A male gamete that can swim actively.	248
stable	Firmly fixed.	61
stellar nurseries	Places within some nebulae where stars are formed.	230
stomata	Small holes in the epidermis of a leaf, which allow gases to diffuse into and out of the leaf (the singular is stoma).	18
sulfate	A salt that is made from sulfuric acid.	180

supply	To provide something; a power supply provides voltage to drive current in a circuit.	309
surface area	Measurement of the space on the surface of an object measured in cm^2.	280
system	In this context, a system is a place where an energy change or transfer occurs.	107
the law of conservation of mass	The principle that there is no loss or gain of mass in a chemical reaction.	197
the law of conservation of energy	The principle that energy cannot be created or destroyed, only changed or transferred.	202
transpiration	The loss of water vapour from a plant's leaves.	149
trial run	A test run of an investigation to check that you can carry it out correctly.	287
trough	The bottom of a wave graph where the line is at its lowest.	207
urea	A waste substance made in liver cells from unwanted proteins.	156
ureter	A tube that carries urine from a kidney to the bladder.	157
urethra	A tube that carries urine from the bladder to the outside.	157
urine	A liquid made by the kidneys; it contains urea dissolved in water.	157
variable resistor	A component whose resistance can be changed.	326
variation	Differences between individuals belonging to the same species.	254
vigorously	With a lot of movement and a lot of energy.	120
voltage	A quantity that is related to either the energy supplied by a power supply or the energy changed by a component.	309
voltmeter	A meter that is connected in parallel with a component in order to measure the voltage across that component.	309
volts	The unit of voltage, V.	309
volume	In the context of sound, a control used in audio equipment for adjusting the loudness of the sound output, or the loudness of sound.	326
waveform	The shape of a graph that shows how vibrations occur in a wave; usually a line with a regular up and down curved pattern.	207
wilted	Collapsed; plant leaves wilt if they are short of water.	154
X chromosomes	Long sex chromosomes; a person with two X chromosomes is female.	250
xylem vessels	Long , hollow tubes through which water moves in a plant; they are made up of dead, empty cells joined end to end.	144

Y chromosomes	Short sex chromosomes; a person with one Y chromosome and one X chromosome is male.	250
yield	The quantity of a crop that is harvested.	20
zygote	A cell formed when a male and female gamete fuse together; it is the beginning of a new life.	249

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