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Cambridge Lower Secondary Science

LEARNER'S BOOK 9

Mary Jones, Diane Fellowes-Freeman & Michael Smyth

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Cambridge Lower Secondary Science

LEARNER'S BOOK 9

Mary Jones, Diane Fellowes-Freeman & Michael Smyth

Introduction

Welcome to Stage 9 of Cambridge International Lower Secondary Science. We hope this book will show you how interesting and exciting science can be.

Science is everywhere. Everyone uses science every day. Can you think of examples of science that you have seen or used today?

Have you ever wondered about any of these questions?

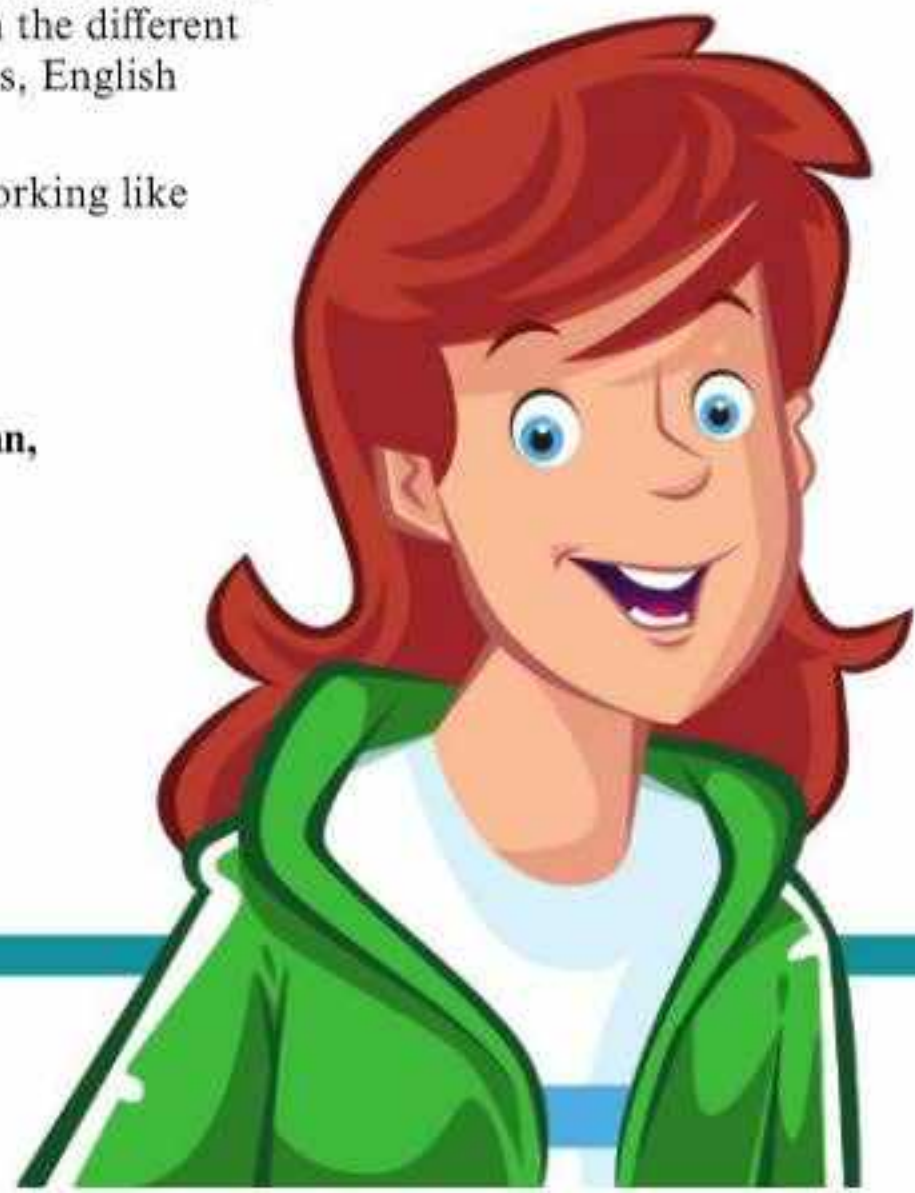
- How do scientists plan experiments to find out if their ideas are correct?
- Why do people all look different from each other, even though we all belong to the same species?
- Why do elements react to form compounds?
- How can we increase the rate at which a reaction takes place?
- Where are stars formed?
- How can two sounds result in silence?

You will work like a scientist to find answers to these questions and more. It is good to talk about science as you investigate and learn. You will share your ideas with classmates to help them understand, and listen to them when you need reassurance. You will reflect on what you did and how you did it, and ask yourself: 'would I do things differently next time?'

You will practise new skills and techniques, check your progress, and challenge yourself to find out more. You will make connections between the different sciences, and how they link to maths, English and other subjects.

We hope you enjoy thinking and working like a scientist.

Mary Jones, Diane Fellowes-Freeman, Michael Smyth



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335 **339** **347**	**Science Skills** **Glossary and index** **Acknowledgements**			

How to use this book

This book contains lots of different features that will help your learning. These are explained below.

This list sets out what you will learn in each topic. You can use these points to identify the important topics for the lesson.

In this topic you will:

- discover that thermal energy always transfers from hotter places to colder places
- understand what is meant by heat dissipation.

This contains questions or activities to help find out what you know already about this topic.

Getting started

1. Thermal is an energy store. List as many other types of energy store as you can remember.
2. Choose two of your energy stores. Describe how the energy can be changed between these energy stores.
3. Describe what is meant by dissipated energy.

Important words are highlighted and explained in the text when they first appear in the book. You will also find definitions of all these words in the Glossary and index at the back of this book.

Key words

chlorophyll light intensity photosynthesis

You will have the opportunity to practise and develop the new skills and knowledge that you learn in each topic. Activities will involve answering questions or completing tasks.

Activity 3.1.1

Densities of some regular objects

In this activity, you will calculate the densities of some different materials, using the mass and volume of regular objects.

You will need:

- a balance, a calculator, a ruler that can measure in millimetres, some regular objects made from different materials.

Method

1. Measure the length, width and height of each object. You should measure to the nearest 0.1 cm.
2. Calculate the volume of each object in cm^3.
3. Measure the mass of each object in grams. Remember to check that the balance is reading 0.0 g before you place the material on the balance.

This provides an opportunity for you to practise and develop practical skills with a partner or in groups.

Think like a scientist

Densities of irregular objects

In this investigation, you will calculate the densities of irregular objects.

You will need:

- a balance, measuring cylinders of various sizes, water, a calculator, small irregular objects that will sink in water and will fit inside the measuring cylinders.

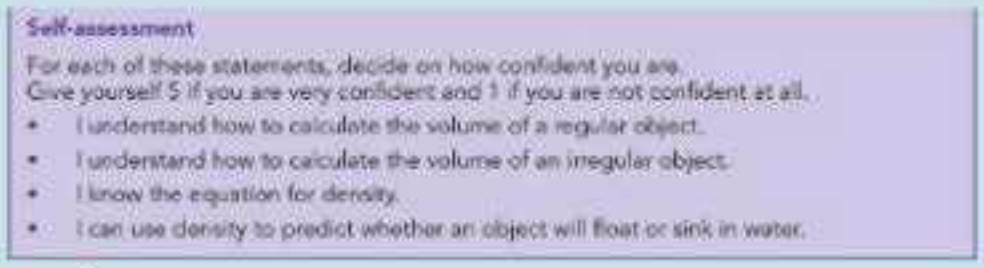
Safety

Do not drop heavy objects into glass measuring cylinders; either use a plastic measuring cylinder, or hold the glass measuring cylinder at an angle, so that the object slides down slowly.

Method

1. Use the displacement method to calculate the volumes of your objects in cm^3.
2. Measure the mass of each object in grams. Remember to check that the balance is reading 0.0 g before you place the material on the balance.

After completing an activity, this provides you with the opportunity to either assess your own work or another student's work.


Self-assessment

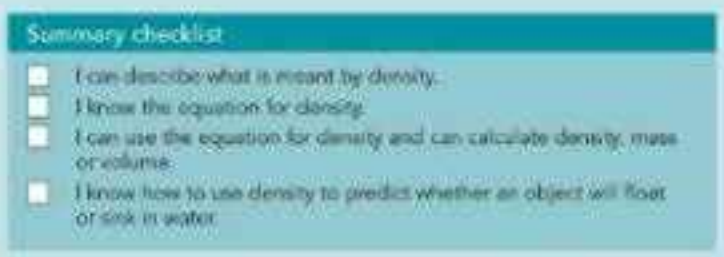
For each of these statements, decide on how confident you are.
Give yourself 5 if you are very confident and 1 if you are not confident at all.

- I understand how to calculate the volume of a regular object.
- I understand how to calculate the volume of an irregular object.
- I know the equation for density.
- I can use density to predict whether an object will float or sink in water.

This contains questions that ask you to look back at what you have covered and encourages you to think about your learning.

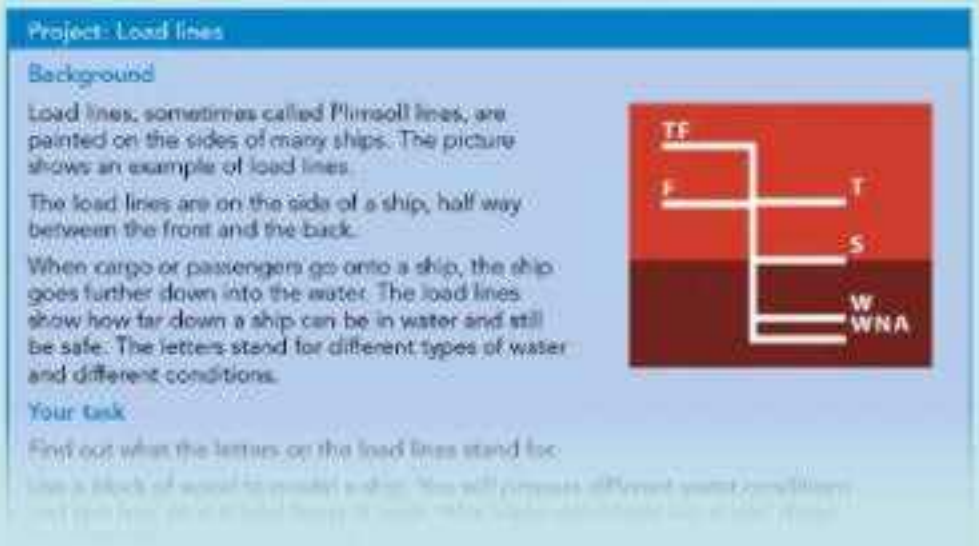
The carbon cycle is a complicated diagram.
What can you do to help you to remember it?

This list summarises the important ideas that you have learned in the topic.


Summary checklist

- I can describe what is meant by density.
- I know the equation for density.
- I can use the equation for density and can calculate density, mass or volume.
- I know how to use density to predict whether an object will float or sink in water.

At the end of each unit, there is a group project that you can carry out with other learners. This will involve using some of the knowledge that you developed during the unit. Your project might involve creating or producing something, or you might all solve a problem together.


Project: Load lines

Background

Load lines, sometimes called Plimsoll lines, are painted on the sides of many ships. The picture shows an example of load lines.

The load lines are on the side of a ship, half way between the front and the back.

When cargo or passengers go onto a ship, the ship goes further down into the water. The load lines show how far down a ship can be in water and still be safe. The letters stand for different types of water and different conditions.

Your task

Find out what the letters on the load lines stand for.

These questions look back at some of the content you learnt in each lesson in this unit. If you can answer these, you are ready to move on to the next unit

Check your progress

3.1 Which of these is the correct equation to calculate density?

Give **one** letter. [1]

A density = weight × volume

B density = $\frac{\text{mass}}{\text{volume}}$

C density = $\frac{\text{volume}}{\text{mass}}$

D density = $\frac{\text{weight}}{\text{volume}}$

1 Photosynthesis and the carbon cycle

1.1 Photosynthesis

In this topic you will:

- practise using the word equation for photosynthesis
- learn what photosynthesis is, how it happens and why it is important.

Getting started

Look at the pictures of the young maize (corn) plants. The plants on the left have been given light, but the ones on the right have not had light.

You may also be able to look at some actual plants that have been grown in the light and in the dark.

With a partner, make a list of the differences you can see between the two sets of plants.

Suggest what has caused these differences.

Key words

chlorophyll light intensity photosynthesis

How plants make food

Plants make food by **photosynthesis**. 'Photo' means 'light'. 'Synthesis' means 'making'. So photosynthesis means 'making with light'.

Activity 1.1.1

Words beginning with photo-

Work in a team.

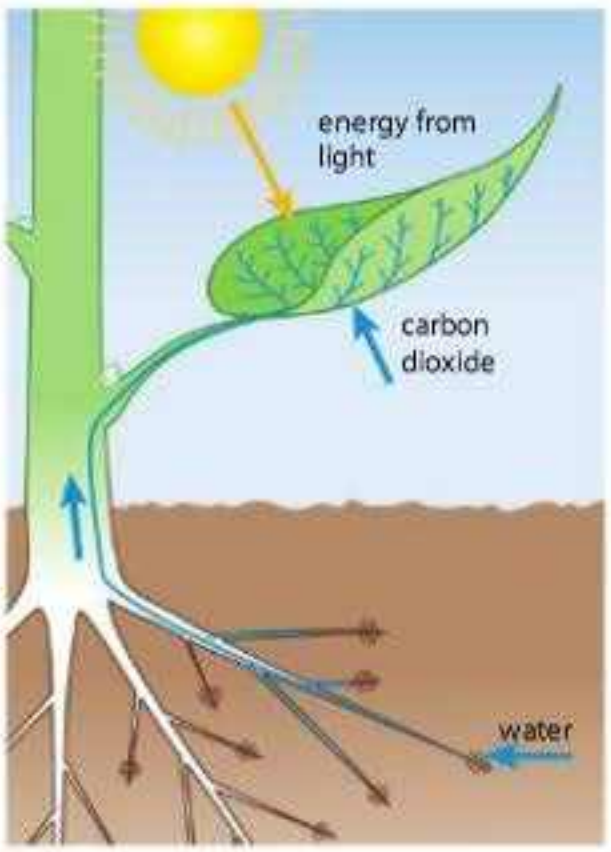
In two minutes, write down as many words as you can think of that start with 'photo'.

The winning team is the one which has thought of the most words – but only if they are all real words, and are spelt correctly.

What does each word have to do with light?

In photosynthesis, plants use:

- water, which they get from the soil
- carbon dioxide, which they get from the air
- energy, which they get from sunlight.



The energy in sunlight is captured by a green pigment, called **chlorophyll**, which is inside some of the cells in the leaves of plants.

The plants use the energy to make the water and carbon dioxide combine together in a chemical reaction.

Two new substances are made in the reaction. These are glucose and oxygen.

You can write the word equation for photosynthesis like this:

water + carbon dioxide → glucose + oxygen

Photosynthesis happens in the leaves of a plant. You will find out more about this in the next topic.

Questions

1 What are the reactants in photosynthesis?

2 What are the products in photosynthesis?

Think like a scientist

Collecting the gas produced in photosynthesis

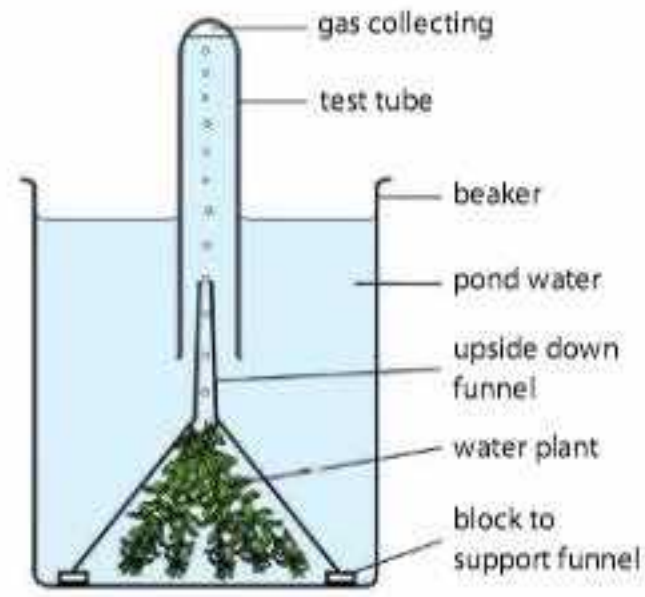
You are going to use a plant that grows in water for this experiment. This makes it easy to collect the gas that it releases.

You will need:

- the apparatus shown in the diagram.

If you do not have any pond water, you can use ordinary tap water.

You can use any plant that grows under water. You can often buy water plants in pet shops, because people like to put them into tanks with their pet fish.



Method

1. Set up the apparatus shown in the diagram.
2. Put the apparatus in a place where the water plant will get sunlight. Leave it for at least one day.
3. When plenty of gas has collected in the top of the test tube, put your hand into the beaker of water.

   Carefully remove the tube from the top of the funnel. Keep the opening of the tube under the water, or the gas will escape!
4. With the tube still upside down, put your thumb over the end of the tube, to keep the water and gas inside.
5. Take the tube out of the water, keeping your thumb over the end. Keep the tube upside down.
6. Very carefully, move your thumb just a little bit, so that the water runs out of the tube but the gas stays inside. Push a stopper into the tube, then place it – right way up – in a test tube rack.
7. Light a splint, and then blow it out so that it is glowing but not burning.
8. Test the gas with the glowing splint. (Try not to touch the wet sides of the test tube, or the splint will be extinguished!) If the gas contains a lot of oxygen, the splint will relight.

Questions

1. Explain why it was best to use a water plant in this experiment.
2. Explain why it was important to leave the apparatus where it would get plenty of sunlight.

Think like a scientist

Investigating how light intensity affects the rate of photosynthesis

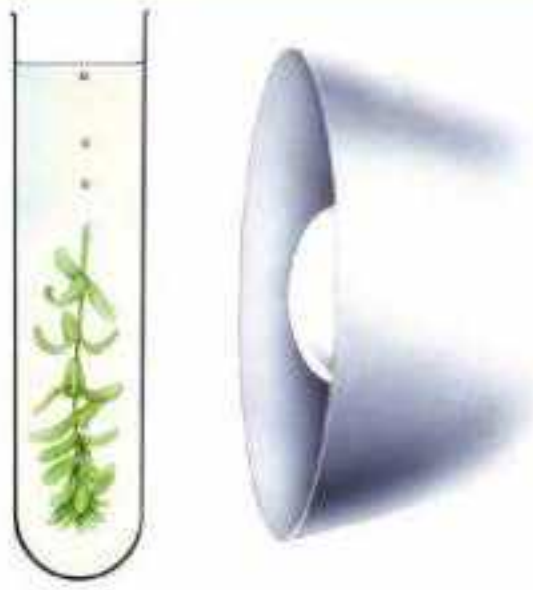
Like the previous experiment, this experiment uses a water plant. You are going to change the amount of light that falls onto the plant and see how this affects the number of bubbles it produces in one minute.

You will need:

- a test tube containing water, a piece of water plant, a lamp, a beaker in which you can stand the test tube, a ruler for measuring the distance between the lamp and the test tube, a timer.

Safety

It is very important to keep electrical wires, plugs and the lamp away from the water.



Method

1. Set up your equipment. Place the lamp close to the test tube. Leave the equipment like that for about 5 minutes, to give the plant time to settle down and start to photosynthesise.

   While you are waiting, read the rest of these instructions and then draw a results chart.

   When you can see bubbles coming from the cut end of the plant stem, you can start your experiment.
2. Measure the distance between the lamp and the test tube, and write it down in your results chart.
3. Start the timer. Count how many bubbles the plant produces in one minute, and write this down.
4. Repeat step 3 two more times.
5. Now move the lamp a little bit further away from the test tube. Measure the new distance.
6. Repeats steps 3 and 4.
7. Repeat steps 5 and 6 for at least two more distances of the lamp, further from the test tube.

Continued

Questions

1 Calculate the mean number of bubbles for each distance of the lamp from the test tube.

2 Plot a graph of your results.

- Put distance of lamp from the test tube on the *x*-axis. Remember to include units.
- Put mean number of bubbles per minute on the *y*-axis.
- Plot your points as small, neat crosses.
- Draw a line to show the trend in your results.

3 **Light intensity** means the amount of light. Copy and complete this sentence:

As the distance of the lamp from the test tube increases, the light intensity .....

4 Now write a conclusion for your experiment, by copying and completing this sentence:

As the light intensity increases, the rate of photosynthesis ..... .

Peer assessment

Exchange your results chart with a partner (not the person who worked with you on your experiment).

How well did they construct and complete their results chart?

Give them a mark, from 0 to 2, to show how well they did on each of the five statements below:

0 if they did not try, or you think they could do better

1 if you think they did quite well

2 if you think they did it really well

- They drew a results chart using a ruler and pencil, so that it was easy for you to read.
- They wrote a heading for the distance of the lamp from the plant, including units.
- They wrote a heading for the number of bubbles per minute.
- They included a column or row for the mean number of bubbles per minute.
- Overall, it was really easy to understand everything in the results chart.

If you gave your partner two marks for everything, the best possible score would be 10. How many marks did you give them out of 10? If it was less than 10, explain to them what they could do better.

If you were asked to draw another results chart in the future, how could you do it better?

Activity 1.1.2

Photosynthesis and respiration

In Stage 8, you learnt about respiration.

Think about each of these questions on your own.
Then turn and discuss them with your partner.

- What similarities are there between photosynthesis and respiration?
- What differences are there between photosynthesis and respiration?

Now share your ideas with the rest of the class.

Why is photosynthesis important?

First, photosynthesis provides energy, in the form of chemical energy in nutrients, for most other organisms.

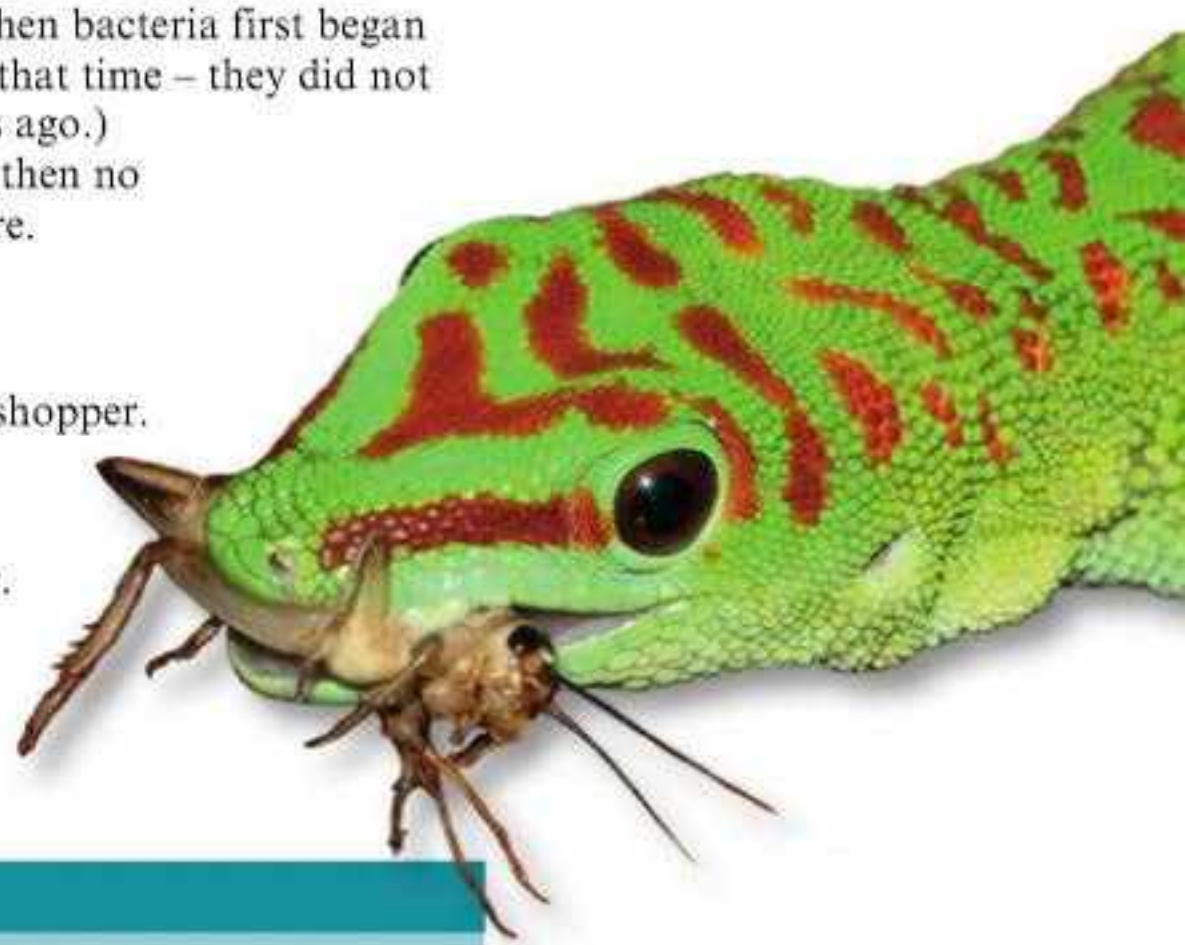
Plants use the energy in sunlight to make glucose and other carbohydrates. These carbohydrates contain some of the energy that was originally in the sunlight.

Think about what you have learnt about food chains. When animals eat food, they get some of the energy that was captured by plants. Most of the energy in all the food in the world comes from plants. A food chain shows us how this energy is passed along from one organism to another.

The second reason that photosynthesis is so important is that it provides oxygen for the Earth's atmosphere. Animals and plants, of course, need oxygen for respiration.

Oxygen is a waste product of photosynthesis. It is released from the leaves of plants and mixes with the other gases in the atmosphere. About 20% of the air around us is oxygen.

When the Earth was first formed, about 4.6 billion years ago, there was almost no oxygen in the Earth's atmosphere. Scientists think that oxygen first began to collect in the air when bacteria first began to photosynthesise. (There were no plants at that time – they did not appear on Earth until about 4.7 million years ago.)
If photosynthesis had never begun on Earth, then no animals would ever have been able to live here.



Questions

3 The picture shows a lizard eating a grasshopper. Grasshoppers eat grass.

Explain how the lizard relies on photosynthesis to provide it with energy.

4 Explain one other reason (apart from food) why the lizard would not be able to survive if there were no plants on Earth.

Summary checklist

- ☐ I can write the word equation for photosynthesis.
- ☐ I can explain that photosynthesis is the way that plants make carbohydrates, using energy from light.
- ☐ I can explain why photosynthesis is important for most life on Earth.
- ☐ I can collect results carefully, and record them in a chart that I design myself.
- ☐ I can use my results to make a conclusion.

1.2 More about photosynthesis

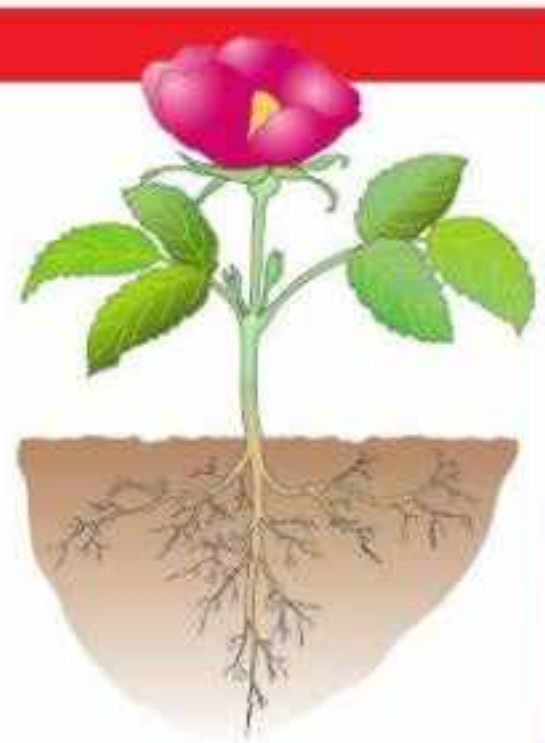
In this topic you will:

- find out where photosynthesis happens in plants
- learn why plants need magnesium and nitrate.

Getting started

Look at a complete plant – one that has stems, leaves, flowers and roots.

1. In which parts of the plant do you think photosynthesis happens?
2. Why do you think photosynthesis happens there?
3. Why do you think photosynthesis doesn't happen in other parts of the plant?



Key words

fertiliser

stomata (singular: stoma)

yield

Chloroplasts and chlorophyll

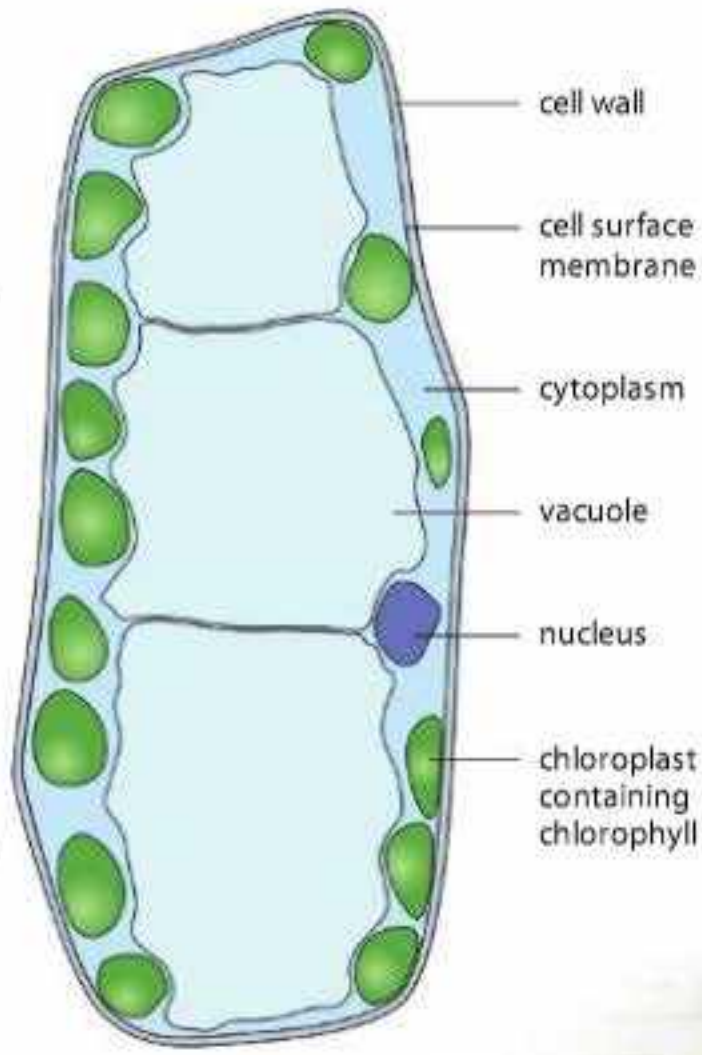
In the previous topic, you saw that chlorophyll is essential for photosynthesis. Chlorophyll captures energy from sunlight. The energy helps water and carbon dioxide to react together.

Chlorophyll is kept inside chloroplasts, inside plant cells.

This means that photosynthesis happens inside chloroplasts. Not all plant cells have chloroplasts, so not all of them can photosynthesise.

In most plants, the cells in the leaves have the most chloroplasts. Inside the cells in a leaf, carbon dioxide and water are made to react, to produce carbohydrates and oxygen. We can think of the field of lettuces in the photograph as a giant carbohydrate factory.

On warm, sunny days, plants can make more carbohydrate than they need to use immediately. So they store some it for use later on – perhaps at night, or at a time of year when there is less sunlight. Plants store carbohydrates as starch. They store the starch inside the chloroplasts in their cells. One way to check whether a leaf has been photosynthesising is to test it for starch.



Think like a scientist

Testing a leaf for starch

You are going to use a test you may already know – the iodine test for starch – to find out if a leaf has been photosynthesising.

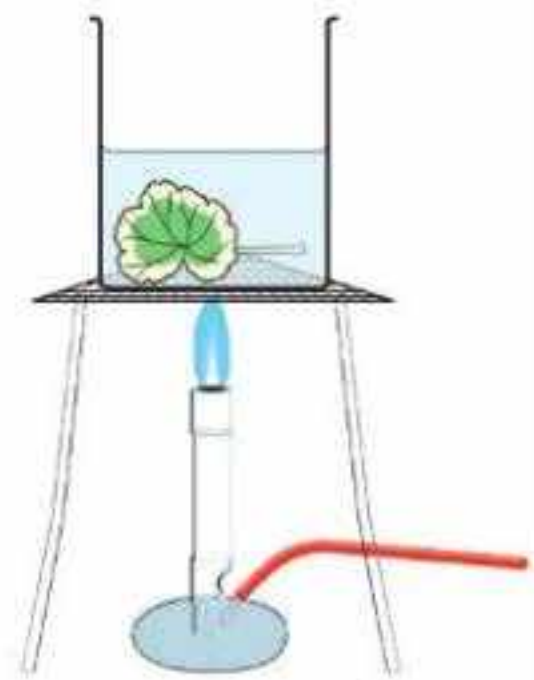
You will need:

- a healthy plant that has been kept where it gets plenty of sunlight (if possible, use a plant whose leaves have some green parts and some white parts), a burner (e.g. a Bunsen burner or a spirit burner), a tripod and gauze, a medium-sized beaker (e.g. 250 cm^3), a large test tube that can be safely heated, some ethanol, tongs or another way of handling a hot test tube, forceps (tweezers), some iodine solution with a dropper, a tile.

Safety

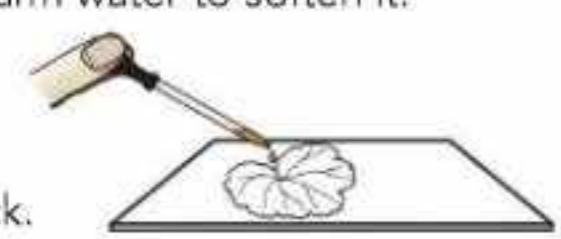
- You will be using hot water, so make sure you keep safe. It is best to stand up while you work, so that if something is spilt you can easily move away.
- Be very careful to turn off the flame before you use any ethanol. Ethanol is very flammable (it catches light easily).

Method



1. Put some water into your beaker. Stand the beaker on the tripod and gauze and heat it until it starts to boil.
2. Take a healthy leaf from the plant. Carefully drop it into the boiling water.
3. After about two minutes, turn off the burner. This is really important, because you will use ethanol in the next step.
4. Collect some ethanol in the large test tube.
5. Use forceps to remove the leaf from the hot water. Carefully drop the leaf into the ethanol in the test tube.
6. Stand the test tube in the hot water. This will safely heat the ethanol. Watch what happens. You should see the green colour dissolve out of the leaf into the ethanol.

7. When you think most of the green colour has come out of the leaf, use forceps to gently take the leaf out of the tube. Be very careful – the leaf will be brittle. Dip it into the warm water to soften it.
8. Spread the leaf out onto a tile. Use the dropper to spread iodine solution over the leaf. If the leaf contains any starch, it will go blue-black.



Continued

Questions

1 Iodine solution cannot get through cell membranes.
Boiling the leaf breaks the cell membranes apart.

   a In which part of a cell is starch stored?

   b Explain why it was important to boil the leaf before the starch test could work.

2 Suggest why it is a good idea to remove the green colour from the leaf before you add iodine solution to it.

3 Did the leaf contain starch? If so, explain where the starch came from.

4 If your leaf had some green parts and some white parts, which parts contained starch? Can you explain why?

Inside a leaf

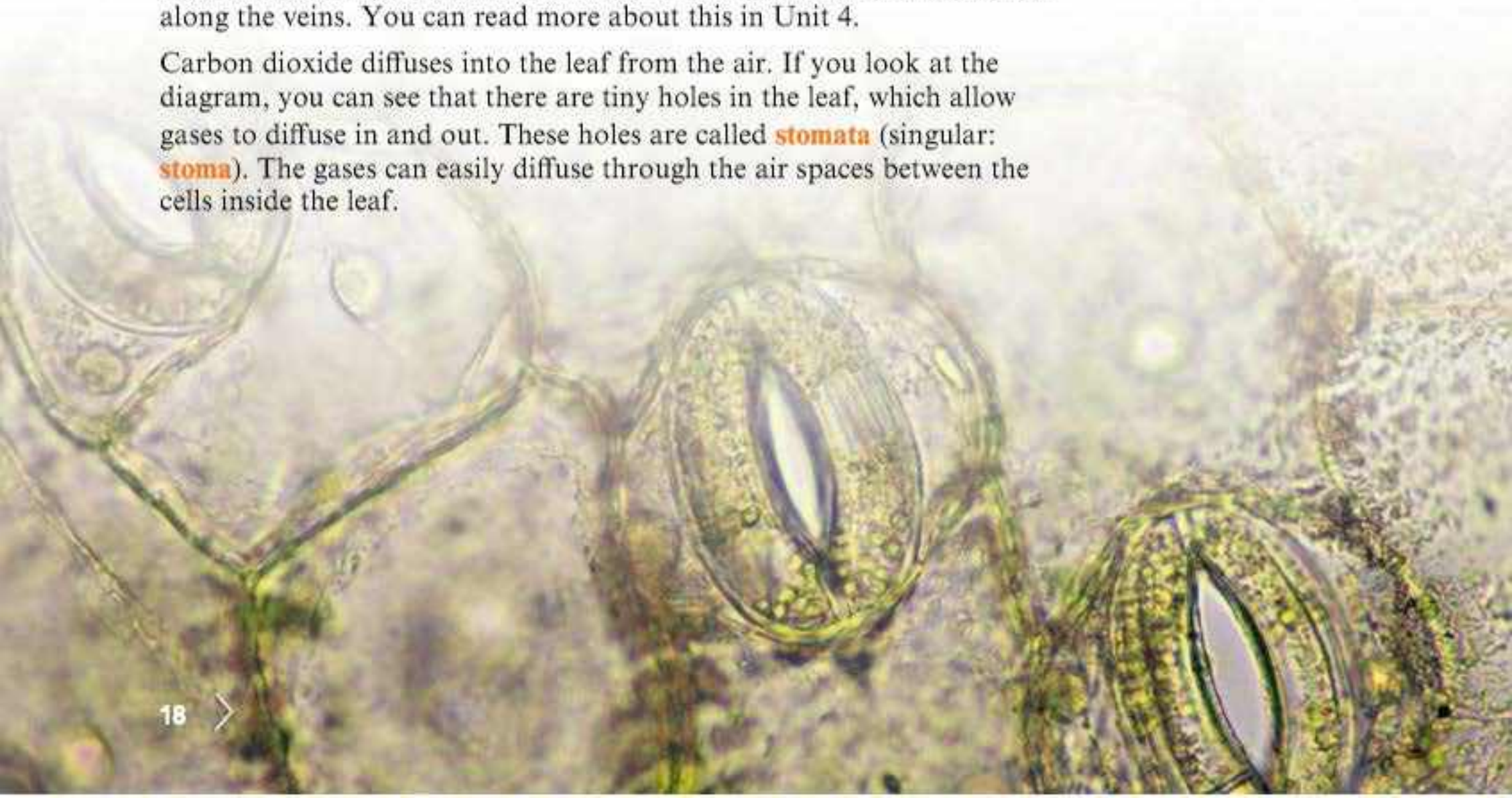
Photosynthesis happens inside chloroplasts, which are inside some of the cells in a leaf.

The diagram opposite shows a magnified view of the inside of a leaf.

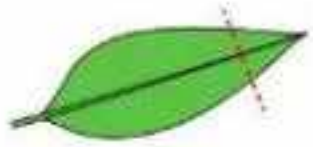
On the diagram, you can see that chloroplasts are mostly inside the cells in the middle layers of the leaf. Leaves are very thin, so it is easy for sunlight to reach these cells.

Chloroplasts also need plenty of water and carbon dioxide, because these are used in photosynthesis. Water is brought to the cells in the leaf along the veins. You can read more about this in Unit 4.

Carbon dioxide diffuses into the leaf from the air. If you look at the diagram, you can see that there are tiny holes in the leaf, which allow gases to diffuse in and out. These holes are called **stomata** (singular: **stoma**). The gases can easily diffuse through the air spaces between the cells inside the leaf.



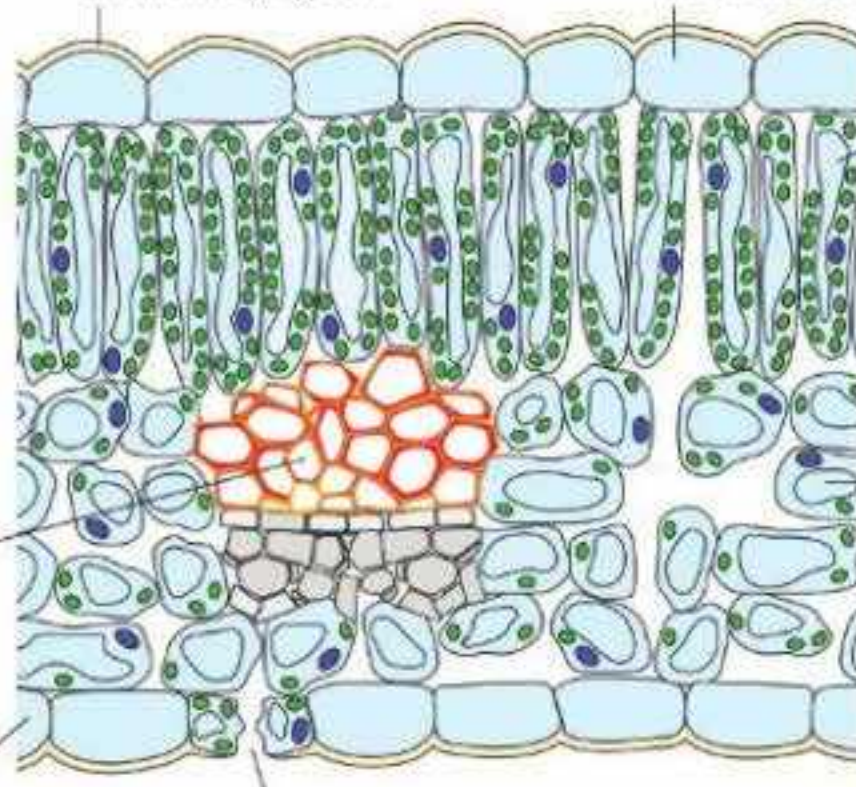
The diagram on the right shows what a leaf looks like if you cut it across, and then look at the cut edge.



Leaves are so thin that it is difficult to imagine they contain several layers of cells. It is the cells in the middle of the leaf that carry out photosynthesis.

A **waxy layer** on the leaf surface stops the leaf cells from drying out.

The **upper epidermis** protects the cells inside the leaf.



The **palisade layer** contains cells that do most of the photosynthesis.

The **spongy layer** has lots of air spaces. The cells in the spongy layer do a small amount of photosynthesis.

A **vein** carries water to the cells in the leaf.

The **lower epidermis** protects the cells inside the leaf.

A **stoma** (plural: stomata) is a tiny hole in the lower epidermis. These holes let carbon dioxide from the air get into the leaf.

Activity 1.2.1

Which surface of a leaf has most stomata?

Work with a partner for this activity.

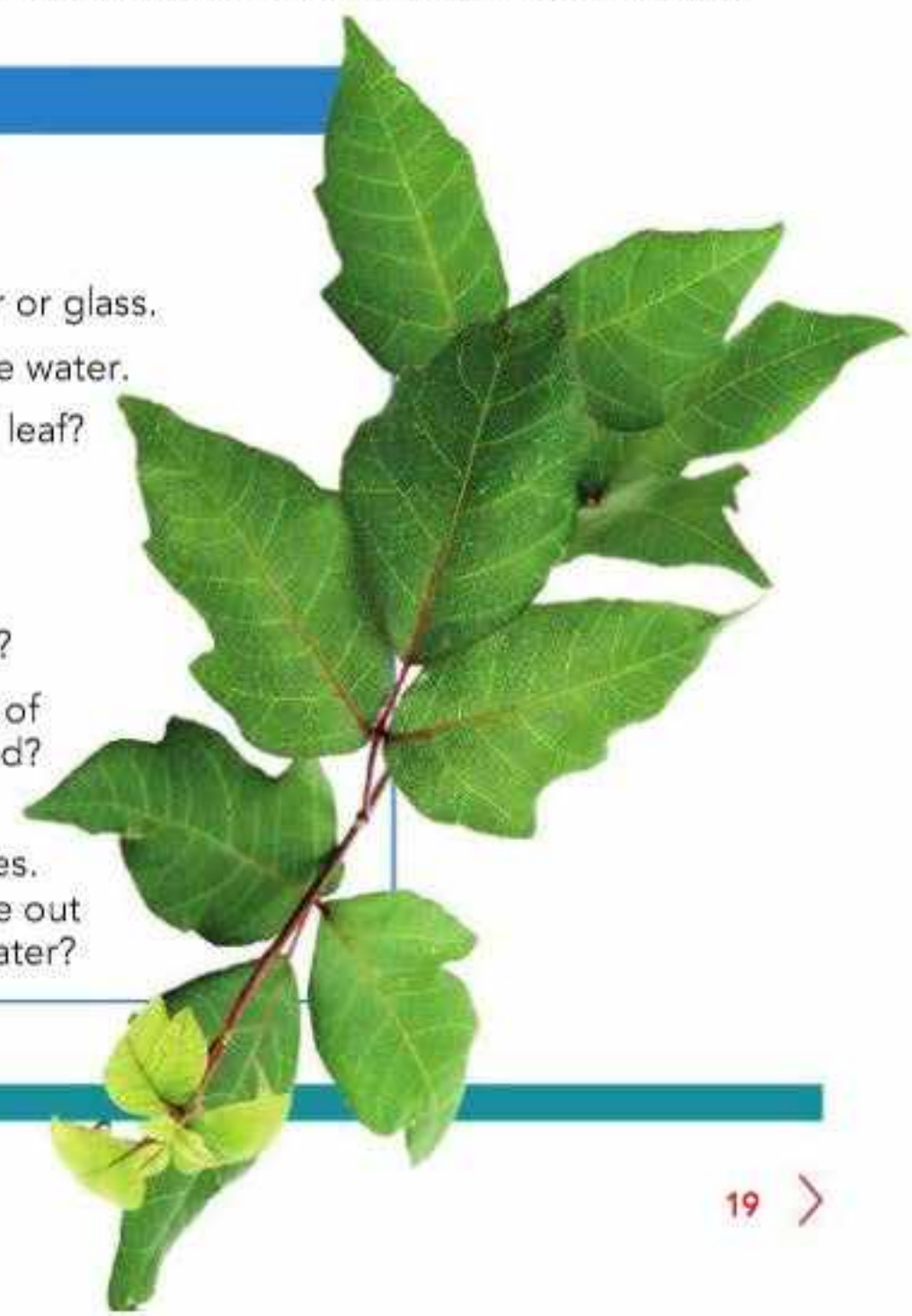
Put some warm (not hot) water into a beaker or glass.

Take a fresh leaf, and push it down under the water.

Can you see any bubbles coming out of the leaf? Which surface of the leaf do most of the bubbles come from?

Discuss these questions with your partner.

- What do you think the bubbles contain?
- If most bubbles came from one surface of the leaf, why do you think this happened?
- Think about what you know about the effect of increased temperature on gases. Can you suggest why the bubbles came out of the leaf when you put it into warm water?



Questions

1 The cells inside a plant leaf use up carbon dioxide when they photosynthesise. Use what you have learnt about diffusion to explain how carbon dioxide diffuses into the leaf.

2 The cells inside a plant leaf produce oxygen when they photosynthesise. Suggest what happens to this oxygen.

Minerals and plant growth

The farmer in the picture is adding **fertiliser** to a field of wheat.

Farmers add fertiliser to their fields because it makes the crops grow larger and produce a higher **yield**. Yield is the quantity of crop that the farmer harvests.

Fertilisers contain minerals. Like the minerals that we need in our diet, plants need only quite small quantities of minerals. They get these minerals from the soil, through their roots. But sometimes the soil does not contain enough of certain minerals. This stops the plants growing to their full potential.

Two important minerals for plants are magnesium and nitrate.

Magnesium is needed to make the green pigment, chlorophyll. If a plant does not have enough magnesium, its leaves look yellow instead of green. It cannot grow well, because it does not have much chlorophyll to absorb energy from sunlight, and so it cannot photosynthesise as much as it should.

Farmers can test the soil in their fields to find out exactly which minerals are lacking in each part of the field. This tells the farmer where they need to add fertiliser, and where it is not needed.

Farmers who can afford the latest technology can use global positioning satellites (GPS) with their machinery.

The screen in the tractor cab shows the farmer exactly where he is in the field, as well as the results of the soil tests. The farmer can easily control how much fertiliser is added in each part of the field.

Nitrate contains nitrogen atoms. These are needed so that the plant can convert carbohydrates to proteins. Proteins are essential for making new cells, so that the plant can grow well. Without enough nitrogen, leaves die and the plant stays small, like these maize (corn) plants. Nitrogen is also needed to make chlorophyll.

Questions

3 All organisms need protein for growth. Compare the way in which plants obtain protein with the way that you and other animals obtain protein.

4 It can be difficult, even for an expert, to tell the difference between a plant that is short of magnesium, and one that is short of protein. Suggest why.

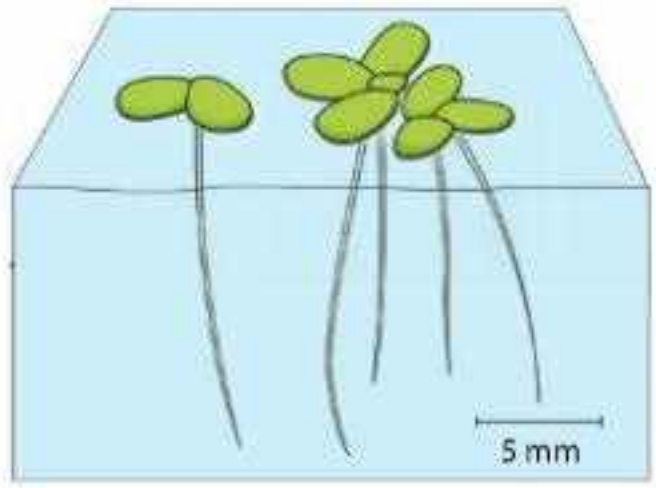
Think like a scientist

Planning an investigation into the effect of fertilisers on plant growth

You are going to plan an experiment to find out how fertiliser affects the rate of growth of duckweed.

You may be able to do your experiment after you have planned it.

Duckweed is a tiny plant. There are lots of different species of duckweed, and they grow in most countries in the world. Some kinds of duckweed have just a single leaf, while others may have little groups of leaves. The leaves float on the water surface. All duckweed plants have roots that dangle down into the water.



- You could investigate effects of different kinds of fertiliser, or you could use just one kind and try different quantities of it.
- You could grow your duckweed in small containers – for example, Petri dishes.
- You could measure how much the duckweed grows by counting the number of leaves.

Part 1: Planning the investigation

1. Decide on a hypothesis that you will test.
2. How will you change your independent variable?
   How many different values will you use?
3. How will you measure your dependent variable?
   How many times will you measure it?
4. Which variables will you try to keep the same?
5. What equipment will you need?
6. What risks might there be in your experiment? How will you control the risks?
7. Predict the results you would expect to find and explain why you think this is what will happen.

Continued

Part 2: Carrying out the investigation

Collect the equipment that you chose in your plan.

Make sure you have your step-by-step method to follow.

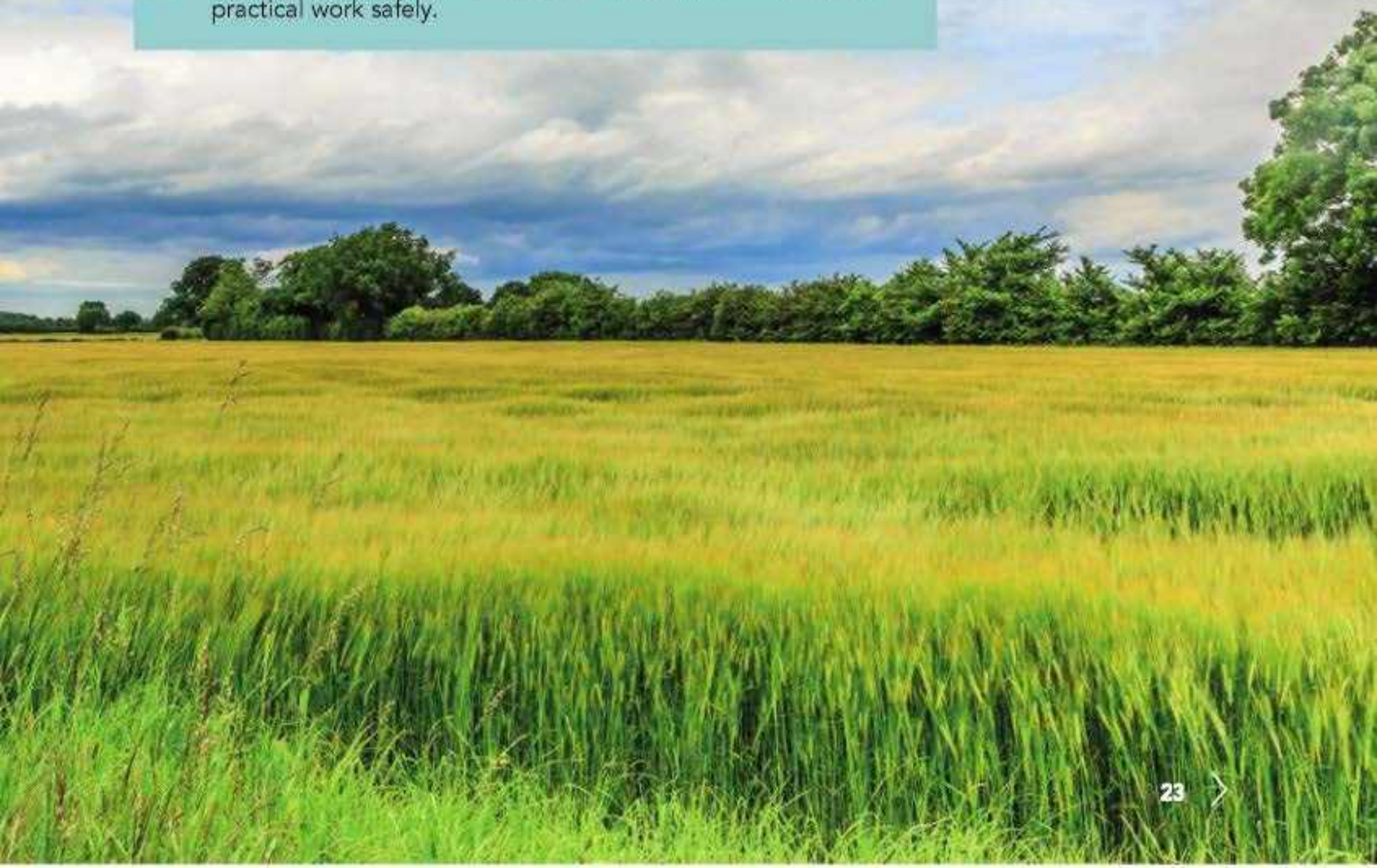
Questions

1 Scientists almost always find that they need to change something – even if it is only very small – when they carry out the experiment they have planned. Did you change anything in your plan? If so, explain what you changed, and why.

2 Write down a conclusion that you can make from your results. Do they support your hypothesis?

Summary checklist

- ☐ I can explain that photosynthesis happens in chloroplasts, because this is where chlorophyll is found.
- ☐ I can explain why plants need magnesium and nitrate.
- ☐ I can suggest a hypothesis, and plan an experiment to test it.
- ☐ I can make a risk assessment of my experiment, and carry out practical work safely.



1.3 The carbon cycle

In this topic you will:

- find out how carbon atoms move between the air, living organisms and fossil fuels
- bring together what you know about respiration and photosynthesis, to think about how they affect the amount of carbon dioxide in the atmosphere.

Getting started

Work with a partner.

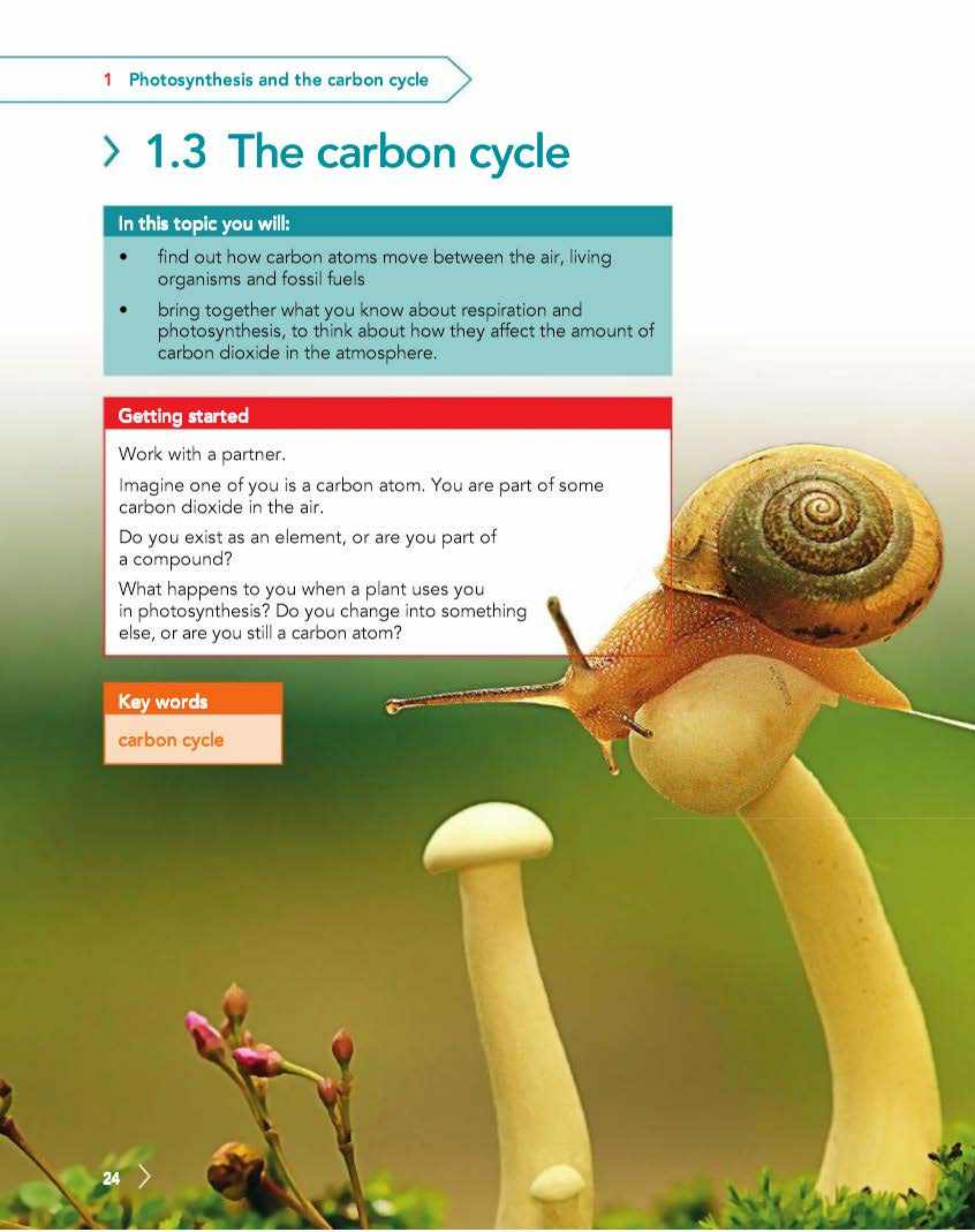
Imagine one of you is a carbon atom. You are part of some carbon dioxide in the air.

Do you exist as an element, or are you part of a compound?

What happens to you when a plant uses you in photosynthesis? Do you change into something else, or are you still a carbon atom?

Key words

carbon cycle



Carbon and living organisms

Carbon is an element. The symbol for carbon is C.

Carbon is a non-metal. It occurs naturally in different forms. (You will find out more about carbon in Topic 2.4.)

Diamonds are made of carbon.

The 'lead' in a pencil is not lead at all - it is another form of the element carbon, called graphite.

Living organisms do not need diamonds or pencil leads, but they do need carbon. Organisms cannot use carbon in the form of an element. They can only use it when it is part of a compound.

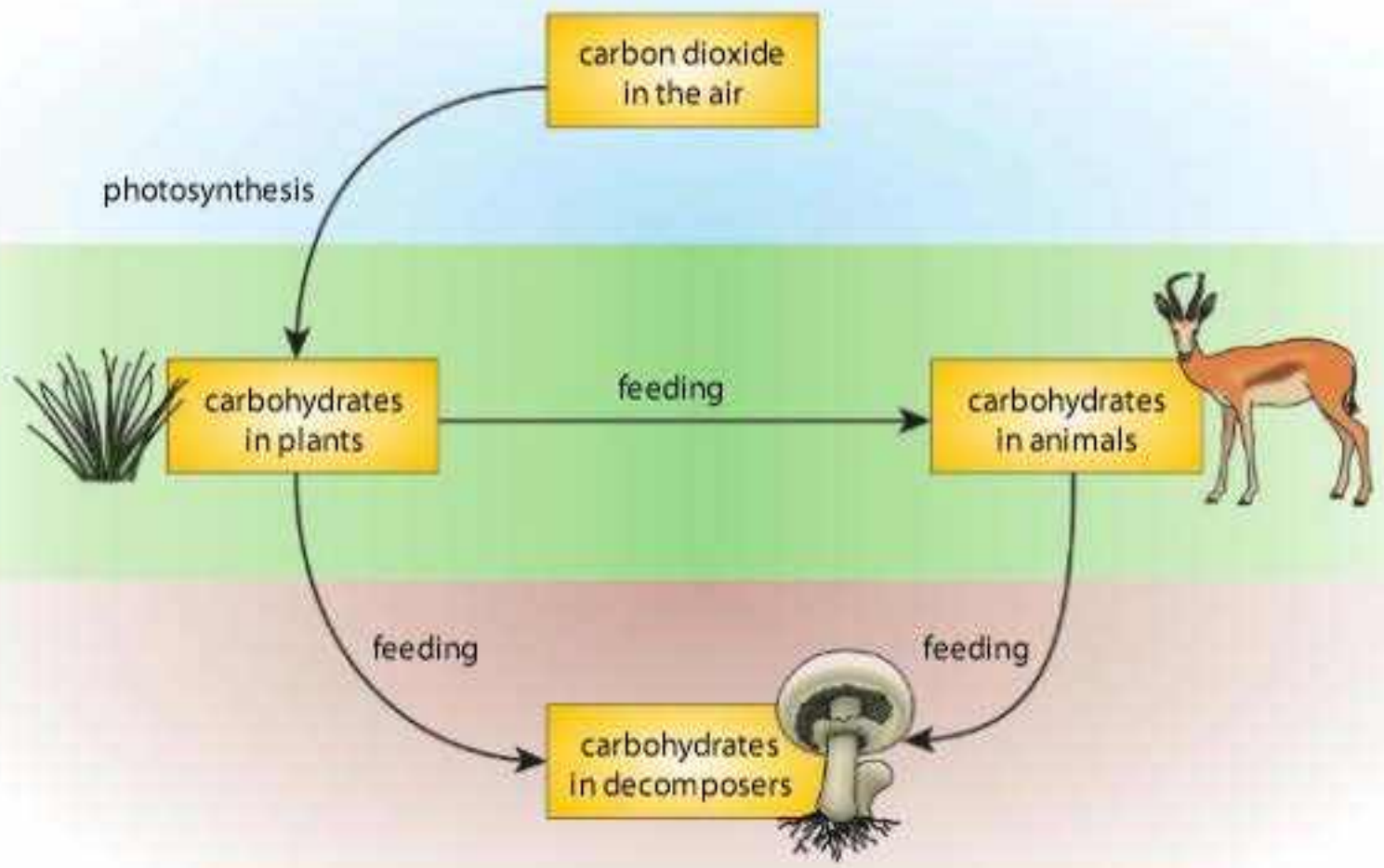
Carbon is part of many different compounds that make up cells. Carbohydrates, proteins and fats are all compounds that contain carbon.

We rely on plants to make these substances. Plants take carbon dioxide from the air and use it in photosynthesis to make carbohydrates. Carbon dioxide is a compound that contains carbon atoms combined with oxygen atoms. (You will find out more about this in Unit 2.) The carbohydrates in plants contain carbon atoms that were originally part of the air.

Plants use the carbohydrates to make proteins and fats. All of these nutrients are compounds that contain carbon atoms.

We are animals, so we get all of these carbon-containing nutrients when we eat plants or other animals. Decomposers get their carbon when they break down waste products from plants and animals.

We can show how carbon gets into the bodies of animals and decomposers using a flow diagram.



Questions

1 a Draw a food chain with one plant and three animals in it.

b The arrows in your food chain represent energy passing from one organism to the next. Do they also show how carbon atoms pass from one organism to the next? Explain your answer.

2 The human body contains atoms of many different elements. Carbon is one of the most common elements. Name three different compounds in your body that contain carbon atoms.

Returning carbon dioxide to the air

A lot of the carbon dioxide that plants take from the air eventually goes back into the air again. This happens when plants and animal respire. You may remember the respiration equation:

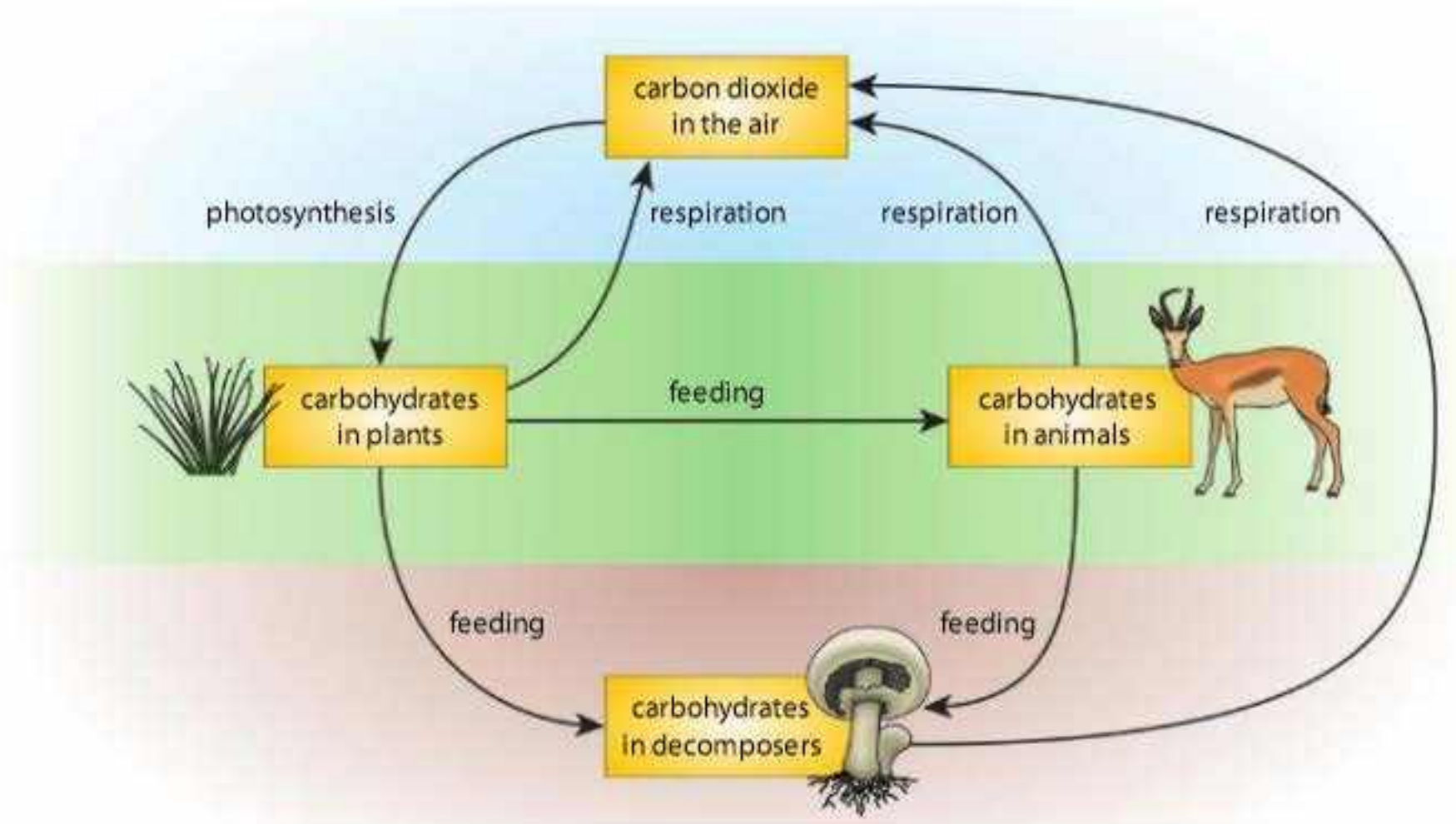
glucose + oxygen → carbon dioxide + water

When you breathe out, carbon dioxide that was produced in your cells, by respiration, goes into the air around you.

All organisms respire. Plants respire all the time. At night, when they cannot photosynthesise, they give out carbon dioxide, just as we do.

Decomposers respire, too. As they break down waste products from plants and animals, they release carbon dioxide into the air.

We can add this information to the flow diagram.



Think like a scientist

How do plants and animals affect carbon dioxide concentration?

In this investigation, you are going to think about two processes that you have learnt about – respiration and photosynthesis – and how they affect the concentration of carbon dioxide.

You will need:

- six clean test tubes, and a beaker or rack to stand them in, rubber bungs to fit the test tubes, small pieces of perforated metal (e.g. zinc gauze) to make platforms inside the tubes (see the diagram), some small pieces of water plant, some small animals such as maggots (fly larvae) or woodlice, blunt forceps (tweezers) for handling the plants and small animals, some black paper and sticky tape, some hydrogencarbonate indicator solution.

Note

The animals did not volunteer to be part of your experiment. Treat them with care. After the experiment is finished, put the animals back into their container, or a safe place outside.

Hydrogencarbonate indicator solution is a liquid that changes colour depending on the concentration of carbon dioxide. The colours are:

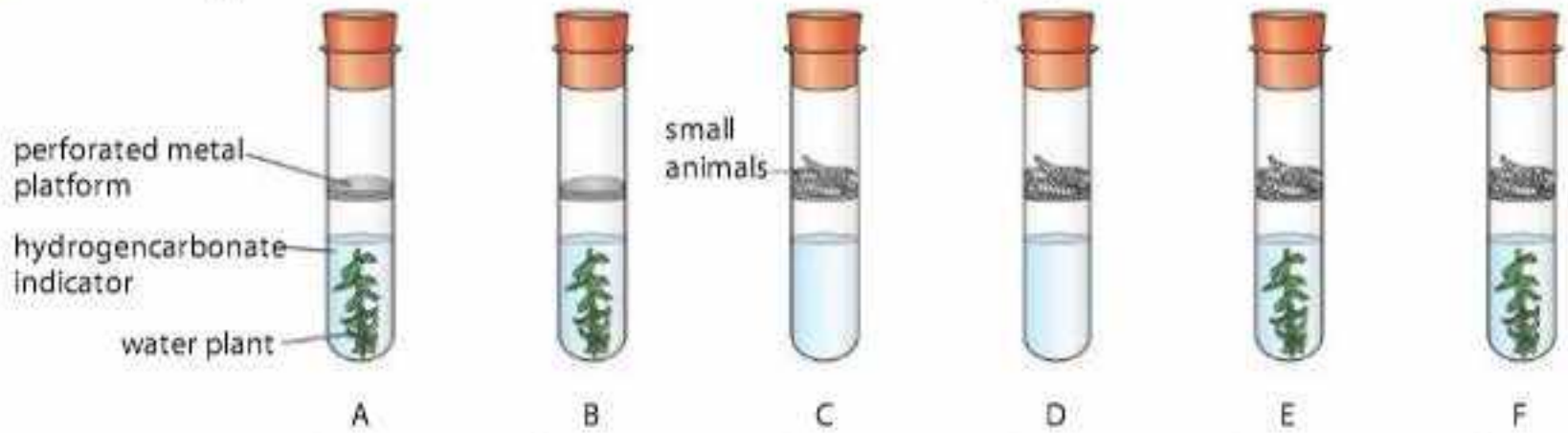
- purple when there is no carbon dioxide
- red when there is a low concentration of carbon dioxide
- yellow when there is a higher concentration of carbon dioxide

Method

1. Label the tubes A, B, C, D, E and F.
2. Use the pieces of perforated metal to make small platforms that can fit inside the tubes. The platforms will stop the animals from falling into the liquid.
3. Take the platforms out of the tubes. Pour about 3 cm depth of hydrogencarbonate indicator into each tube.
4. Put a piece of water plant into the indicator in tubes A, B, E and F.
5. Put the platforms back into the tubes. Try to make them level, with each one at approximately the same position in each tube.

Continued

6 Carefully place animals on the platforms in tubes C, D, E and F and fit the bungs.



Tube A: water plant **Tube B:** water plant **Tube C:** maggots **Tube D:** maggots **Tube E:** water plant and maggots **Tube F:** water plant and maggots

7 Record the colour of the hydrogencarbonate indicator in each tube.

8 Now wrap black paper around tubes A, C and E, so that no light can get in.

9 Leave all the tubes in the same place for at least 30 minutes. (It is even better if you can set your experiment up in the morning, and then check it in the afternoon.) While you are waiting:

- write down your prediction of the results you expect to find.
- draw a results chart, ready to fill in.

10 Return to your tubes and take off the black paper. Record the colour of the indicator in each tube.

Questions

1 Use the colours of the indicator to record how much carbon dioxide is present in each of the six tubes.

2 All organisms respire all the time. In which tubes were organisms respiring?

3 Plants also photosynthesise when they have light. In which tubes were plants photosynthesising?

4 In the light, plants photosynthesise faster than they respire.

a In which tubes would you expect carbon dioxide to be used?

b In which tubes would you expect carbon dioxide to be given out?

5 Use your answers to the questions above to explain your results. (If your results do not match what you expect, try to suggest why they do not.)

6 Suggest why you were asked to put a little platform into each tube, even if there were no animals to put onto it.

Continued

Self-assessment

The instructions for this experiment are quite long.

How carefully did you follow the instructions?

How fully do you feel you understand why the indicator changed to different colours in the different tubes?

Fossil fuels and combustion

There is one more very important set of processes to add to the diagram showing how carbon moves from the air, through organisms, and back to the air again.

When organisms die, they are not always broken down quickly by decomposers. Sometimes, their bodies fall into places where there is no oxygen, such as deep in the ocean. In these places, the decomposers cannot respire, because there is not enough oxygen for them. Instead, the organisms' bodies get gradually buried, as more and more sediment builds up on top of them. High pressure and heat change their remains into fossil fuels, including coal, oil or natural gas.

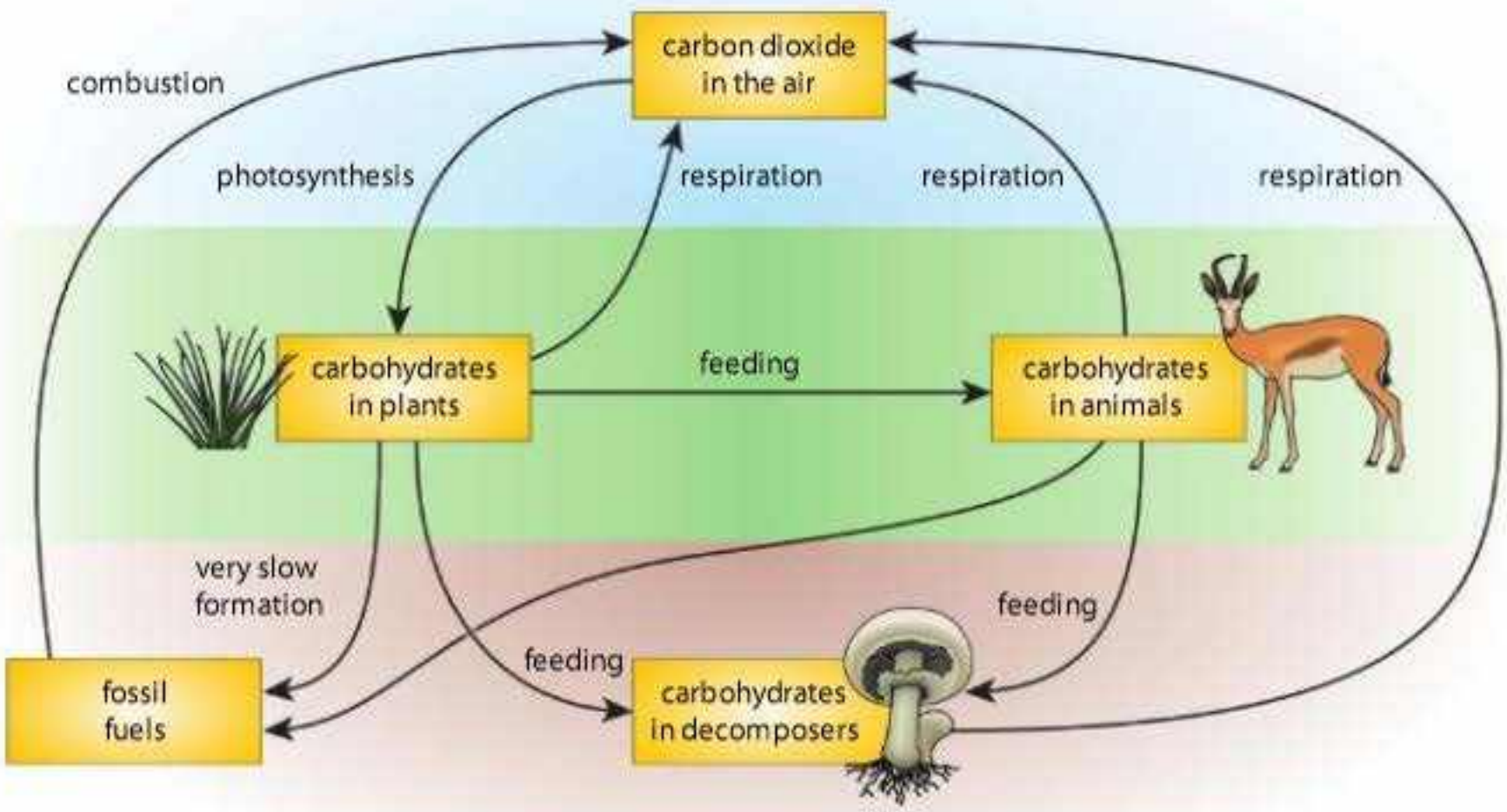
Changing dead organisms to fossil fuels takes a very long time. Most of the fossil fuels that we use on Earth today were formed hundreds of millions of years ago.

Oil and natural gas formed when tiny marine organisms died and fell to the sea bed. This oil rig, in the sea off West Africa, has pipes that go deep into the sea bed where deposits of liquid oil are present. The oil is brought up through the pipes, and taken ashore to be used as fuel.

Coal was formed from the remains of plants that grew in huge swamps. Their remains were buried over millions of years, slowly turning into coal. Coal is dug out of the ground and then used as a fuel for cooking or heating homes, but most of it is used in power stations to generate electricity.

Fossil fuels contain carbon. This came from the carbohydrates, fats and proteins in the dead organisms. When we burn a fossil fuel, the carbon in it combines with oxygen from the air and forms carbon dioxide. This is called combustion.

We can add the formation and combustion of fossil fuels to the flow diagram. The completed diagram is called the **carbon cycle**.



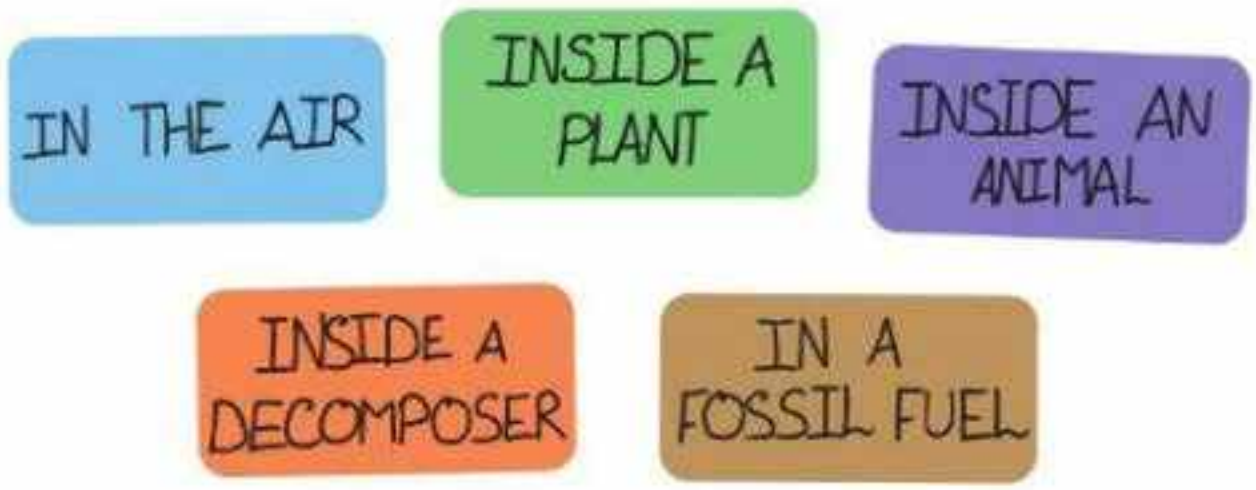
It is important to remember that fossil fuels are not the same as fossils. A fossil is the remains of an organism, or traces of it (such as its burrows) that have turned to rock. We can still see the shape of the organism in a fossil. But fossil fuels do not look like organisms at all, and oil and gas are not even rocks. Fossil fuels are given this name because – like fossils – they were formed a very long time ago and buried underground.

Activity 1.3.1

Modelling the carbon cycle

In this activity, you will play the part of a carbon atom in the carbon cycle.

First, make some big labels and stick them in five different places in the room. You only need one set of labels for the whole class.



Now write the following numbers and what they mean on the board, where everyone will be able to see them from every part of the room:

1 photosynthesis
2 respiration
3 feeding
4 formation of fossil fuels
5 decomposition
6 combustion.

Divide the class except one person (who could be your teacher) between the five places. Each person is a carbon atom.

The one person who is not a carbon atom now holds a die. (A die is a cube with the numbers 1 to 6 on it. The plural is dice.) They roll it, and call out the number. All the carbon atoms who are affected by the process linked to this number, move to

Continued

the correct place. For example, if the number is 1, then all the carbon atoms in the air move into a green plant, as a result of photosynthesis. If the number is 3, then all the carbon atoms in a green plant move into an animal.

You can keep a record of how many carbon atoms are in each place after each roll of the die.

Questions

1 In this model, all the carbon atoms in one place move to another place at the same time. Is that what happens in the real carbon cycle? If not, how could you modify this model to make it a better representation? If you can, try out your suggestion on your model.

2 Predict what would happen to the carbon atoms if one of the processes stopped completely – for example, combustion. If you can, try it out on your model.

The carbon cycle is a complicated diagram. What can you do to help you to remember it?

Questions

3 If you drew a carbon cycle to show what was happening before humans were present on Earth, how would it differ from the carbon cycle diagram above?

4 Explain why fossil fuels are non-renewable resources.

Summary checklist

- ☐ I can describe the carbon cycle, including photosynthesis, respiration, feeding, decomposition and combustion.
- ☐ I can explain how these processes affect the concentration of carbon dioxide in the air.

1.4 Climate change

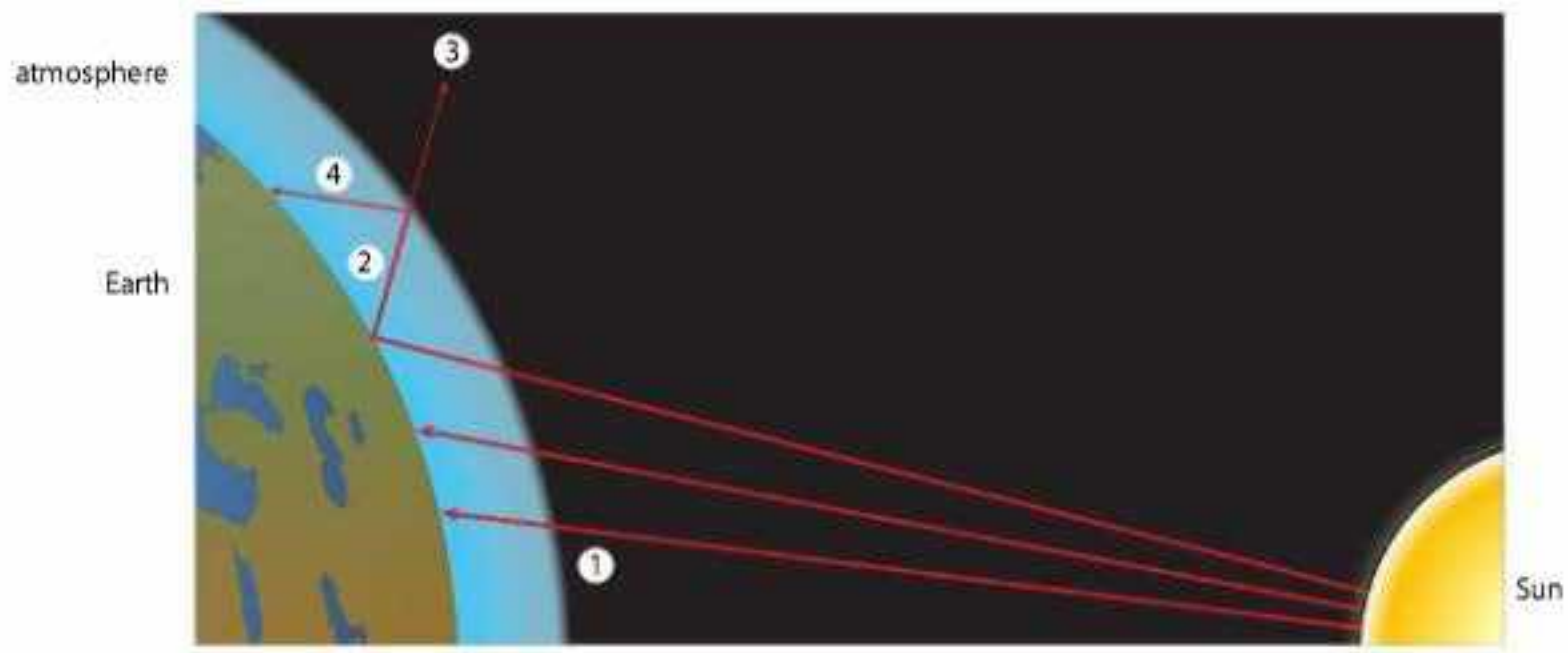
In this topic you will:

- find out how the Earth's climate has changed in the past
- learn what happened when an asteroid collided with Earth
- consider how the increase in carbon dioxide in the atmosphere affects climate today and also in the future, and describe some of the predicted impacts of climate change.

Getting started

In Stage 8, you learnt how carbon dioxide concentration in the atmosphere has been steadily increasing. Carbon dioxide is a greenhouse gas, which traps heat energy in the atmosphere and keeps the Earth warm.

Look at this diagram. It is similar, but not identical, to one that you may remember.



With a partner, match each of these statements to one of the numbers on the diagram.

A Some of the reflected energy passes back out through the atmosphere and is lost to space.

B Energy from the Sun passes through the atmosphere and warms the surface of the ground.

C Some of the reflected energy is blocked by carbon dioxide in the atmosphere, so it stays close to the Earth.

D Some of the energy that reaches the ground is reflected.

Key words

slush mass extinction meteorites meteoroids meteors

Greenhouse gases

Carbon dioxide and methane are 'greenhouse gases'. In Stage 8, you learnt how carbon dioxide helps to keep the Earth warm. Without any carbon dioxide in the atmosphere at all, the Earth would be a frozen place, unable to support life. But at the moment, we have too much carbon dioxide in the atmosphere.

Look back at the carbon cycle diagram in Topic 1.3. You can see that some carbon from the atmosphere ends up in fossil fuels. It takes a long time to form fossil fuels, and they can then stay buried in the ground for millions of years. But if we extract them and burn them, we release the carbon in them back into the air, in the form of carbon dioxide.

Carbon dioxide levels in the atmosphere are increasing. This is affecting the climate on Earth.

Climate change in the past

Climate is the long-term pattern of temperatures, wind and rainfall on Earth. The Earth's climate has been very different in the past compared to the climate today. Here are some examples of changes.

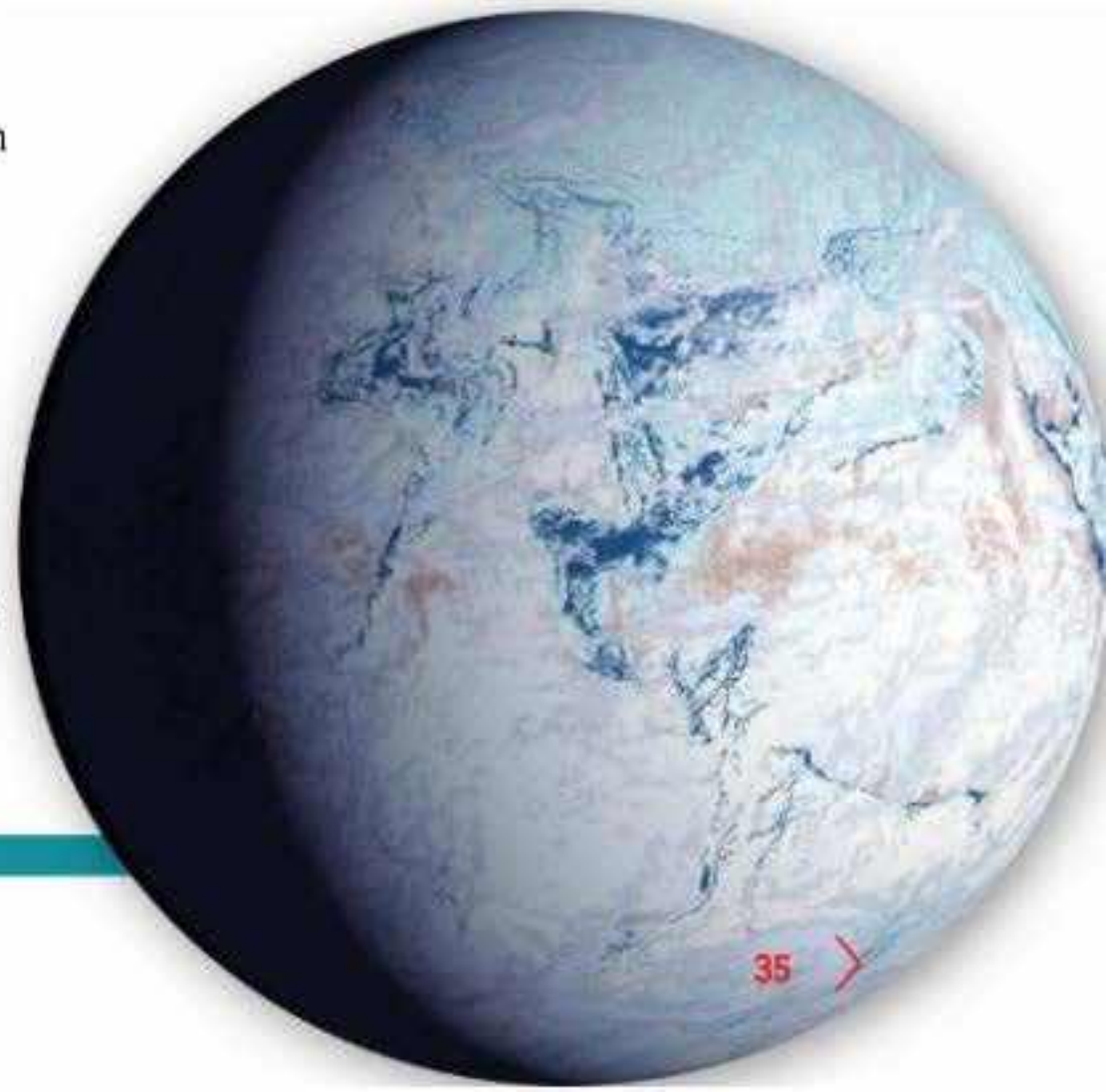
Ice ages

About 2 billion years ago, the Earth experienced the first ice age that we know about. Since then, the Earth has cycled between relatively warm periods and relatively cold ones. In the warm periods, there was no ice at all, even at the poles. In the colder periods, called ice ages, there was ice at the poles.

Snowball Earth

On at least one occasion, perhaps about 650 million years ago, the whole Earth was covered with ice and snow. Scientists call this 'snowball Earth', or sometimes 'slushball Earth', because they are not sure whether everything was completely frozen. (**Slush** is melting ice.) Scientists still do not completely understand what caused this to happen.

This is what the Earth may have looked like, 650 million years ago. At that time, the continents were not in the same positions as now.



Asteroids colliding with each other

Around 470 million years ago, scientists think that two asteroids collided with one another when they were in space, somewhere in-between Earth and Mars.

The collision produced huge quantities of dust. The dust reduced the amount of light and heat from the Sun reaching the Earth's surface. This triggered an ice age. The Earth became much colder – the ice caps spread much further from the poles and sea level fell.

Asteroids colliding with Earth

Around 67 million years ago, an asteroid collided with Earth. Researchers have identified an area on the coast of Mexico where the asteroid impact took place. There was huge devastation close to where the asteroid fell. It would have been like a massive bomb exploding, with shock waves and very high temperatures spreading out from the crater.

But the collision affected the whole planet, not just the surrounding area, because it threw huge quantities of rock and dust into the air. It would also have created a massive tsunami (a huge sea wave), which could have spread across all of the Earth's oceans.

The dust in the air meant that less light reached the Earth's surface. Plants could not photosynthesise, so animals had less food. As well as the disruption to food chains, the Earth became much colder, because less heat from the Sun could reach the surface.

Most scientists think that these changes in climate, caused by the asteroid impact, explain why dinosaurs became extinct around this time. Not only the dinosaurs, but also many other species on Earth, were destroyed as a result of the climate change following the asteroid collision. The asteroid caused a **mass extinction**. Up to three-quarters (75%) of all the species on Earth that were alive at that time are thought to have become extinct because of the asteroid collision.

There are about 175 known asteroid impact craters around the world. The crater shown in the picture is in the USA. The crater is more than 1 km wide and 170 m deep. It is estimated that the asteroid collision that formed this crater happened 50 000 years ago.

Could other objects collide with Earth?

Objects in space that are smaller than an asteroid are called **meteoroids**. When meteoroids enter Earth's atmosphere they are called **meteors**. Some people call meteors shooting stars because they appear like stars moving very fast across the sky. They usually present little risk because they burn in the atmosphere due to heat from friction. Some large ones can create shockwaves; in 2013 a meteor exploded over Russia and shattered windows. The parts of meteoroids that do collide with Earth are called **meteorites**. Around 500 of these reach Earth's surface each year.

If an object is large enough, it can cause local damage, or even damage that affects the whole planet.

In 1998, scientists started making detailed observations of objects that could possibly cause damage to Earth. When assessing the possible risk to Earth, scientists look at:

- the mass or diameter of the asteroid
- the closest possible approach to Earth.

An asteroid passing further from Earth may be a greater risk than one passing closer if its mass is greater.

The picture shows an asteroid, called 2006 DP14, that passed 2 400 000 km from Earth in 2014. This asteroid measures 200 m × 400 m so is considered a potential risk. An asteroid such as 2006 DP14 colliding with Earth would cause an explosion equivalent to about 20 million tonnes of explosives.

Questions

1 You learnt about asteroids in Stage 8. Describe what an asteroid is, and where asteroids are found.

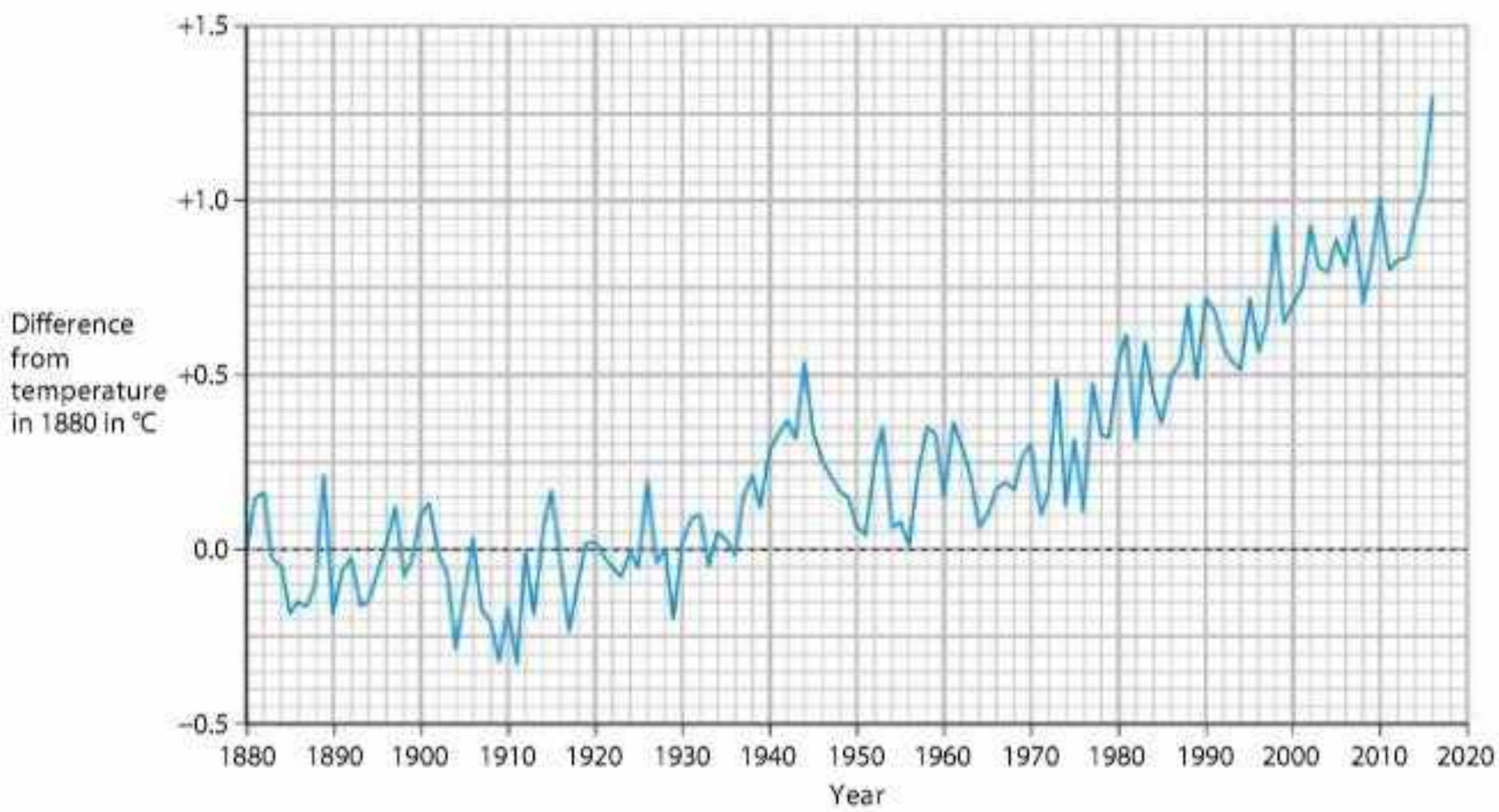
2 Outline **three** different ways in which the asteroid collision 67 million years ago would have made it difficult for plants and animals to survive.

Climate change today and in the future

For the last 2000 years or so, our climate has been fairly stable. People living in different places have become used to having more rain at some times of year than at other times, or temperatures that change in a predictable way during one year. Knowing this helps people to choose the best crops to grow, and to know when they should sow seed and collect the harvest.

Now, however, the mean temperatures on Earth are increasing. This is caused by an increase in carbon dioxide concentration in the atmosphere. Remember that carbon dioxide is a greenhouse gas, which traps heat energy close to the Earth's surface. When carbon dioxide concentrations increase, more heat is trapped.

The graph shows how the Earth's mean temperature changed between 1880 and 2016. Notice that the y-axis on the graph does not show the actual temperature – it shows how much it differs from the temperature in 1880.



Questions

3 Look at the graph. How much higher was the mean temperature in 2016 than in 1880?

4 Describe the trend shown by the graph between:
- 1880 and 1910 and
- 1910 and 2016.

Impacts of climate change

More extreme weather events

We are already feeling the effects of this increase in temperature. The higher temperatures mean that there is more energy in the atmosphere. This increases the chance of extreme weather events, such as hurricanes and typhoons. Many scientists think that we are already seeing an increase in the number of storms, and in their severity. It is difficult to be certain, because there has always been a lot of variation each year in the number of big storms.

Tropical cyclone Idai hit the east coast of southern Africa in 2019. It was one of the worst storms ever to affect Africa and killed more than 1300 people. Severe flooding destroyed homes and fields, damaging people's livelihoods. Was this a result of climate change? We cannot say, because storms like this can happen anyway. However, there seem to be more of them now, and they are more violent.

Less predictable rainfall

The changing climate is also making it more difficult for people in some parts of the world to grow crops. Rains may come late, or might not come at all. Or rain may fall when it doesn't normally fall – or fall much more heavily, causing flooding.

Monsoon rains are usually welcomed, but not when they are so heavy that they cause severe flooding. In 2019, the monsoon rains in Pakistan, India, Nepal and Bangladesh came later and were heavier than usual. Millions of people in these countries were affected by floods.

When rains fail, people may lose their harvests. Long droughts also increase the risk of wildfires. All of these changes affect not only people, but also plants and animals.

This wildfire in Australia followed a long period of drought.

Rising sea levels

The increase in the Earth's mean temperature affects sea level. Water expands as it is heated, so if the sea temperature increases, sea level rises. Melting ice caps and glaciers add extra water to the oceans.

This glacier is getting smaller (retreating) as temperatures increase. The ice used to reach much higher up the sides of the valley.

Sea level has been rising at a rate of about 3 mm per year. Scientists estimate that more than 600 million people are at risk from flooding caused by sea-level rise by the end of this century. Many megacities are built on the coast – such as Shanghai, Mumbai and Los Angeles – and these are especially vulnerable to sea-level rise.

Questions

5 Calculate by how much sea level is predicted to rise by the end of this century.

6 Explain why sea level is predicted to rise.

Think like a scientist

How do rising temperatures affect sea level?

In this experiment, you will investigate how rising temperature can affect sea level.

Experiment 1

You will need:

- two large measuring cylinders, a funnel big enough to hold 10 ice cubes, 20 ice cubes all the same size.

Method

1. Put 10 ice cubes into one of the measuring cylinders. Add water so that the cylinder is about three quarters full. Record this level.
2. Add water to the second measuring cylinder to exactly the same level as in the first one.
3. Place the funnel in the second measuring cylinder. Put 10 ice cubes into the funnel.
4. Leave both cylinders at room temperature, until the ice melts.
5. When the ice has melted, record the new levels in both measuring cylinders.

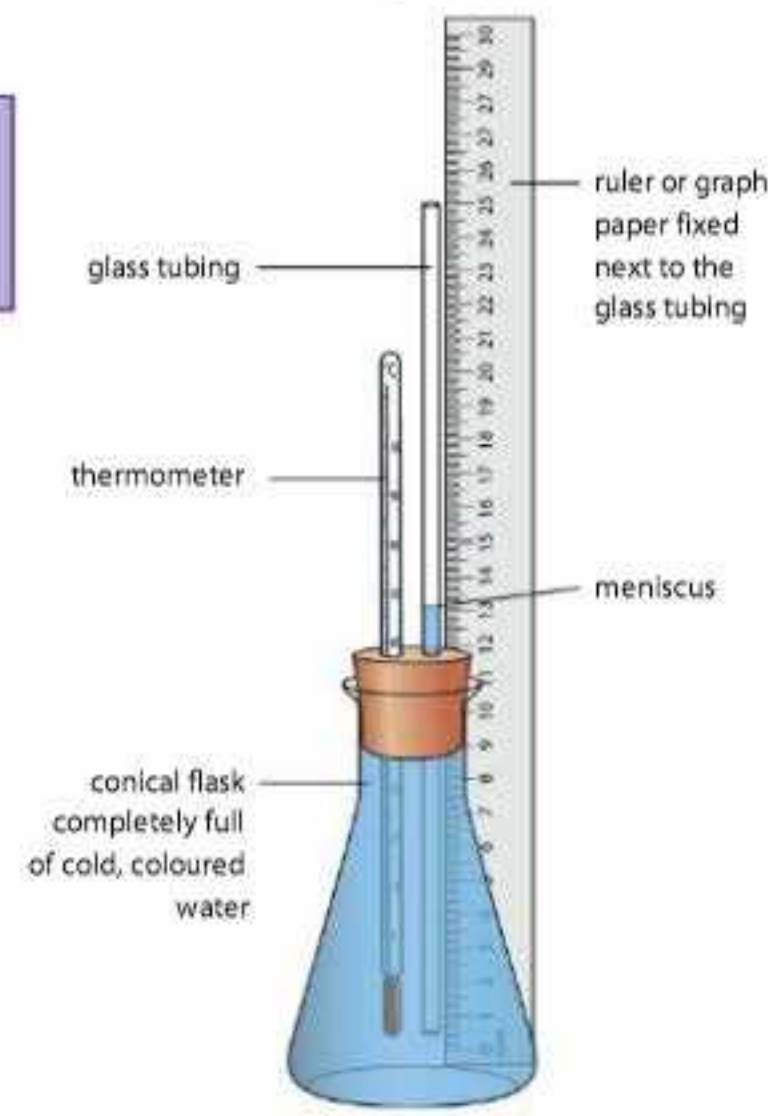
Experiment 2

You will need:

- the apparatus shown in the diagram – make sure that the water is really cold, a lamp.

Method

1. Read the temperature on the thermometer, and the level of the water in the glass tubing. Record them in a results chart.
2. Place a lamp close to the conical flask and switch it on. The lamp will gently warm the water in the flask.
3. Approximately every five minutes (the exact timing does not matter), record the temperature and the level of the water in the glass tubing. Keep going until you have at least 10 readings.



Continued

Method

4 Draw a graph to display your results. Put temperature on the *x*-axis and height of water in the glass tube on the *y*-axis. (Remember to include the units when you label the axes.)

Questions

1 Which of these changes increased the level of the 'ocean' in your experiment?
- melting ice in the sea
- melting ice on the land
- increasing water temperature

2 How do your results relate to what might happen to sea level as a result of climate change?

Activity 1.4.1

The carbon cycle and climate change

Work in a group of three or four.

Look at the complete diagram of the carbon cycle in Topic 1.3.

Which activities *increase* the quantity of carbon dioxide in the atmosphere?

Which activities *decrease* the quantity of carbon dioxide in the atmosphere?

Use your answers to these two questions to suggest what we can do to help to slow climate change. Write a list.

With the other groups in your class, build up a list of suggestions. For each one:
- explain why it would help
- explain why it might be difficult to make it happen.

Summary checklist

- ☐ I can describe some examples of how the Earth's climate has changed in the past.
- ☐ I can explain how an asteroid collision is believed to have caused climate change and mass extinctions.
- ☐ I can explain how scientists predict climate change will affect the Earth in future, including rising sea level, more flooding, more droughts and more extreme weather events.

Project: What happened to the dinosaurs?

You are going to work in a group to contribute to a display about the extinction of the dinosaurs.

Choose one or more of these issues to research. Try to make sure that each group researches a different issue.

Issues to research

- Who first developed the idea that there was an asteroid impact that killed the dinosaurs? When did they put forward this theory, and what was their evidence?
- What do scientists think could have happened as a result of the asteroid impact? What is their evidence?
- Scientists think that other events may have contributed to the extinction of the dinosaurs. What are these events, and what is the evidence for them?
- How have the early theories changed over time? Why have they changed?
- Are dinosaurs really extinct? Some biologists think that a very familiar group of animals that live on Earth today are really dinosaurs. What are they, and why do biologists think this?

Doing your research

Use the internet to find information.

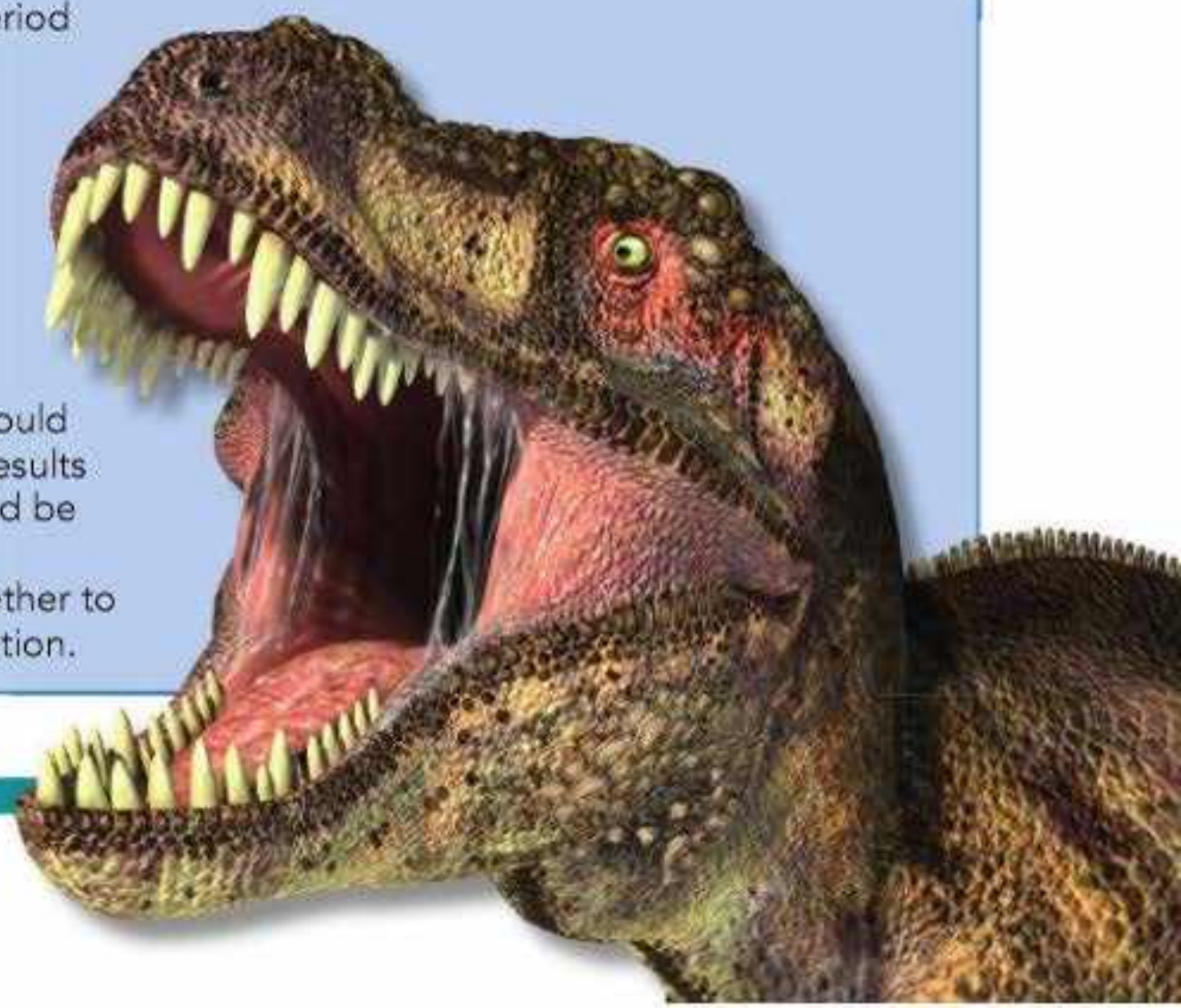
Before you begin, discuss in your group how you will choose the most trustworthy websites.

Here are some possible search terms you could try:

- dinosaur extinction event
- asteroid in the Cretaceous period
- Luis Walter Alvarez
- asteroid impact
- living dinosaurs.

Making the display

Work with the rest of the class to decide how the display will be made. For example, each group could produce a poster containing the results of their research. The posters could be displayed on the wall together. Alternatively, you could work together to create a multimedia class presentation.



Check your progress

1.1 Choose the correct word from the list to match each description. You can use each word once, more than once or not at all.

air **carbon dioxide** **chlorophyll** **chloroplast** **oxygen** **soil** **stomata** **veins**

a This gas is used by plants in photosynthesis. [1]

b This gas is made by plants in photosynthesis. [1]

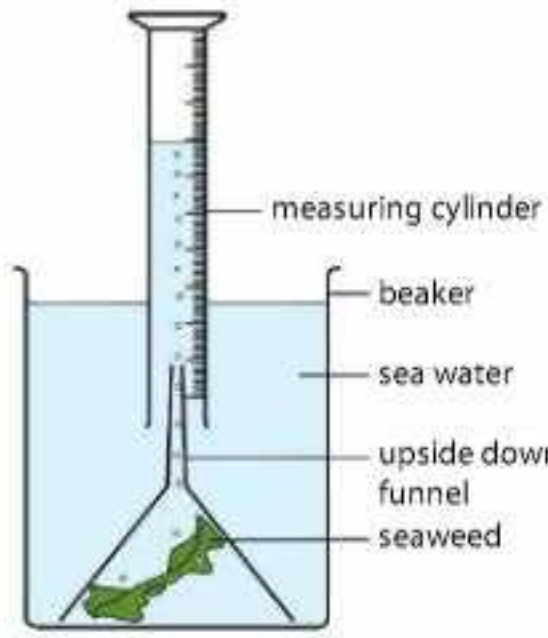
c Plants get their water for photosynthesis from here. [1]

d This green pigment absorbs energy from sunlight. [1]

e These tiny holes in a leaf allow gases to diffuse in and out. [1]

1.2 Marcus did an experiment to compare the rate of photosynthesis of two types of seaweed. Seaweeds are plant-like organisms that live in sea water.

The diagram shows the apparatus he used.

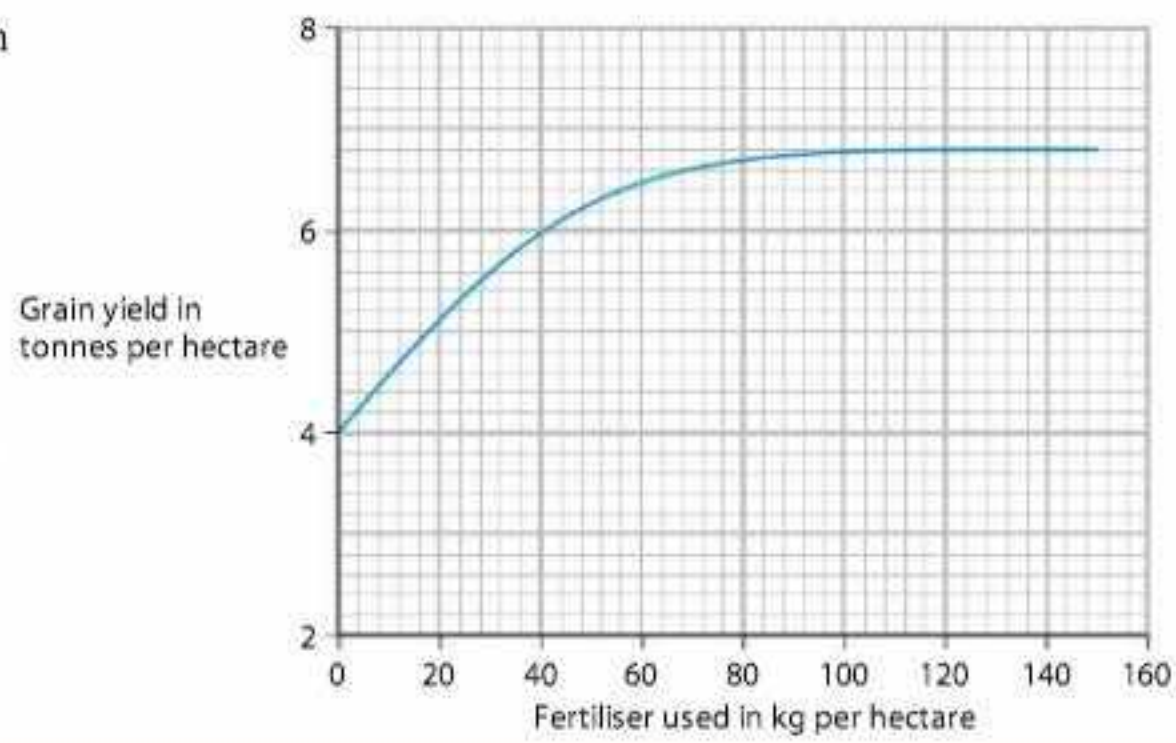


a What variable should Marcus change in his experiment? [1]

b List **three** variables that Marcus should keep the same. [3]

c What should Marcus measure during his experiment? [2]

1.3 A farmer carried out an experiment to find out how adding different quantities of nitrate-containing fertiliser affected the quantity of grain that she harvested from her wheat crop. The graph shows the results.



a What yield of grain did the farmer get when she did not add any fertiliser? [1]

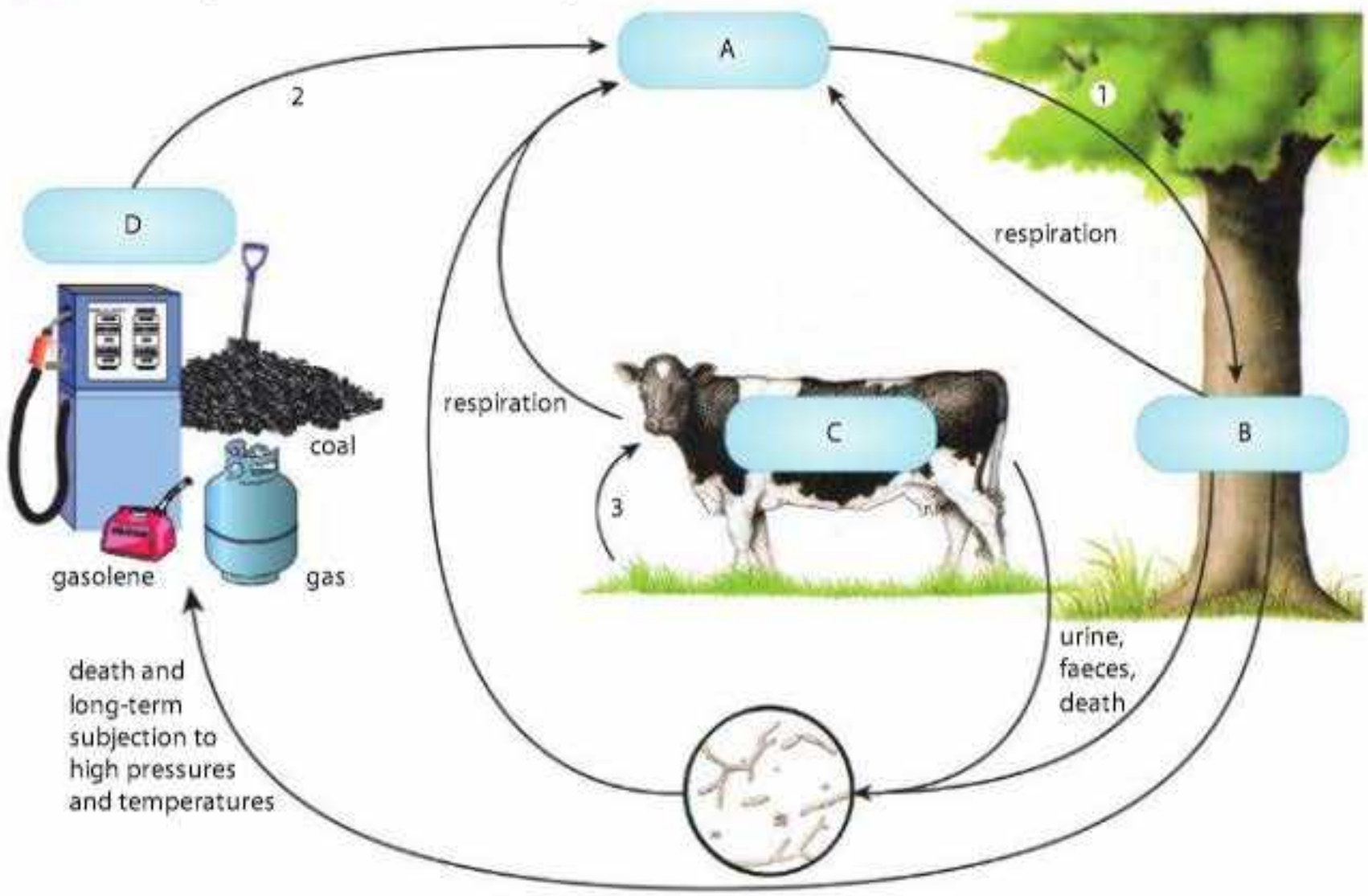
b The farmer decided that there was no need to add more than about 60 kg of fertiliser per hectare. Explain how the results of the experiment support her decision. (Remember that fertiliser is expensive.) [2]

c Explain why the yield of grain increases when nitrate-containing fertiliser is added. [2]

d Suggest why the results of this experiment might be different if it was repeated in a different place. [2]

e Name **one** mineral, other than nitrate, that plants need for healthy growth. Explain why they need this mineral. [2]

1.4 The diagram shows the carbon cycle.



a Match each of these labels to the correct **letter** on the diagram.

i carbon in fossil fuels

ii carbon compounds in plants

iii carbon dioxide in the air

iv carbon compounds in animals [3]

b Match each of these labels to the correct **number** on the diagram.

i feeding

ii combustion

iii photosynthesis **[2]**

c Name **one** compound found in plants that contains carbon. **[1]**

1.5 a Carbon dioxide concentration in the atmosphere is increasing. This is causing the Earth's climate to change.

Choose the statements that describe predicted future impacts of climate change.

- The mean temperature at the North and South Poles will decrease.
- Sea level will rise.
- There will be more extreme weather events, such as typhoons and hurricanes.
- There will be less sunlight reaching the surface of the Earth.

b In the past, asteroids have collided with the Earth. Scientists believe this has caused mass extinctions.

i Explain what is meant by a mass extinction. **[1]**

ii Explain how an asteroid collision can cause mass extinctions. **[3]**

2 Properties of materials

› 2.1 Atomic structure and the Periodic Table

In this topic you will:

- learn more about the structure of the atom
- learn how the structure of the Periodic Table is related to the structure of the elements.

Getting started

1 List the parts of an atom. Give at least one fact about each part.

2 Use the names of the parts and the information about them to write a description of the atom.

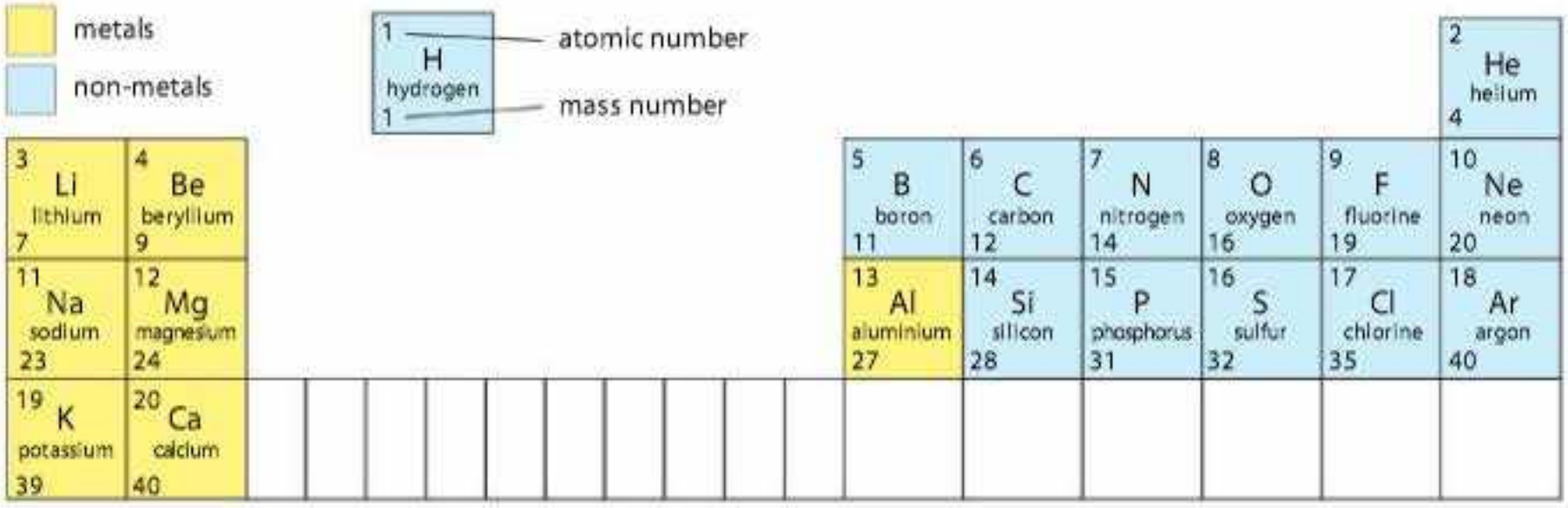
Be prepared to share your ideas with the class.

Key words

atomic number
electron shells
electronic structure
electrostatic forces
energy levels
mass number
Periodic Table

The Periodic Table

In Stage 8, you learnt about the first 20 elements and their symbols in the **Periodic Table**. Now you will learn more about the structure of the atoms of these elements.

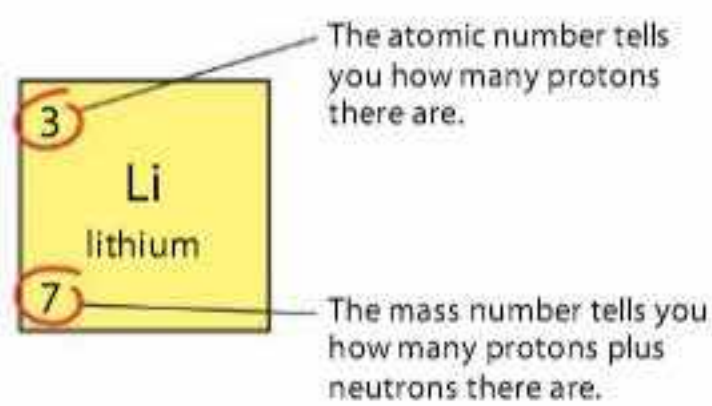


- The atoms of the elements increase in mass as you progress from left to right (starting with hydrogen) and downwards in the Periodic Table. For example, an atom of hydrogen has less mass than an atom of sodium.
- Each element has an **atomic number**. This tells you how many protons it contains. The atomic number increases by one with every element.
- Each element has a **mass number**. This tells you how many protons and neutrons each atom in the element has in total.
- Protons have a positive charge. Electrons have a negative charge. Neutrons have no charge.
- An atom has no overall charge, because the number of protons is the same as the number of electrons.

Let's take a look at the metal lithium as an example.

Lithium (metal)

- Atomic number = 3
- Mass number = 7
- Number of protons = 3
- Number of electrons = 3
- Number of neutrons = ?



The mass number tells you that, for lithium, the number of protons and neutrons is seven. We know that there are three protons so we can work out that there are four neutrons (7 – 3 = 4).

The higher the mass number, the more mass the atom has. Hydrogen has an atomic mass of 1. Carbon has an atomic mass of 12. So, one atom of carbon has 12 times more mass than one atom of hydrogen.

Let's compare the mass of a piece of sodium measuring 1 cm^3 with the mass of a piece of iron measuring 1 cm^3. The mass of the piece of sodium is 0.97 g and the mass of the piece of iron is 7.87 g. The mass of the iron is more than the mass of the sodium.

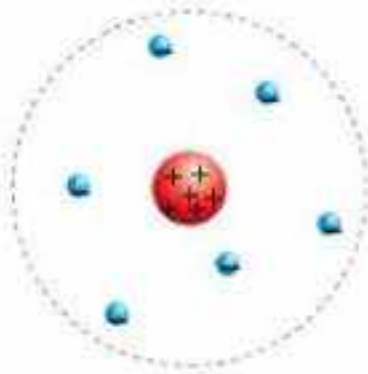
This measure of the mass for a fixed volume of a substance is called the density. The density is given using the unit g/cm^3.

The density of iron is 7.87 g/cm^3 and that of sodium 0.97 g/cm^3. So, iron is more dense than sodium.

For more information on how to find the densities of solids, liquids and gases and to compare them, see Unit 3, Topic 3.1.

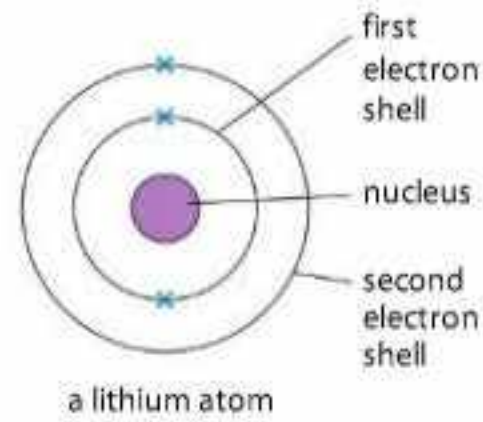
Arranging electrons

In Stage 8, you learnt about the development of a model for the structure of the atom. This used ideas from a number of scientists such as, J. J. Thompson and Ernest Rutherford. They developed the model shown here:

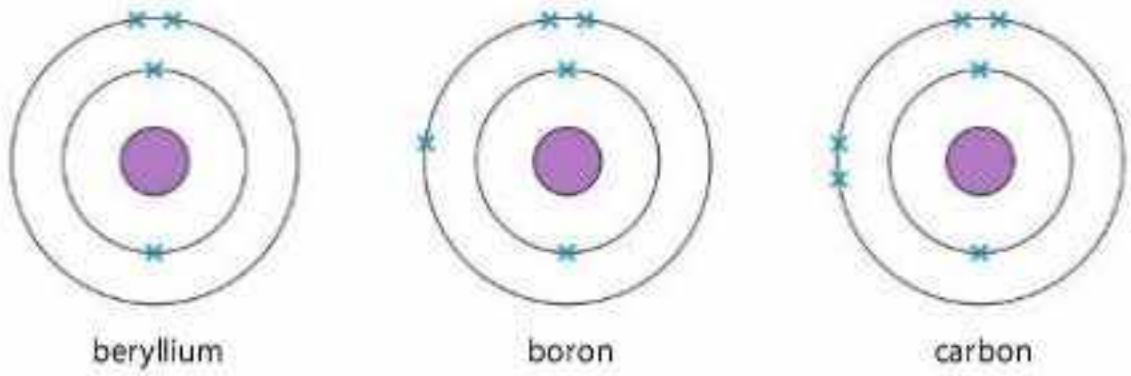


In 1913, the Danish scientist Niels Bohr developed Rutherford's model of the atom further. He had the idea and evidence that the electrons move in different **electron shells** (also called **energy levels**) around the nucleus. He was awarded the Nobel Prize for his work. His idea changed the model of the structure of the atom to the one we use today.

The electrons are arranged in electron shells around the nucleus. This is the **electronic structure**. The first electron shell only has room for two electrons. The second and third electron shells have room for up to eight electrons. The crosses represent the electrons. Remember that the electrons are held in place by **electrostatic forces**.



Look carefully at the diagrams, showing atoms of increasing mass.



The arrangement of the electrons in an atom is often written as numbers. For example, the electronic arrangement for a boron atom can be written as 2,3. This means that there are two electrons in the first electron shell and three in the next electron shell. The first shell always fills up before electrons go into the second shell.

Questions

1 How many electrons are there in an atom of carbon?

2 How many protons are there in an atom of beryllium?

You will need to look at the Periodic Table to answer the following questions.

3 How many neutrons are there in an atom of boron?

4 Draw a diagram to show the structure of an atom of magnesium.

5 What is the name of the element that has the electronic structure 2,8,3?

6 Draw a labelled atomic diagram of the element fluorine.

7 How is the model of the atom we use today different from the Rutherford model?

Activity 2.1.1

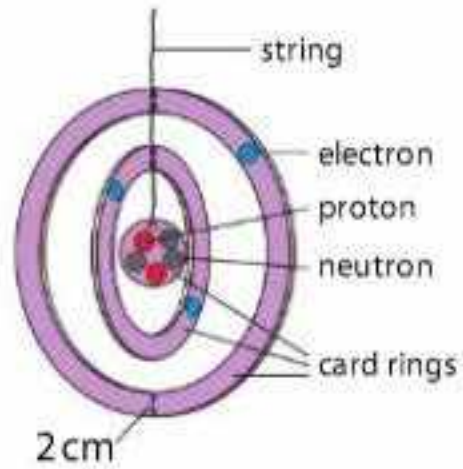
A model of an atom

In this activity, you will build a model of an element.

You will need:

- scissors, hole punch, string, glue, card in different colours (white, red, grey, blue and another colour for the shells).

Method



1. Cut a white circle of card about 6 cm diameter. This will act as the base for the nucleus.
2. Cut out small red circles of about 1.5–2 cm diameter to represent the protons in your chosen element, and grey circles of about 1.5–2 cm diameter to represent the neutrons. Stick these onto one side of the nucleus. Repeat this step, but stick the protons and neutrons onto the other side of the nucleus. Make sure you have the correct number on both sides.
3. Cut out concentric rings of card to represent the electron shells. The rings should be about 2 cm wide. Concentric means circles of different radius sharing the same centre.
4. Cut out small blue circles to represent the electrons in your chosen element. Stick these onto one side of the relevant electron shell. Repeat this step, but stick the electrons onto the other side of each shell. Make sure you have the correct number of electrons on both sides.
5. Assemble the model as shown in the diagram.
6. Make a label for your model that gives the name and symbol for your element, and the number of protons, neutrons and electrons. Hang the label from the bottom of your model.

Look carefully at the model atom you made. How good a model is it? How does it help you to understand the structure of an atom?

Summary checklist

- ☐ I can draw and describe a model of an atom.
- ☐ I can interpret information about the electronic structure of an atom.
- ☐ I can explain how the elements are arranged in the Periodic Table.

2.2 Trends in groups within the Periodic Table

In this topic you will:

- learn about the similarities between different elements in the same groups in the Periodic Table
- relate the structure of the Periodic Table to the structure of the elements
- use the Periodic Table to predict the structure and properties of elements
- make careful observations.

Getting started

Use a copy of the Periodic Table to find

- a metal in the same group as magnesium
- a metal in the same period as magnesium
- a non-metallic solid in the same period as magnesium
- a gas in the same period as magnesium.

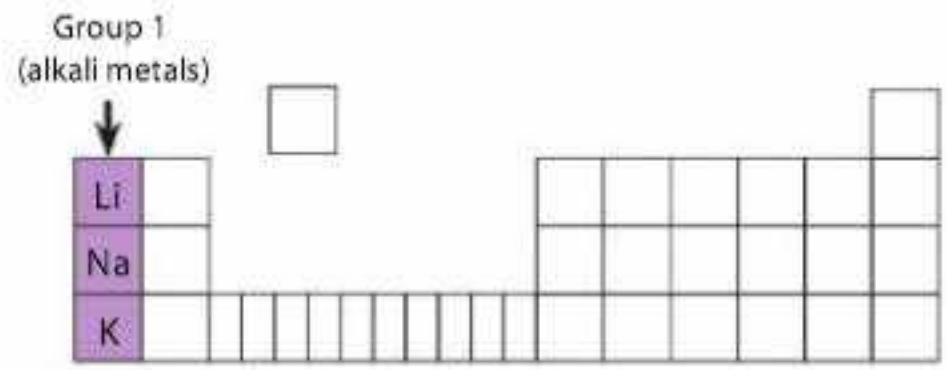
Compare your answers with a partner and use both of your answers to include all the elements that apply in each answer.

Key words

alkali metals
halogens
noble gases

Group 1: The alkali metals

In Stage 8, you learnt that the columns in the Periodic Table are called groups. The first group, also known as the **alkali metals**, includes the elements lithium, sodium and potassium. The elements have some properties in common. The table below contains data about three of the elements in Group 1.



Element	Atomic number	Mass number	Melting point in °C	Boiling point in °C
lithium, Li	3	7	180	1360
sodium, Na	11	23	98	900
potassium, K	19	39	63	777

As you can see, the atomic number increases as you go down the group. The mass number also increases as you go down the group. These increasing numbers tell you that the size of the atom is increasing. When you look at the melting points you can see that they go down as you go down the group. The next element down in the group is the metal rubidium. We can predict it would have a melting point lower than 63 °C.

Questions

1 Where in the Periodic Table do you find the metals?

2 What is the trend in the boiling points of Group 1 elements?

3 What prediction can you make about the boiling point of rubidium?

4 How many more electrons than lithium does sodium have?

Think like a scientist

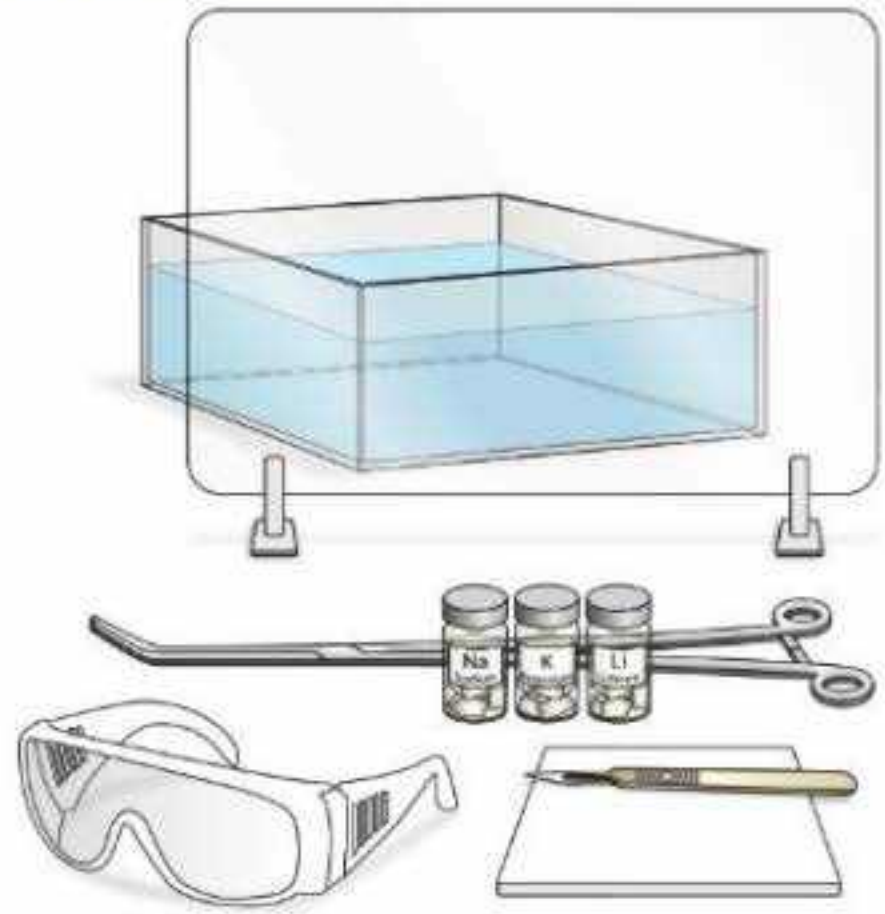
Observation of the reactions of Group 1 metals with water

You will need:

- safety glasses.

Your teacher needs

- safety glasses, large trough of water, white tile, scalpel or knife, long forceps, samples of the three metals – lithium, sodium and potassium – stored in the normal way, safety screen or screens large enough to protect everyone in the class (including the teacher).



Method

Your teacher will demonstrate the reactions of lithium, sodium and potassium with water. The three elements are stored in a particular way and a small piece of the metal will be cut off and placed one at a time in the trough of water to react.

Watch carefully and record your observations.

Questions

1. Describe the safety precautions your teacher took.
2. Describe what you saw happen when each of the metals reacted with water.
3. Write a word equation for each reaction.
4. What similarities do you notice about the reactions of these metals?
5. What differences do you notice about the reactions of these metals?
6. List the properties that these elements share.
7. Suggest why the next element, rubidium is not used in schools.
8. Why do you think this group is sometimes called the alkali metals?

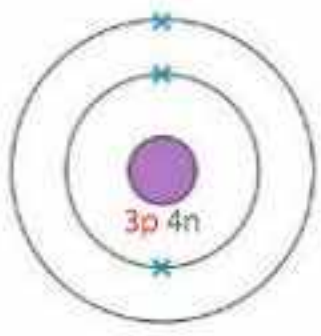
The structure of the Group 1 metals

The properties of lithium, sodium and potassium are similar and so is their atomic structure.

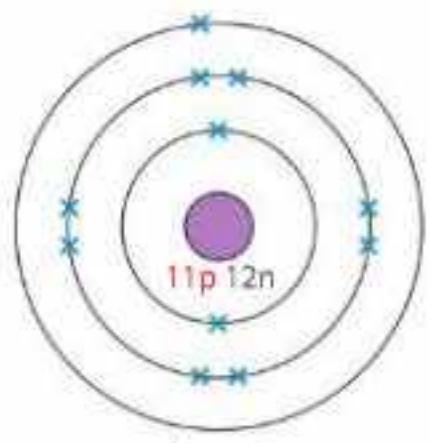
Lithium has an atomic number of 3 and a mass number of 7. This atom contains 3 protons, 3 electrons and 4 neutrons. The electrons are arranged as 2,1. This means there are two electrons in the lowest electron shell (which is full) and one electron in the second electron shell.

Sodium has an atomic number of 11 and a mass number of 23. This atom contains 11 protons, 11 electrons and 12 neutrons. The electronic structure is 2,8,1. This means there are two electrons in the lowest electron shell (which is full) and eight electrons in the second electron shell (which is full) and one electron in the third electron shell.

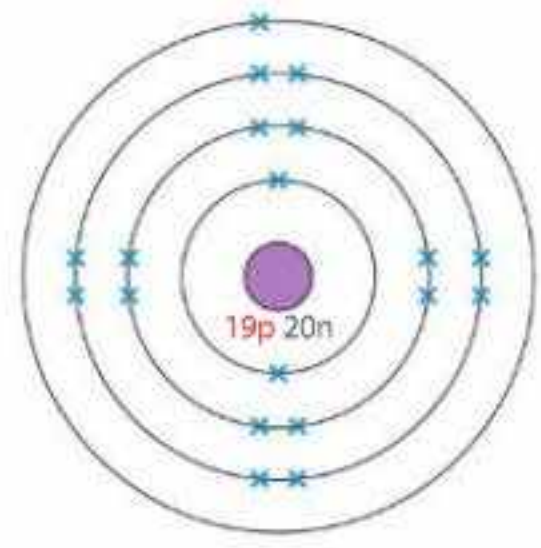
Potassium has an atomic number of 19 and a mass number of 39. This atom contains 19 protons, 19 electrons and 20 neutrons. The electronic structure is 2,8,8,1. This means there are two electrons in the lowest electron shell (which is full), eight electrons in the second electron shell (which is full), eight electrons in the third electron shell (which is full) and one electron in the fourth electron shell.



lithium atom



sodium atom



potassium atom

Questions

5 What happens to the size of the atoms as you go down this group?

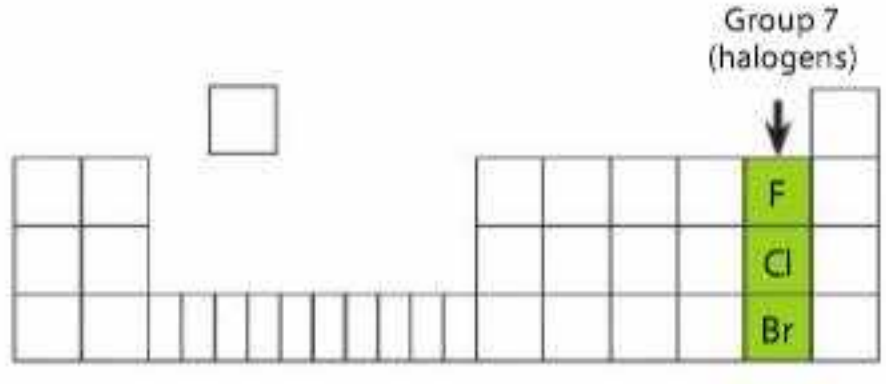
6 What similarity is there in the structure of these atoms? (Look at the electron shell arrangements.)

7 Suggest why this group of metals is called Group 1.

8 What are the trends in the structure and behaviour of these elements in Group 1?

Group 7: The halogens (extension material)

Group 7 is another group in the Periodic Table, known as the **halogens**. The group includes fluorine, chlorine and bromine. These elements have a number of properties in common. The first two elements (fluorine and chlorine) are gases at room temperature. Bromine is a liquid. The most reactive is fluorine, then chlorine. Bromine is the least reactive of the three.



Element	Atomic number	Electronic structure	Mass number	Colour	Melting point in °C	Boiling point in °C
fluorine, F	9	2,7	19	pale yellow	−220	−188
chlorine, Cl	17	2,8,7	35	yellowish green	−101	−34
bromine, Br	35		80	brown	−7	59

Questions

9 Are the halogens metals or non-metals?

10 What is the trend in melting points in Group7?

11 What is the trend in colour in Group 7?

12 What is the trend in boiling points in Group 7?

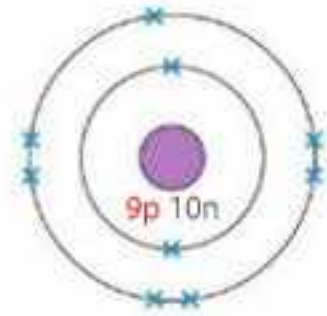
13 What would you predict about the boiling point and melting point of iodine, the next element in Group 7?

14 Would you expect iodine to be more or less reactive than bromine?

15 The electronic structure for bromine is missing from the table. How many electrons do you predict will be in the outer shell?

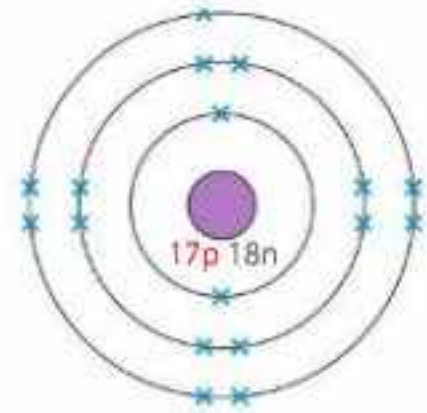
The structure of fluorine and chlorine

Fluorine has an atomic number of 9 and a mass number of 19. This atom contains 9 protons, 9 electrons and 10 neutrons. The electronic structure is 2,7. This means that the first electron shell has 2 electrons and is full. The second electron shell has seven electrons.



fluorine

Chlorine has an atomic number of 17 and a mass number of 35. This atom contains 17 protons, 17 electrons and 18 neutrons. The electronic structure is 2,8,7. This means that the first electron shell has two electrons and is full. The second electron shell has eight electrons and is full. The third electron shell has seven electrons.



chlorine

Questions

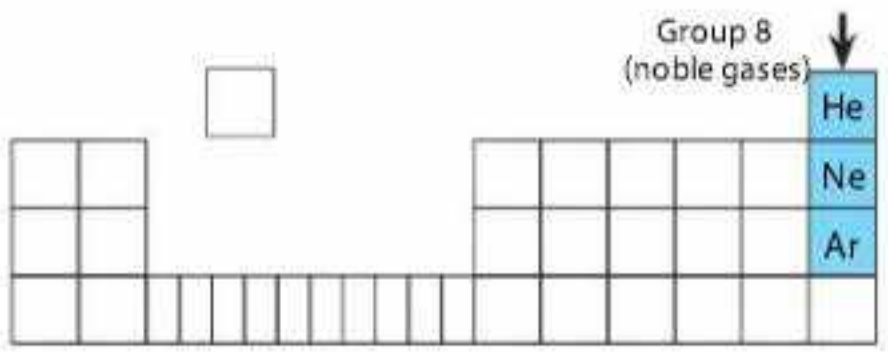
16 What happens to the size of the atoms as you go down this group?

17 What similarity is there in the structure of these atoms?

18 Suggest why this group is called Group 7.

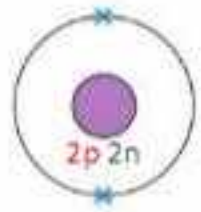
Group 8: The noble gases

Group 8 includes the elements helium, neon and argon. They are all gases. They are inert (unreactive) and do not form compounds. They are called the **noble gases**.



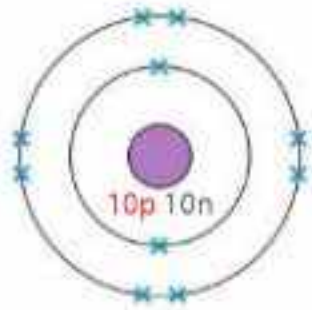
Element	Atomic number	Electronic structure	Mass number	Melting point in °C	Boiling point in °C
helium, He	2	2	4	−270	−269
neon, Ne	10	2,8	20	−249	−246
argon, Ar	18	2,8,8	40	−189	−186

Helium has an atomic number of 2 and a mass number of 4. This atom contains 2 protons, 2 electrons and 2 neutrons. The electrons are arranged with 2 in the first shell. The shell is full.



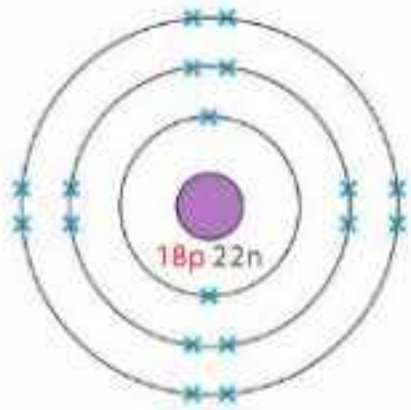
helium

Neon has an atomic number of 10 and a mass number of 20. This atom contains 10 protons, 10 electrons and 10 neutrons. The electrons are arranged with 2 in the first shell and 8 in the second shell. Both shells are full.



neon

Argon has an atomic number of 18 and a mass number of 40. This atom contains 18 protons, 18 electrons and 22 neutrons. The electrons are arranged with 2 in the first shell, 8 in the second shell and 8 in the third shell. All three shells are full.



argon

Questions

19 What trend in melting points can be seen in Group 8?

20 What happens to the size of the atoms as you go down Group 8?

21 What similarity is there in the structure of these atoms?

22 Suggest why this group is called Group 8.

23 What predictions can you make about the melting point and boiling point of krypton, which is the next gas in this group?

How does the atomic structure of an element relate to its position in the Periodic Table?

Summary checklist

- ☐ I can explain how the structure of the Periodic Table is related to the atomic structure of the elements.
- ☐ I can identify the similarities and differences between the atomic structure of elements in the same group in the Periodic Table.
- ☐ I can use the Periodic Table to predict the structure and properties of elements.
- ☐ I can make accurate observations.

2.3 Why elements react to form compounds

In this topic you will:

- describe the structure of an ion and compare it with that of an atom
- explain how ionic and covalent bonds are formed
- explain what a molecule is
- write the formulae of some ionic and covalent compounds.

Getting started

The electronic structure of lithium is 2,1.
Draw the structure of this atom.

The electronic structure of fluorine is 2,7.
Draw the structure of this atom.

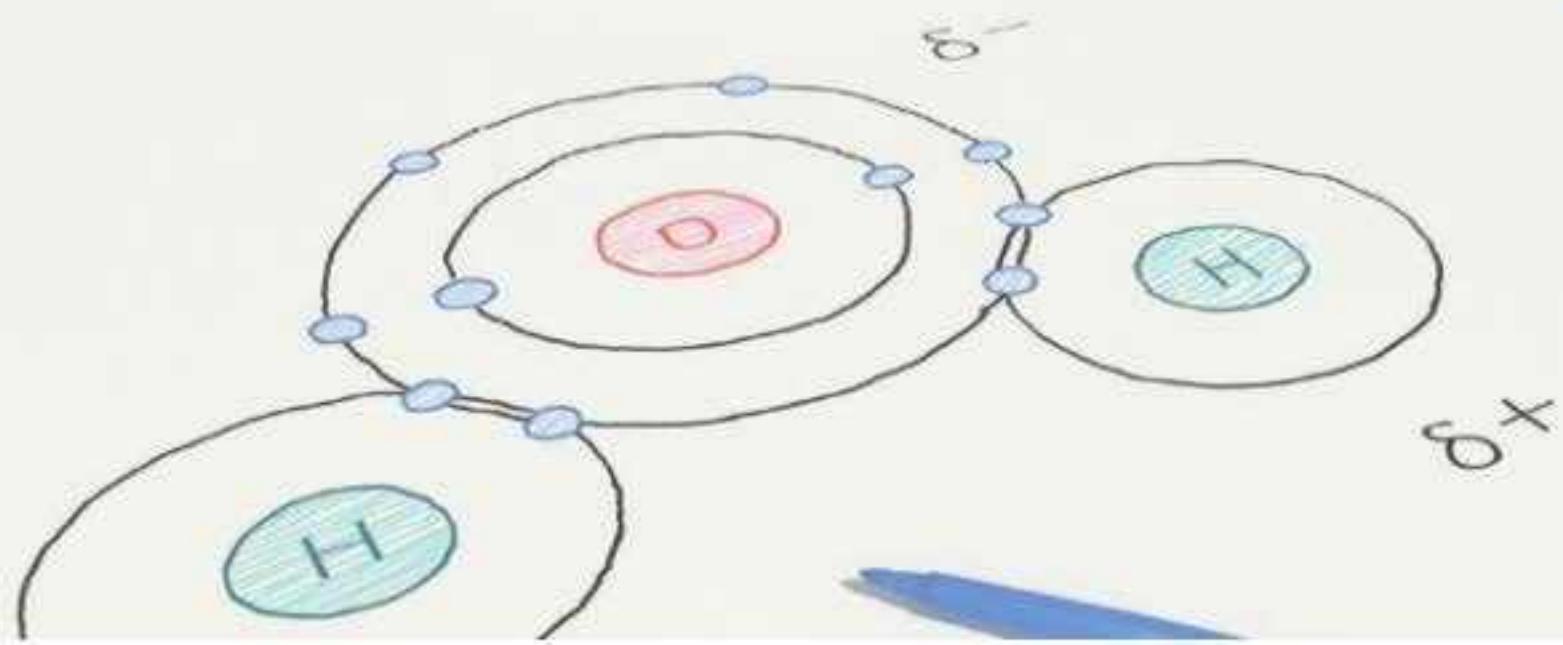
When you have drawn them, compare them with a partner's drawings.

Discuss which group in the Periodic Table each of these elements is in.

Be prepared to share your drawings with the class.

Key words

chemical bonds
covalent bond
dot and cross diagram
ion
highest energy level
ionic bond
ionic compounds
molecule
stable
outermost electron shell



Thinking about atomic structure

Atoms have electrons arranged in different electron shells or energy levels around the nucleus. The shell with the **highest energy level** is the one on the outside of the atom. It is called the **outermost electron shell**.

In the different shells, there is room for two electrons in the first electron shell, eight electrons in the second electron shell, and eight electrons in the third electron shell.

The number of electrons in an atom is the same as the number of protons in that atom.

The atomic number tells us how many protons there are in an atom.

The electrons have an electrical charge of −1 and protons a charge of +1.

Atoms have no overall charge because there are an equal number of protons and electrons.

Electrons are held in place by electrostatic forces

Why do elements react together?

Atoms are more **stable** when the outermost electron shell (highest energy level) is completely full of electrons.

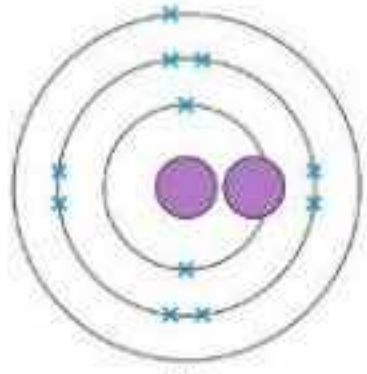
The elements in Group 8, the noble gases, have their outermost energy level of electrons full, so they do not react to form compounds.

All the other groups do not have full outer shells of electrons so they can react to form compounds. In doing so, they fill the outermost electron shells with electrons. The elements in compounds are held together by **chemical bonds**. These bonds can be formed in two ways:

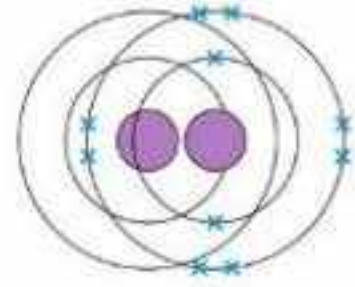
- the atoms can lose or gain electrons
- atoms can share electrons.

Losing electrons

Sodium reacts with other elements by losing an electron. When this happens, the sodium atom forms an **ion**.



Na
sodium atom [2,8,1]



Na^+
sodium ion [2,8]$^+$

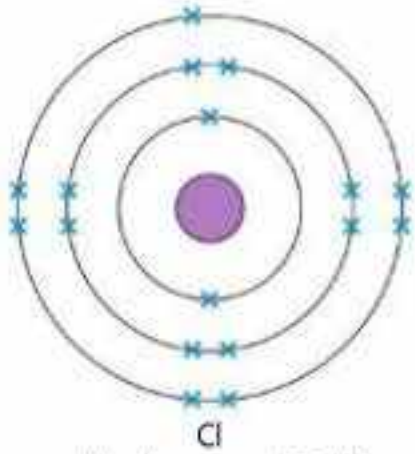
When the sodium atom loses an electron, it forms a sodium ion.

When a sodium atom loses the electron from the outer shell, which is the outermost electron shell, the next shell becomes the outermost electron shell. This electron shell is full. So, the sodium ion is more stable than the sodium atom. We write the symbol for a sodium atom as Na. When a sodium ion is formed it has one less electron than the atom so there is now one more positively charged proton than negatively charged electrons. So, we write the symbol for a sodium ion as Na^+.

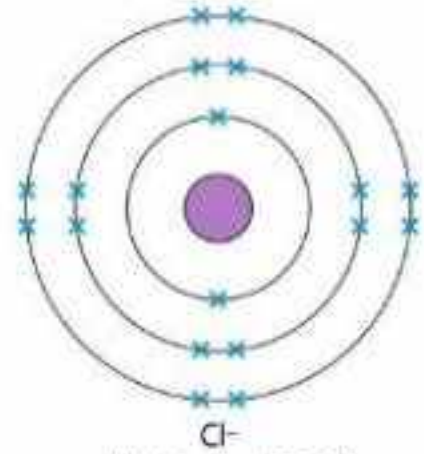
Gaining electrons

An atom can also become an ion by *gaining* electrons.

In some groups in the Periodic Table, the elements have their outermost electron shells almost full. In Group 7, elements such as chlorine have seven electrons in the outermost electron shell. To fill its outermost electron shell, a chlorine atom gains an electron and forms a chlorine ion. The outermost electron shell in the chlorine ion is now full, so the chlorine ion is more stable than the chlorine atom.



Cl
chlorine atom [2,8,7]



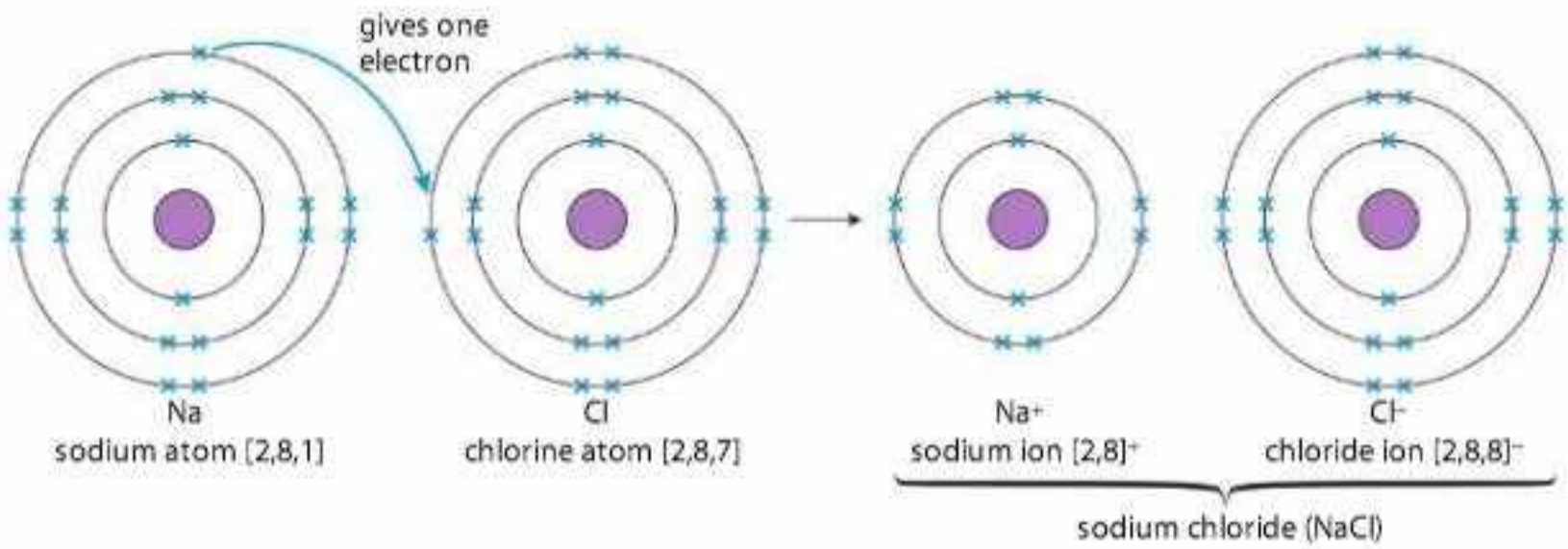
Cl^-
chlorine ion [2,8,8]$^-$

The chlorine atom needs to gain an electron to make it more stable.

We write the symbol for a chlorine atom as Cl. When a chlorine ion is formed, it has one more negatively charged electron than the atom, so there is now one more electron than the positively charged protons. So, we write the symbol for a chlorine ion as Cl^-.

Ionic bonding

A sodium ion and a chlorine ion can form an ionic chemical bond to form the compound sodium chloride. In an **ionic bond** there is an attraction between the positively charged ion, sodium, and the negatively charged ion, chlorine.



When the sodium atom loses one electron and becomes a sodium ion, it has 10 electrons and 11 protons. This means that there are 11 positive charges from the protons but only 10 negative charges from the electrons in the ion. This means that the sodium ion has a positive electrical charge of +1. The symbol for a sodium ion is written as Na^+. The electronic structure for a sodium ion is written as $[2,8]^+$.

When the chlorine atom gains one electron and becomes a chlorine ion, it has 18 electrons and 17 protons. This means that there are 17 positive charges from the protons but 18 negative charges from the electrons in the ion. This means that the chlorine ion has a negative electrical charge of −1. The chlorine ion is written as Cl^-.

The charges on the ions of sodium and chlorine form a bond and the two elements are held together to form sodium chloride, NaCl.

Other metals in Group 1 react with Group 7 elements in a similar way. For example, lithium and potassium with chlorine and fluorine:

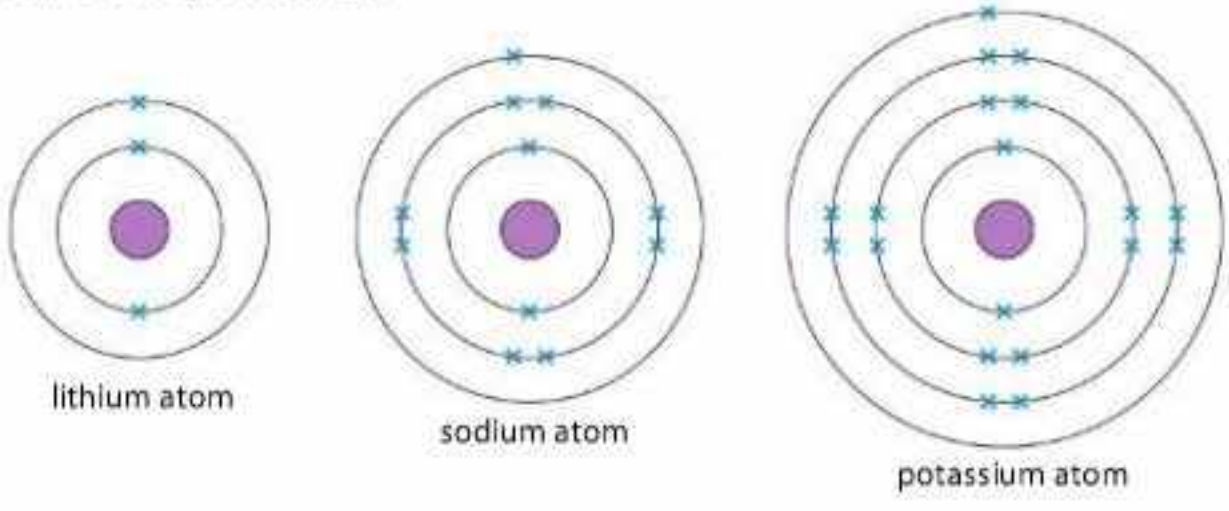
lithium + chlorine → lithium chloride

lithium + fluorine → lithium fluoride

potassium + chlorine → potassium chloride

potassium + fluorine → potassium fluoride

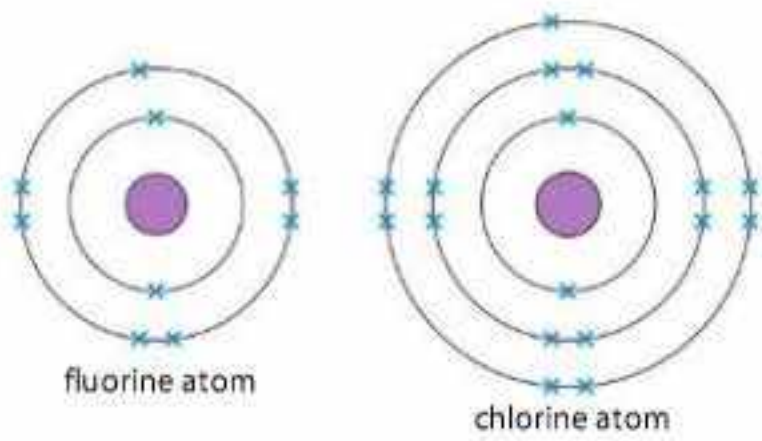
Look at the electronic structures for the elements lithium, sodium and potassium.



Potassium is the most reactive and lithium the least reactive.

Potassium loses the electron in the outermost electron shell more easily than sodium or lithium can lose theirs. The electrons are held in their electron shells by electrostatic forces between the positive charge on the protons and the negative charge on the electrons. The electron in the outermost electron shell of potassium is furthest away from the protons so it is easier to overcome these forces. It is more difficult for the electron in the outermost electron shell in the lithium atom to escape than in a sodium or potassium atoms as it is more difficult to overcome the electrostatic forces.

Now look at the electronic structures for the elements fluorine and chorine.



Fluorine is more reactive than chlorine.

Fluorine gains an electron in the outermost electron shell more easily than chlorine. The electrons are held in their electron shells by electrostatic forces between the positive charge on the protons and the negative charge on the electrons. The electron in the outermost electron shell of fluorine is closest to the protons so an additional electron is attracted by the electrostatic forces more readily than in chlorine.

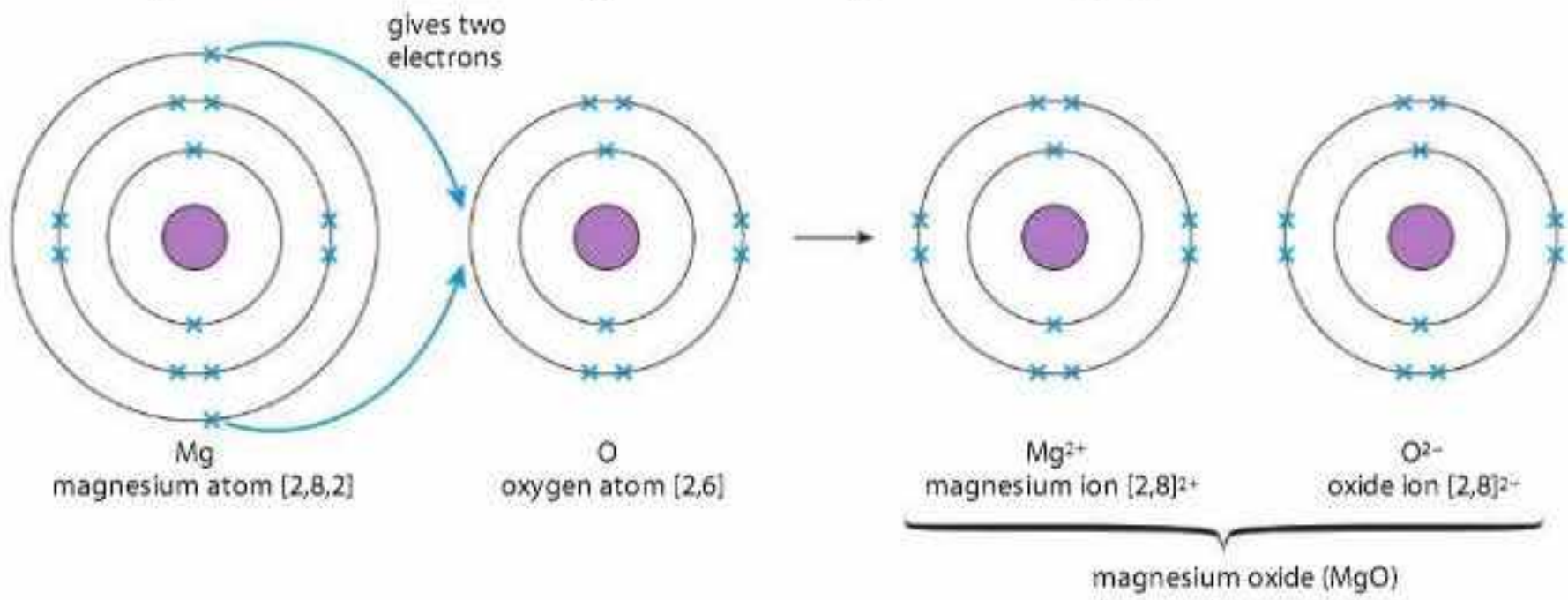
Questions

1. What is the electronic structure of a sodium atom?
2. What is the electronic structure of a sodium ion?
3. What is the symbol for a chlorine atom?
4. What is the symbol for a chlorine ion?
5. Draw the electronic structure of a potassium ion.
6. Draw the electronic structure for a fluorine ion.
7. Potassium is more reactive than lithium because it can lose an electron more easily. Why is this?
8. Fluorine is more reactive than chlorine because it can gain an electron more easily. Why is this?

Other ionic compounds

Ionic compounds are those that are made from ions. They form when a metal reacts with a non-metal.

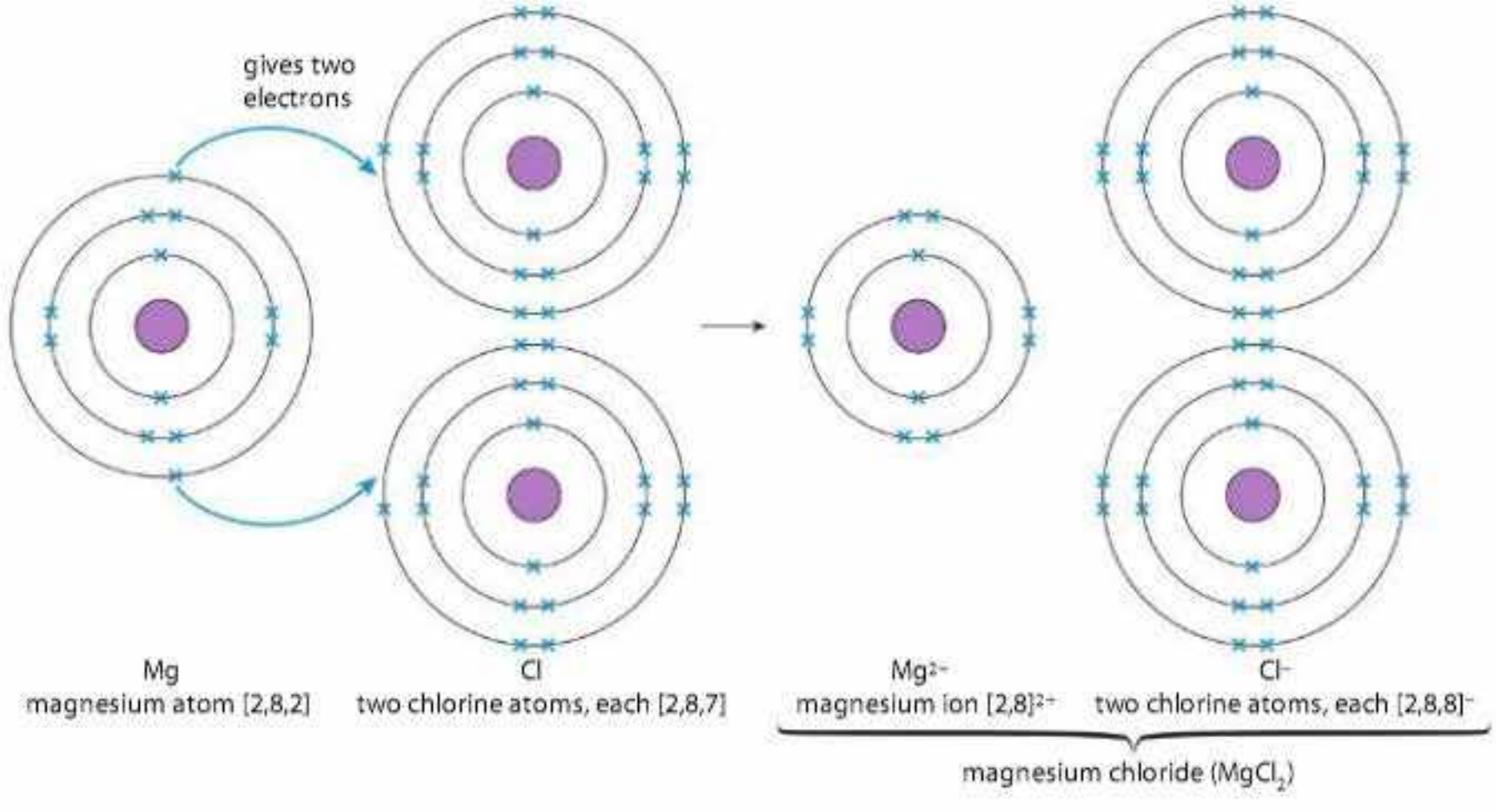
In some elements more than one electron is lost or gained. For example, when magnesium combines with oxygen to form magnesium oxide, MgO.



A magnesium atom has two electrons in the outermost electron shell, its electronic structure is 2,8,2. An oxygen atom has six electrons in its outermost electron shell, 2,6.

The magnesium atom loses the two electrons and forms a magnesium ion, Mg^{2+} The oxygen atom gains two electrons and becomes an oxygen ion O^{2-}. The two ions are attracted to one another and form an ionic bond to form the ionic compound magnesium oxide, MgO.

Magnesium reacts with chlorine to form magnesium chloride (extension material).



Extension material: When magnesium forms an ionic compound with chlorine, two ions of chlorine are formed.

The magnesium atom loses the two electrons from its outermost shell and forms a magnesium ion, Mg^{2+}. Two chlorine atoms both gain one electron and become two chloride ions, 2 Cl^-. The two chlorine ions are attracted to the magnesium ion and form an ionic bond to form the ionic compound magnesium chloride, $MgCl_2$.

Questions

9 Draw diagrams to explain how the structure of an atom of calcium is different from an ion of calcium.

10 How many ions of chlorine react with one ion of calcium to form calcium chloride?

11 Write the chemical formula for calcium chloride.

12 Write the chemical formula for calcium oxide.

Activity 2.3.1

Forming ionic compounds

You will need:

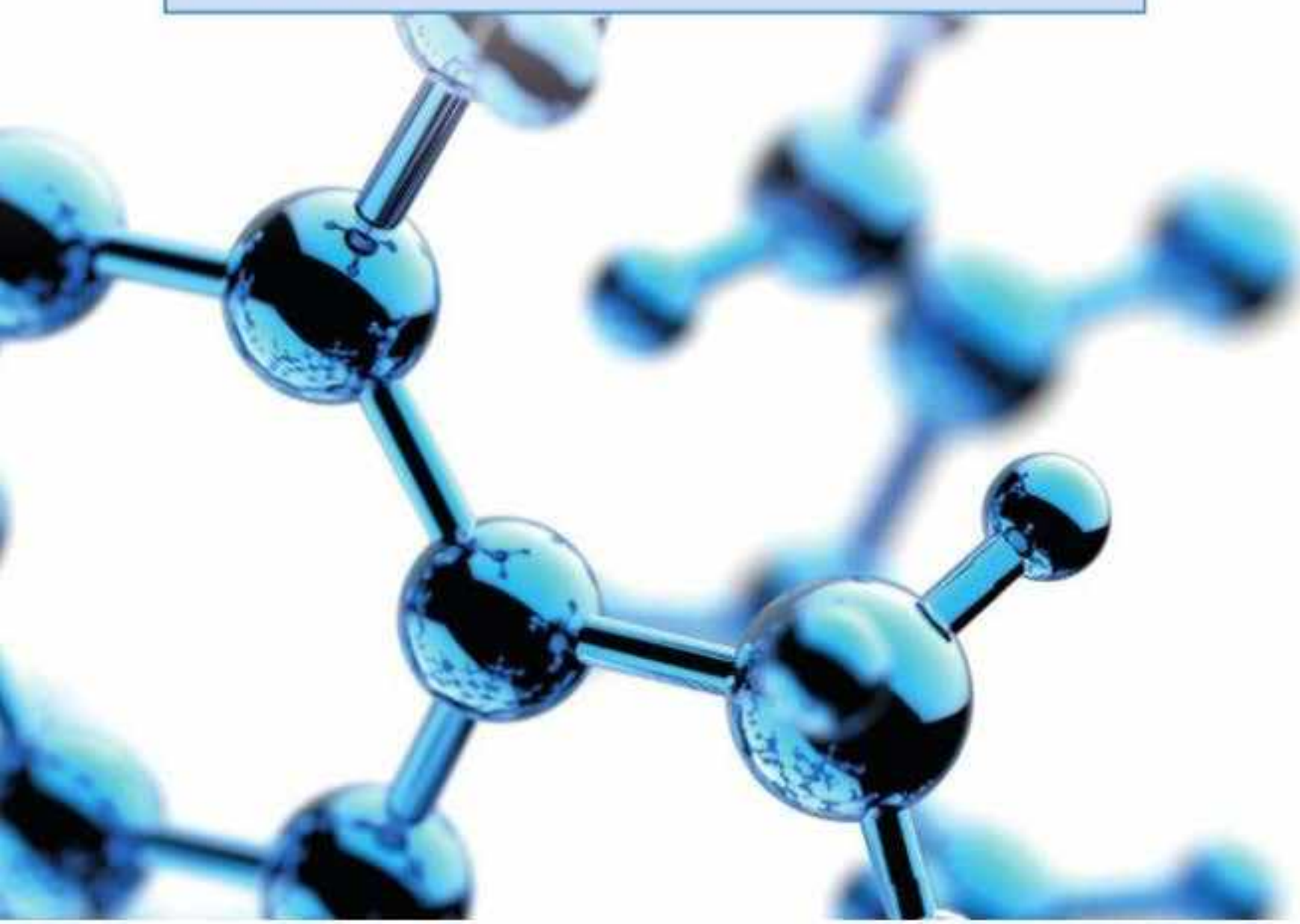
- coloured paper and/or card, glue, scissors, ruler, large sheet of paper, pair of compasses and/or string and a drawing pin.

Method

1. In pairs, choose one of the following metals: calcium, magnesium, lithium, sodium or potassium.
2. Choose one of the following non-metals: fluorine, chlorine or oxygen.
3. Make a poster to illustrate the structure of the atoms of these elements and show how an ionic bond is formed to make an ionic compound.
4. Make sure you add the name of the elements and their symbols, the name of the compound and its formula.

Peer assessment

When you have completed your poster, swap it with another pair. Suggest two things they have done well and one thing they could do to improve their poster.



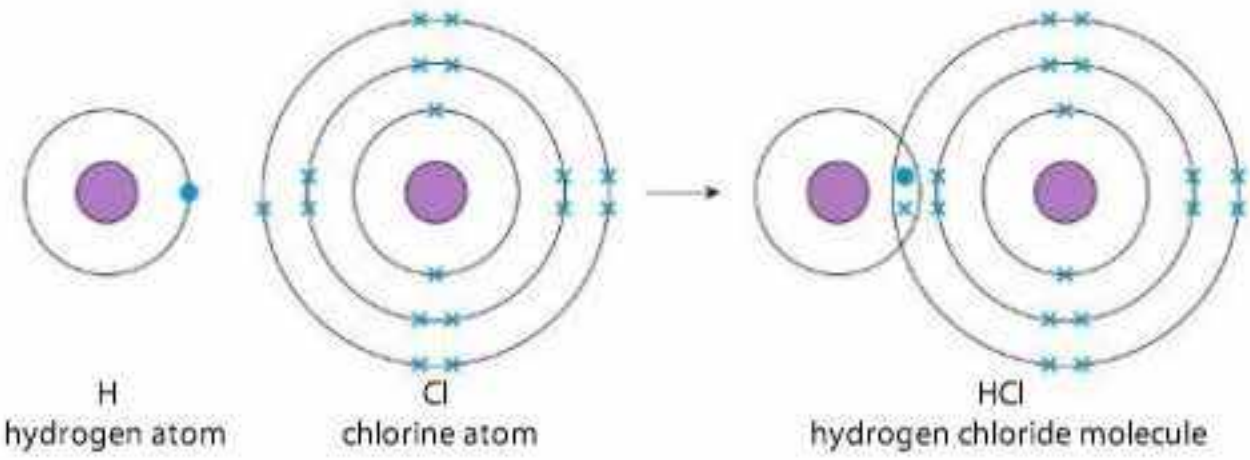
Sharing electrons

When non-metals form compounds with other non-metals they do so by sharing electrons to fill their outermost electron shells.

Hydrogen and chlorine

An example of this is when hydrogen and chlorine react to form hydrogen chloride:

- a hydrogen atom has just one electron in its outermost electron shell; in this first shell there is only room for two electrons
- a chlorine atom has seven electrons in its outermost electron shell; in this electron shell there is room for eight electrons
- the atoms share a pair of electrons, so both hydrogen and chlorine have their outermost electron shells full of electrons
- a **molecule** of hydrogen chloride is formed; its formula is HCl.



The electron in the hydrogen atom is shown as a dot and the electrons in the chlorine atom are shown as crosses. This type of diagram is known as a **dot and cross diagram**.

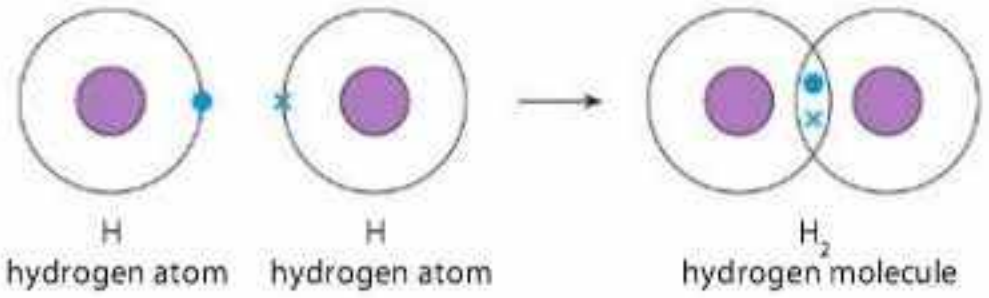
This type of chemical bond where electrons are shared is called a **covalent bond**.

Hydrogen and hydrogen

Covalent molecules are formed when atoms of different non-metals join together to form compounds and when atoms of the same non-metal join together.

For example, two atoms of hydrogen join together to form a molecule of hydrogen:

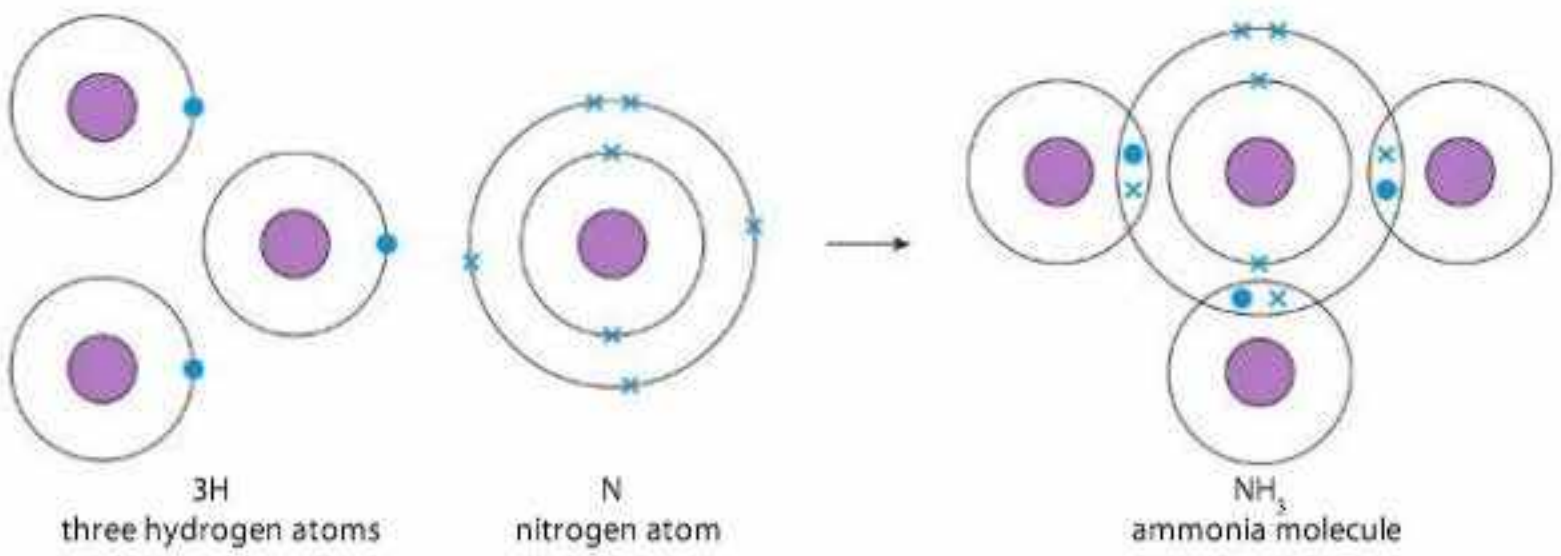
- an atom of hydrogen has one electron in its outermost electron shell; this electron shell has room for only two electrons
- the hydrogen atoms share a pair of electrons, so both atoms have two electrons in the outermost electron shell so the shell is full and more stable
- a molecule of hydrogen is formed; the formula is written as H_2.



Hydrogen and nitrogen

Another example of a covalent compound is ammonia. This compound is formed when hydrogen and nitrogen share three pairs of electrons:

- an atom of hydrogen has only one electron in the outermost electron shell, but there is room for two electrons in this shell
- an atom of nitrogen has an atomic number of 7, so it has two electrons in the first electron shell and has five electrons in its outermost electron shell, but there is room for eight electrons in this shell
- three atoms of hydrogen combine with one atom of nitrogen and share three pairs of electrons, so all the atoms have their outermost electron shells full of electrons
- a stable molecule of ammonia is formed; its formula is NH_3.



The hydrogen chloride, hydrogen and ammonia molecules can also be represented using diagrams like the ones shown below. There are some more examples of covalent compounds, too.

hydrogen chloride molecule
HCl

hydrogen molecule
H_2

ammonia molecule
NH_3

oxygen molecule
O_2

methane molecule
CH_4

chlorine molecule
Cl_2

water molecule
H_2O

nitrogen molecule
N_2

carbon dioxide molecule
CO_2

Questions

13 Which of the nine molecules shown in the diagram above are compounds?

14 Draw a dot and cross diagram to show how a molecule of chlorine is formed.

15 Is the compound calcium chloride an ionic or a covalent compound? Give a reason for your answer.

16 Write the formula for a molecule of methane, a molecule of carbon dioxide and a molecule of nitrogen.

How can I be sure if the bond is ionic or covalent?

Summary checklist

- ☐ I can show the differences between the structure of an ion and an atom.
- ☐ I can explain how ionic and covalent bonds are formed.
- ☐ I can explain what a molecule is.
- ☐ I can write the formulae of some ionic and covalent compounds.

2.4 Simple and giant structures

In this topic you will:

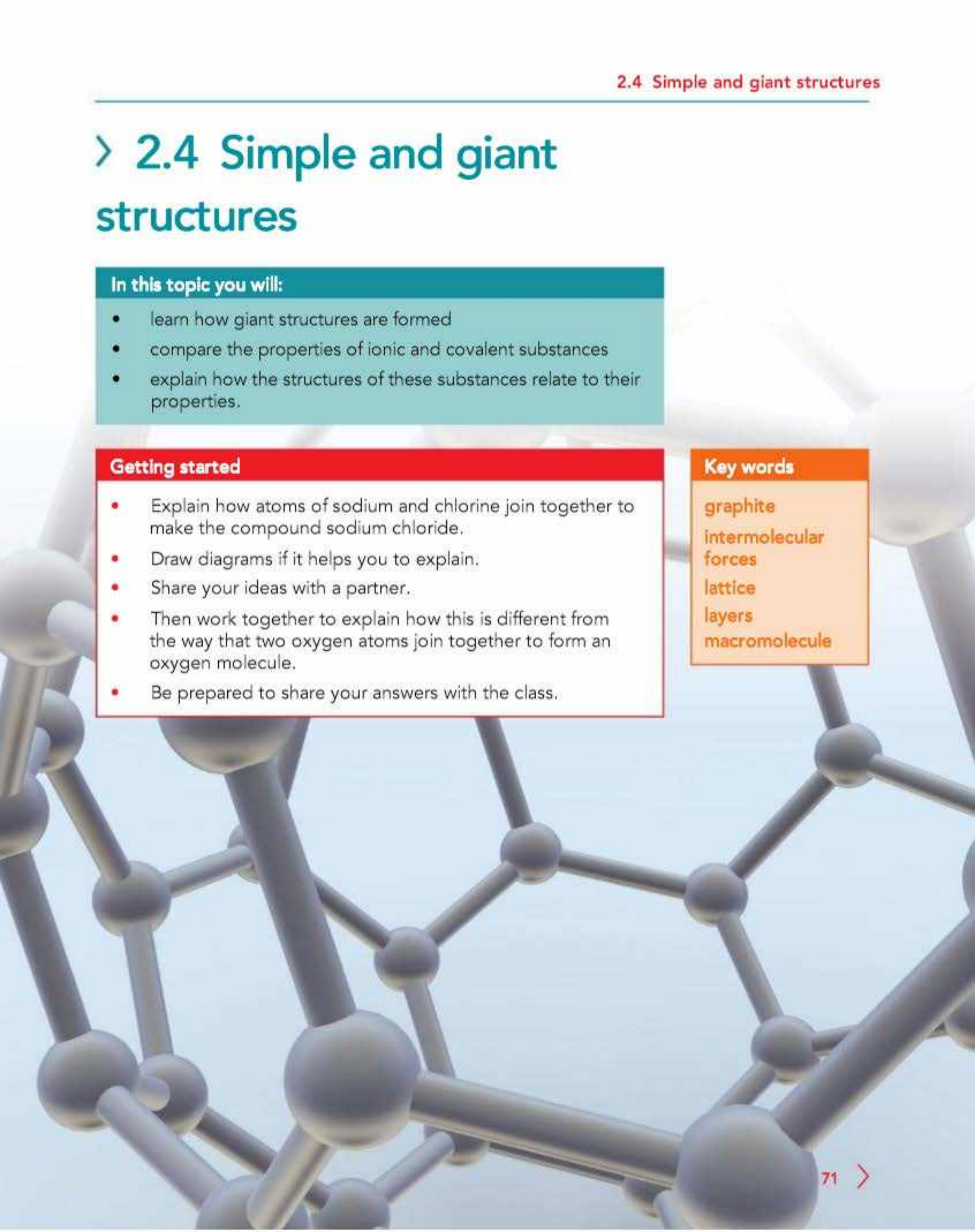
- learn how giant structures are formed
- compare the properties of ionic and covalent substances
- explain how the structures of these substances relate to their properties.

Getting started

- Explain how atoms of sodium and chlorine join together to make the compound sodium chloride.
- Draw diagrams if it helps you to explain.
- Share your ideas with a partner.
- Then work together to explain how this is different from the way that two oxygen atoms join together to form an oxygen molecule.
- Be prepared to share your answers with the class.

Key words

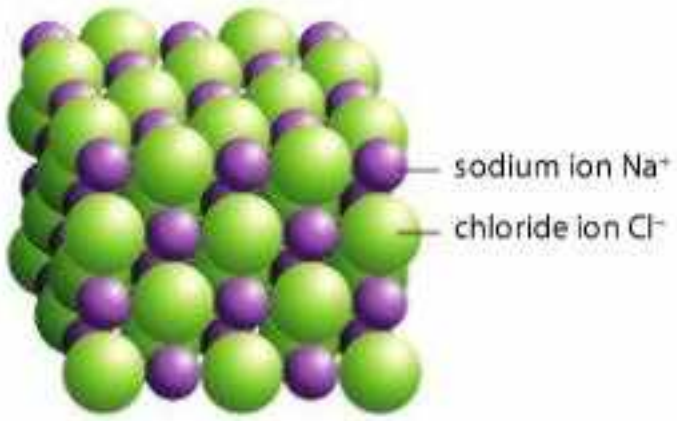
graphite
intermolecular forces
lattice
layers
macromolecule



Giant structures in ionic compounds

Sodium chloride is an ionic compound. The ions of sodium, Na^+, and chlorine, Cl^-, have equal and opposite electrical charges so they are strongly attracted to one another. These forces, called electrostatic forces, act in all directions and form ionic bonds.

The ions in sodium chloride make a giant structure known as a **lattice**.



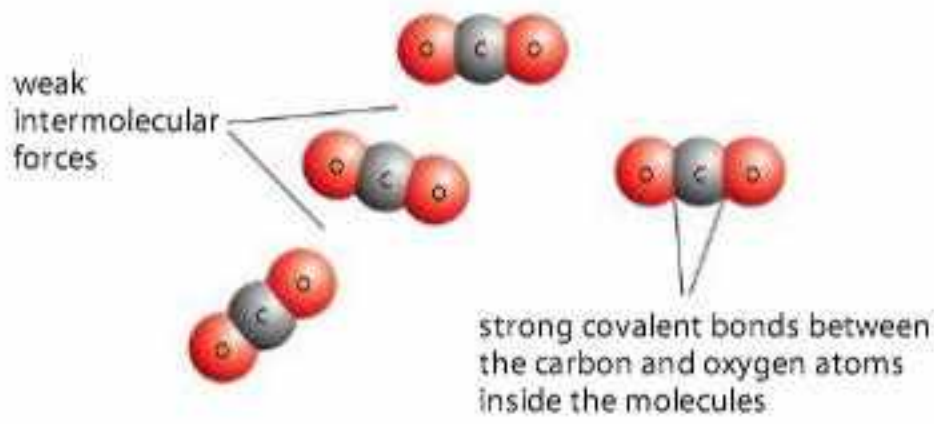
The giant lattice structure of sodium chloride

Sodium chloride crystals

In the lattice structure, a sodium ion, Na^+, is surrounded by six Cl^- ions. Sodium chloride forms crystals with a regular shape because the ions are arranged in a regular pattern.

Giant covalent structures

Many substances that have covalent bonds are formed of simple molecules: oxygen, carbon dioxide and methane, for example. This is because the forces holding the molecules together are very strong but the forces between the molecules are weak. The forces between the molecules are called **intermolecular forces**.



Carbon dioxide molecules

However, some covalent substances such as silicon dioxide have giant covalent structures.

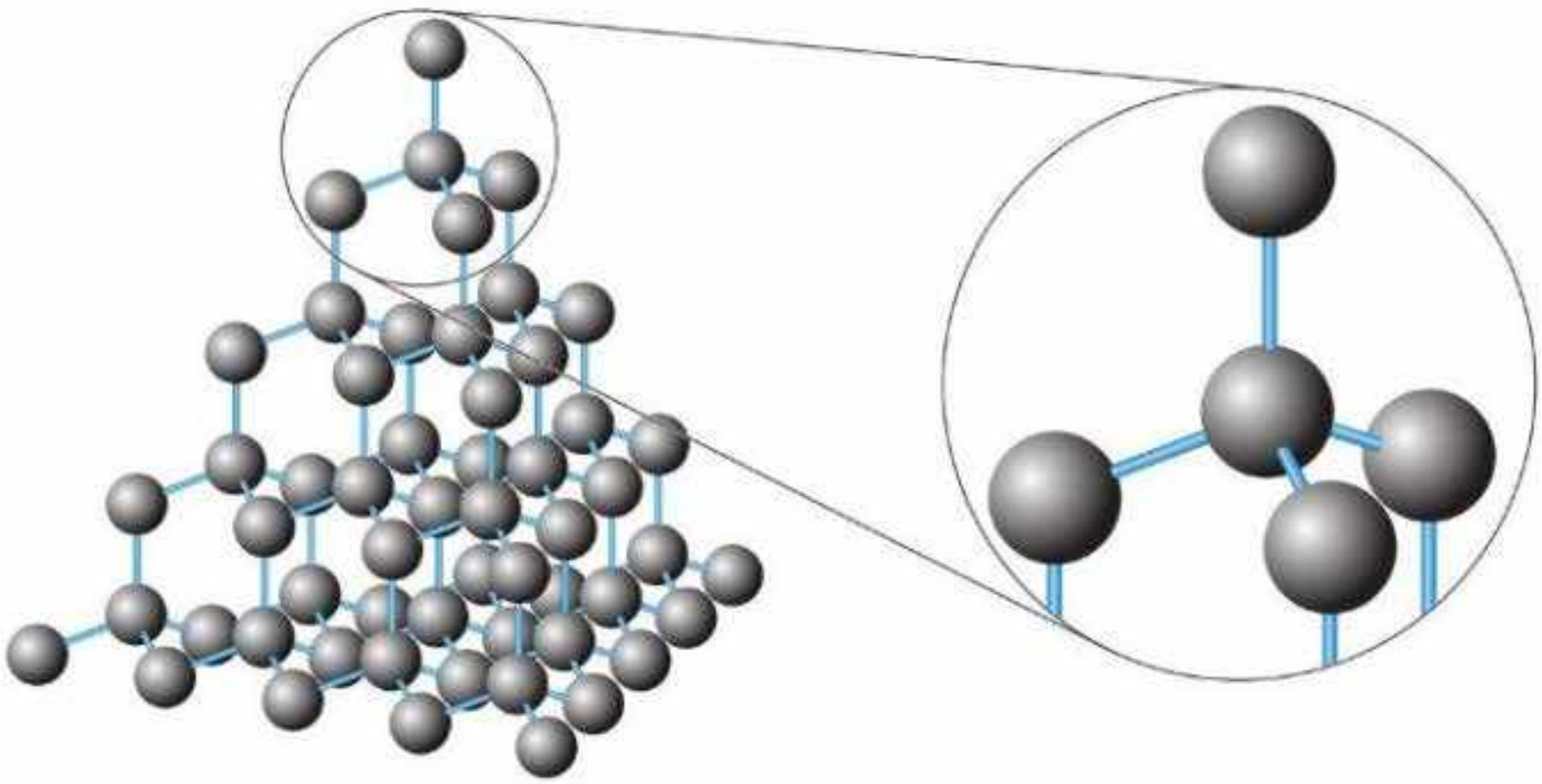
Giant structures of carbon

The carbon atoms in diamond form a giant structure. Each carbon atom forms four strong covalent bonds.

Diamond is the hardest material on Earth. It is not just used for jewellery but it is used for cutting and drilling tools. It is so hard because of the strong, rigid, three-dimensional structure of the lattice.

A diamond

Diamond drill bits have small pieces of diamond powder embedded in them



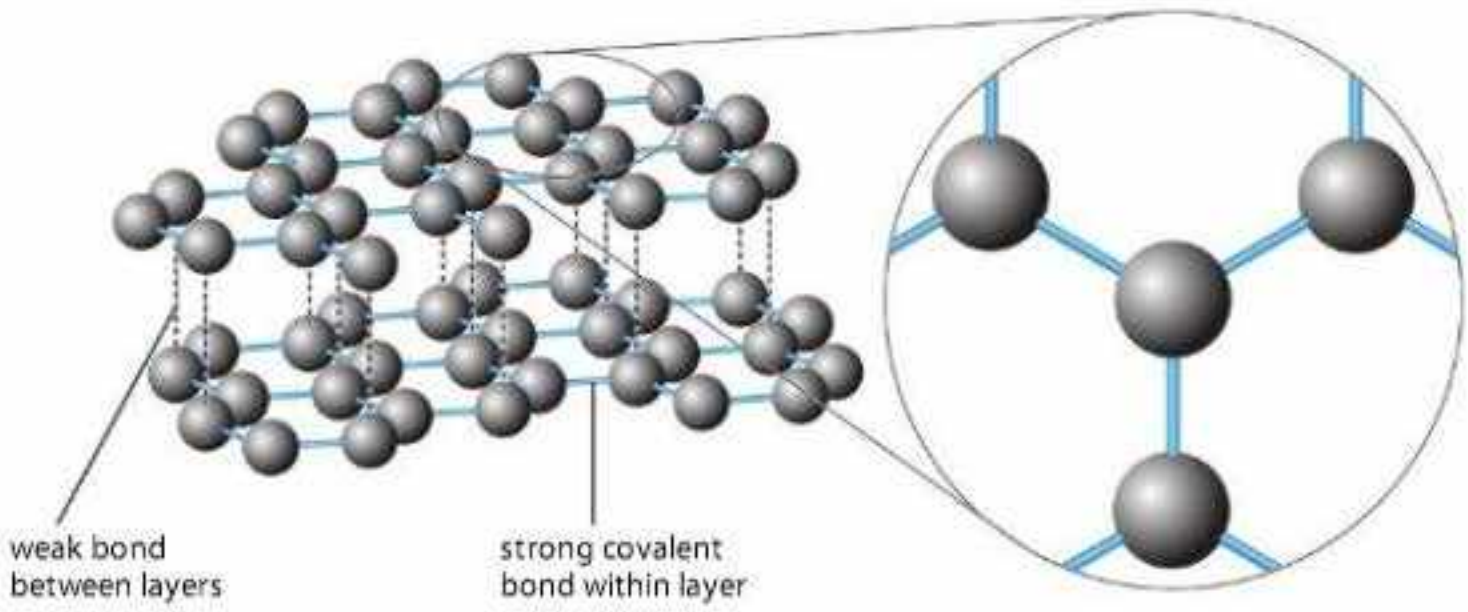
A diamond lattice structure; each carbon atom forms four strong covalent bonds

These large structures are called **macromolecules**.

Carbon also forms a giant structure for a very soft material, **graphite**.

Graphite is used for the 'lead' in pencils, and for lubricating moving parts in machines.

In graphite, the carbon atoms each make bonds with three other atoms. This forms **layers**, which can easily slide over one another. The covalent bonds between the carbon atoms in the layers are strong. The bonds between the layers are weak so the layers slide over each other very easily. This makes the surface very soft and it easily comes away. This is what happens when you make a pencil mark on paper.



Graphite giant structure; in graphite layers, each carbon atom forms three covalent bonds

Why are the properties of diamond and graphite so different when they are both made up of carbon atoms?

Activity 2.4.1

Building giant structures

You will need:

- poster-making equipment, such as coloured paper and/or card, glue, sticky tape, scissors, paper straws or wires to make covalent bonds, small polystyrene or foam balls or modelling materials to make particles such as atoms or ions.

Method

1. In a group of three, make models of the giant structures of sodium chloride, diamond and graphite. Each model should be labelled and have a list of its properties. Write an explanation of how the structure is linked to the properties of each of your giant structures.
2. Before you begin, discuss how you will construct your models. When you have completed the task, pass your work to another group to assess it.

How did making the models help me to understand the giant structures of sodium chloride, diamond and graphite?

Questions

1. How is an ionic bond different from a covalent bond?
2. When a metal joins with a non-metal, is a covalent or an ionic compound made?
3. Oxygen atoms join together to form an oxygen molecule. Explain what the word molecule means.
4. What is a macromolecule? Give an example.

Covalent and ionic substances have different properties

Melting and boiling points

Ionic substances have very high melting points and boiling points. This is because there are very strong electrostatic forces holding the ions together.

Covalent substances made from simple molecules have low melting points and boiling points because, although the forces holding the molecules together are strong, the forces between the molecules – intermolecular forces – are weak. This means that only a small amount of energy is needed to overcome these forces in order to melt or boil them.

Questions

Use this table to help answer questions 5–9 .

Substance	Melting point in °C	Boiling point in °C
sodium chloride	801	1413
methane	−182	−161
magnesium chloride	714	1412
ammonia	−77	−34
calcium oxide	2613	2850
chlorine	−101	−34.6
water	0	100

5 Is magnesium chloride an ionic compound or a simple molecule with covalent bonds? Give reasons for your answer.

6 Is ammonia an ionic compound or a simple molecule with covalent bonds? Give reasons for your answer.

7 Is ammonia a solid, liquid or gas at room temperature?

8 Why do magnesium chloride and calcium oxide have high melting points?

9 Why do methane and chlorine have low melting points?

10 Look at this photograph of copper sulfate crystals.

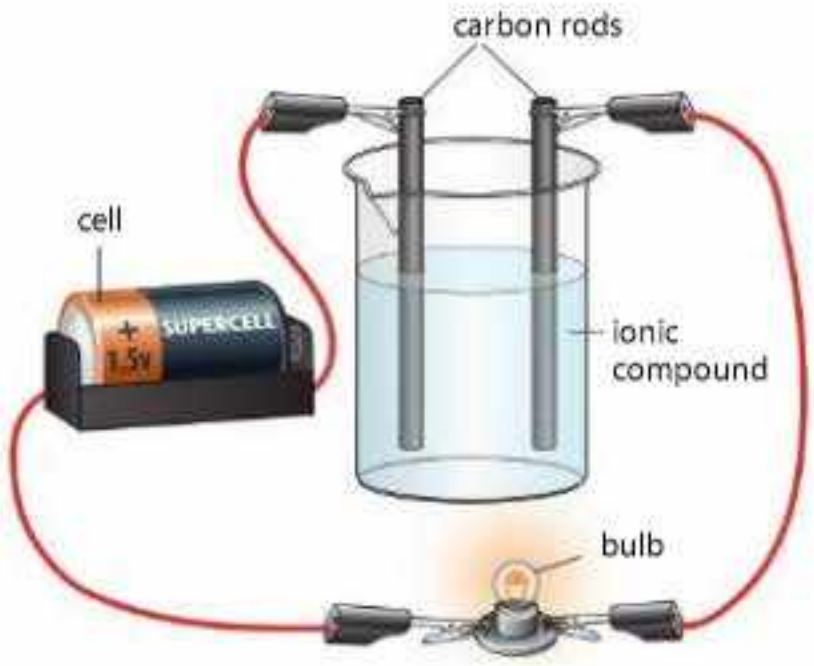
What sort of chemical bonds does this substance have?
Give a reason for your answer.

11 A substance has a melting point of 3078 °C and a boiling point of 4300 °C. What sort of chemical bonds does it have? Give a reason for your answer.

12 Silicon dioxide is a compound formed from two non-metals, silicon and oxygen. It is the chemical name for sand. It is a hard substance with a melting point of 1610 °C. Which properties of silicon dioxide suggest that it has a giant covalent structure?

Conducting electricity

Ionic compounds will conduct electricity if they are dissolved in water or if they are melted to form a liquid.



Ionic compounds can conduct electricity because the ions have an electrical charge. The ions must be free to move about and carry the electrical charge.

Covalent substances made from simple molecules do not conduct electricity.

Think like a scientist

Ionic compounds conducting electricity

You will need:

- safety glasses, surgical gloves, electrical wires, lamp, cell, carbon electrodes, beaker, scalpel or knife, selection of crystals of ionic compounds such as copper sulfate and sodium chloride, selection of crystals of ionic compounds, such as copper sulfate and sodium chloride.

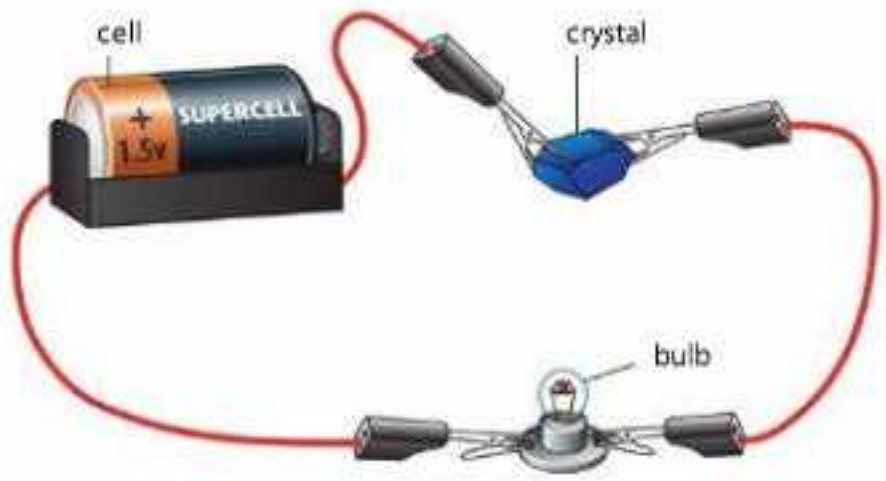
Safety

Some crystals and solutions such as copper sulfate are irritants. Take care when using these and avoid touching them. Wear surgical gloves and safety glasses.

Method

1 Set up your apparatus as shown in the diagram on the previous page, but without the solution. Test to check that the bulb is working before you start.
2 Place a solution of one of your ionic compounds in a beaker.
3 Add your beaker containing the ionic compound to your circuit, but do not connect the final link until you have checked your circuit carefully.
4 Complete the circuit.
5 Repeat this for all the solutions you are using.
6 Record your results.

7 Place one of the crystals in position in the circuit and then complete the circuit. Take care that the connections on the crystal are not touching.



8 Repeat this for all the crystals you are using.
9 Record your results.

Questions

1 Did all your ionic solutions conduct electricity?
2 Explain your answer.

Continued

Questions

3 Did all the ionic crystals conduct electricity?

4 Explain your answer.

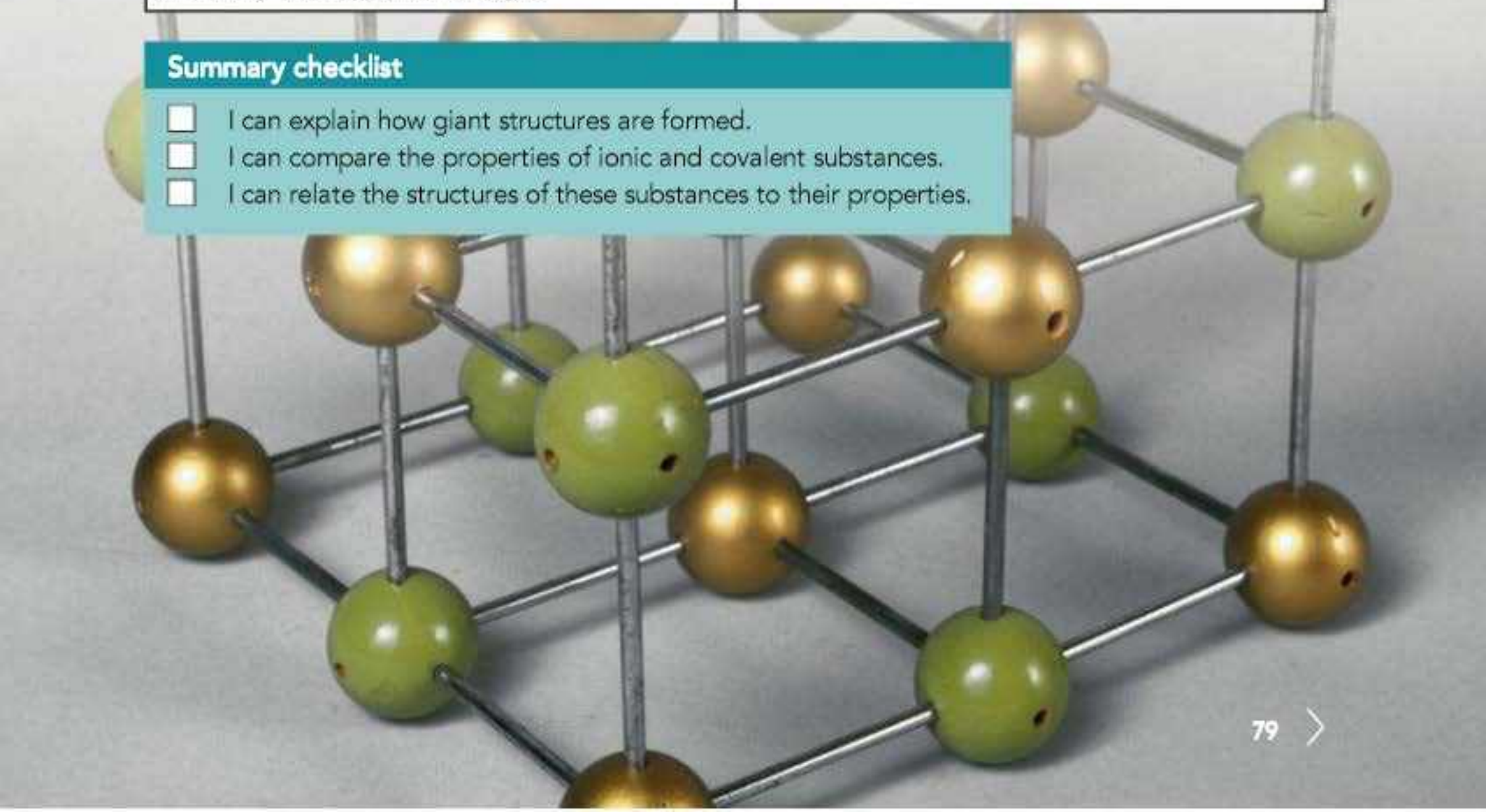
5 Predict, with reasons, what would happen if you used a covalent substance in place of an ionic crystal or solution.

Summary of the properties of ionic and covalent substances

Ionic substances	Covalent substances
Compounds made from ions form giant lattices. These ionic compounds have very high melting points and boiling points because the forces between the ions are so strong.	Substances made from simple molecules have low melting points and boiling points because there are only weak forces between the molecules. Atoms that share electrons can form giant structures called macromolecules. These have very high melting points because the atoms are joined by strong covalent bonds.
When ionic compounds are dissolved in water or melted, they can conduct electricity because the ions are free to move about and carry the electrical charge.	Simple covalent molecules do not conduct electricity.

Summary checklist

- ☐ I can explain how giant structures are formed.
- ☐ I can compare the properties of ionic and covalent substances.
- ☐ I can relate the structures of these substances to their properties.



Project: Building the Periodic Table

Scientists often try to make sense of large amounts of information by grouping similar things together. For example, they group similar types of animals together such as mammals, fish, insects and so on.

The same happened with the elements as more and more were discovered. Three important scientists contributed to the Periodic Table that we use today.

The timeline and information below explain a little about their ideas and work.

Your task is to make a report, a presentation using slides or a presentation in any other way to explain and describe the development of the Periodic Table. You should stress the way that scientists collaborate, building on the work of others and changing their ideas once they have more information. You can do this in groups of two or three.

-------- 1817 --------	-------- 1864 --------	-------- 1869 --------
Johann Dobereiner	John Newlands	Dmitri Mendeleev
'law of triads'	every eighth elements had similar properties	modified and extended John Newlands's work

Johann Dobereiner grouped elements in threes based on their properties and their appearance: this is his 'law of triads'.

At about the same time, other scientists began to find out the mass of the atoms of the elements.

This is one of Johann Dobereiner's triads. The numbers are the atomic numbers of the elements.

salt forming elements	
lithium	3
sodium	23
potassium	39

In 1864, there were 63 known elements. John Newlands arranged them in order of the mass of their atoms, starting with the lightest. He noticed that every eighth element in this arrangement had similar properties, a similar element appeared periodically. This pattern did not continue through all the elements.

Continued

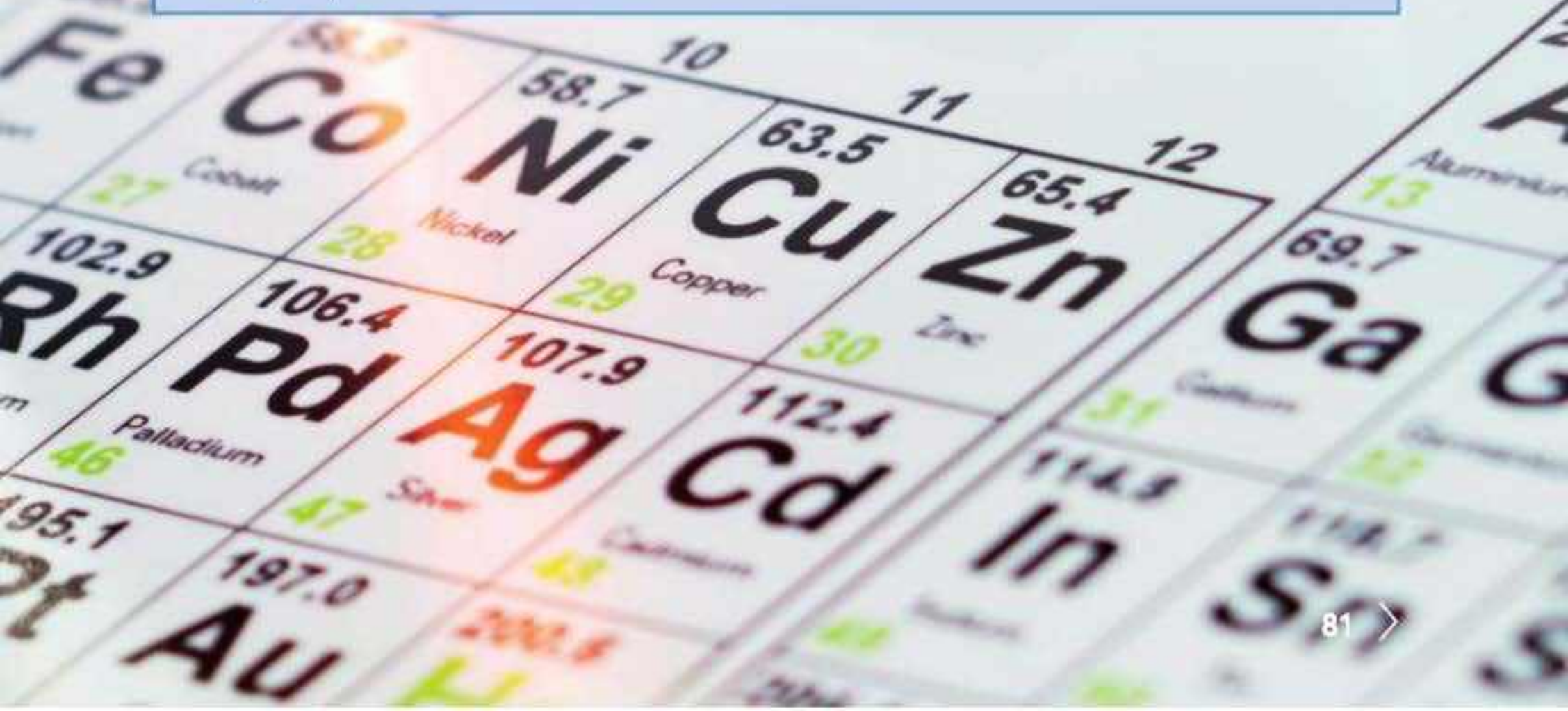
In 1869, Dmitri Mendeleev used John Newlands's ideas. He left gaps in the arrangement of elements, so that the pattern of eights continued and the elements with similar properties were grouped together.

Mendeleev predicted the properties of some undiscovered elements that would fill the gaps in his 'periodic table'. These predictions turned out to be correct. His table forms the basis of the Periodic Table we use today.

Here is a list of questions that you may find helpful when preparing your report or presentation.

1. Find out a little background information about Johann Dobereiner.
   Such as: Where and when was he born? Where did he work? When did he die?
2. Explain how Johann Dobereiner arranged the elements.
3. Suggest how John Newlands was influenced by Johann Dobereiner's ideas.
4. Find out a little background information about John Newlands.
   Such as: Where and when was he born? Where did he work? When did he die?
5. Why did the pattern of elements in Newlands's table not continue?
6. Find out a little background information about Dmitri Mendeleev.
   Such as: Where and when was he born? Where did he work? When did he die?
7. Describe how Dmitri Mendeleev modified Newland's table.
8. Suggest why Mendeleev's table did not contain helium, argon or neon.
9. How many elements are known today?
10. Some elements today are made by scientists and are known as synthetic elements. Name some of these. Try to find the names of some of the newest elements.

Make your presentation to the class.



Check your progress

2.1 The table shows some information about four elements. These elements are from the same group in the Periodic Table. They are given in the same order as in the Periodic Table.

Element	Melting point in °C	Boiling point in °C	Reaction with water
lithium	180	1342	Gives off bubbles of gas and gives off heat
sodium		883	
potassium	63		Gives off gas and gives off so much heat that it catches fire
rubidium	39	688	Explodes with such force that the container cracks.

There is a trend in the melting points and boiling points of these elements.
Use the trend to predict the following:

a the melting point of sodium **[1]**

b the boiling point of potassium **[1]**

c The elements all react with water to produce a gas. Name the gas. **[1]**

d Use the information about the reaction with water to predict the reaction between sodium and water. **[1]**

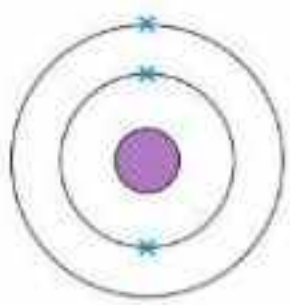
e The following are the mass numbers of the four elements in the table above.

23	7	39	85

Match the numbers with the elements. **[1]**

f What does the mass number tell you about the atom of each element? **[1]**

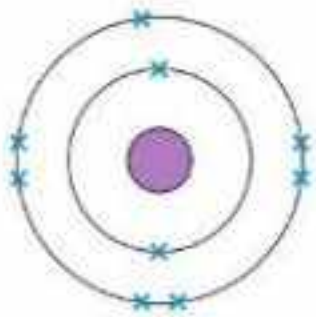
g Lithium has two electron shells. The electronic structure is 2,1.
This can be seen in the diagram below.



lithium

Sodium has the electronic structure 2,8,1. Draw a similar diagram to show the electronic structure of sodium. **[3]**

2.2 The fluorine atom has the electronic structure 2,7. This is shown in the diagram below.



fluorine

a Draw a similar diagram to show the electronic structure of a fluorine ion. **[1]**

b Why is a fluorine ion more stable than a fluorine atom? **[1]**

c The symbol for a fluorine atom is F. Write the symbol for a fluorine ion. **[1]**

2.3 For each of the following, state whether this applies to a substance with covalent or ionic bonds.

a When a metal joins with a non-metal to form a compound. **[1]**

b When two atoms share electrons. **[1]**

c When two non-metals join together. **[1]**

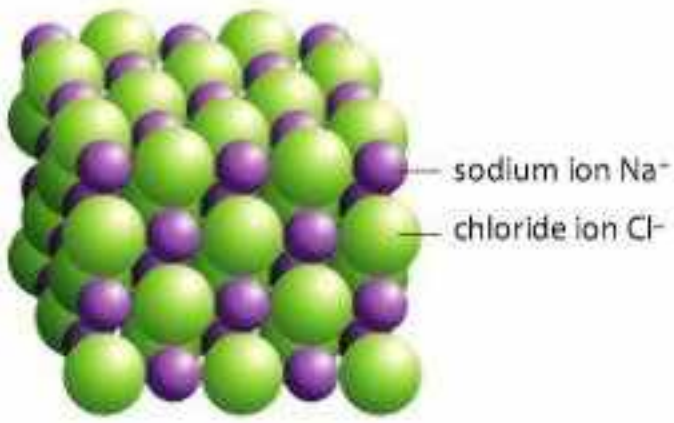
d When a compound that is dissolved in water conducts electricity. **[1]**

e When atoms gain or lose electrons. **[1]**

2.4 The diagram shows a molecule of methane.

Write the formula for a molecule of methane. **[1]**

2.5 The diagram shows the lattice structure of sodium chloride.



a What holds the lattice together? **[1]**

b What does this lattice structure tell you about the melting point and boiling point of sodium chloride? **[1]**

3 Forces and energy

3.1 Density

In this topic you will:

- discover what is meant by density
- find out how to calculate density
- compare the densities of solids, liquids and gases
- understand and predict whether objects will float or sink in water.

Getting started

Work in groups to discuss answers to these questions.

1 What is the scientific meaning of the word volume?

2 Which of these has a larger volume?
- 1 kg of rock
- 1 kg of feathers

3 Which of these has a larger mass?
- 1 cm^3 of polystyrene
- 1 cm^3 of iron

Key words

density
hollow
irregular
regular
solid

Mass and volume

People often think that materials such as rocks or metals are heavier than objects such as feathers or polystyrene. This is not always true. A very large block of polystyrene may have a larger mass than a small piece of metal.

Think about the food containers and the nails in the pictures.

The food containers are made from polystyrene. They feel very light, because they have a large volume and a small mass. The containers are also **hollow**, which means they have a space filled with air inside them.

The nails are made from iron. The nails feel heavy because they have a high mass and a small volume. The nails are also **solid**. The word solid in this case means that each nail has no space with air inside. The word solid can be used as the opposite of hollow.

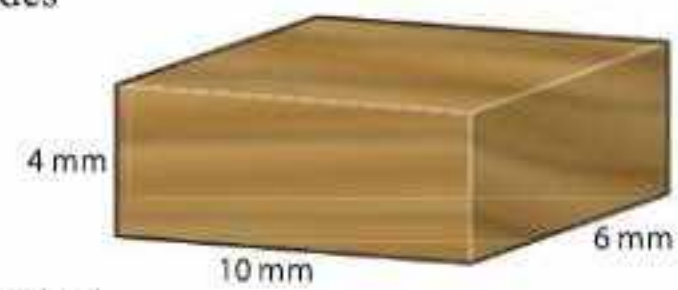
One of the polystyrene food containers has a larger mass than one of the nails. However, the same volume of iron has a larger mass than the same volume of polystyrene.

We use the word **density** to describe this difference.

Calculating volume

When calculating the volume of a **regular** block of material, we measure the lengths of the sides. When talking about a block of material, regular means that we can use an equation to calculate its volume.

This block of wood has a regular shape. The lengths of its sides have been measured.



You can work out the volume of the block by multiplying the lengths of the sides:

$10 \times 6 \times 4 = 240\ mm^3$

The unit is mm^3 because the lengths of the sides are in millimetres.

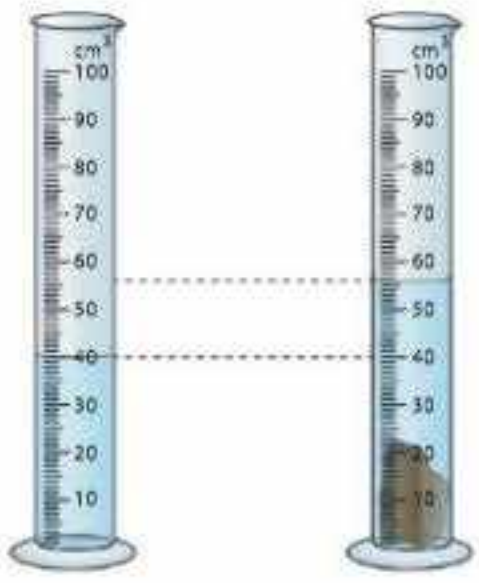
It does not matter in what order you multiply the sides.

Try multiplying the numbers in a different order. You will get the same answer.

If the shape of the material is **irregular**, then we work out the volume using the displacement method. Irregular means the sides or angles of the shape are not equal. The object is placed into a measuring cylinder of water. The increase in volume of the water is the volume of the object.

This piece of rock has an irregular shape.

It is placed into a measuring cylinder containing 40 cm^3 water:



The water rises to the 56 cm^3 mark. So, the volume of the rock is:

$56 - 40 = 16\ cm^3$.

The unit is cm^3 because the measuring cylinder measures in cm^3.

Calculating density

We say that iron has a higher density than polystyrene. Density means mass per unit volume.

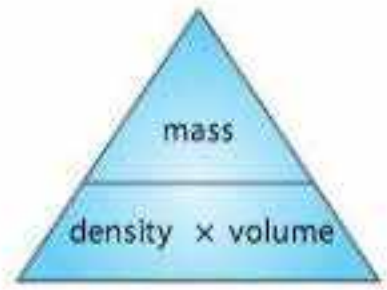
A solid block of iron measuring 1 cm × 1 cm × 1 cm has a mass of 7.9 g.

A solid block of polystyrene measuring 1 cm × 1 cm × 1 cm has a mass of 0.05 g.

We can calculate density using the equation:

$$\text{density} = \frac{\text{mass}}{\text{volume}}$$

or using the formula triangle shown here.



Because density is mass divided by volume, the unit of density is the unit of mass divided by the unit of volume. For example:

- if mass is in g and volume is in cm^3 then density will be in g/cm^3
- if mass is in kg and volume is in m^3 then density will be in kg/m^3.

This leads to the definition of density: density is mass per unit volume of a substance.

Using the example of the block of iron	Using the example of the polystyrene
volume = 1 cm × 1 cm × 1 cm = 1 cm^3 mass = 7.9 g density = $\frac{7.9}{1}$ = 7.9 g/cm^3 We say that iron has a density of 7.9 g/cm^3.	volume = 1 cm × 1 cm × 1 cm = 1 cm^3 mass = 0.05 g density = $\frac{0.05}{1}$ = 0.05 g/cm^3 We say that polystyrene has a density of 0.05 g/cm^3.

Comparing densities

This table shows the densities of some materials:

material	helium	air	wood	water	concrete	aluminium	osmium
density in g/cm^3	0.00018	0.0012	0.35 – 0.95	1.0	2.4	2.7	22

Look at the densities of the materials in the table. Helium and air are gases. Gases have lower densities than liquids or solids because the particles in a gas are far apart.

As particles in a material get packed closer together, the density of the material increases. So, the materials with the highest densities are all solids.

For the elements, the density usually increases as the atomic number increases. Osmium has atomic number 76 and is more dense than iron, which has atomic number 26.

Did you know, the substance with the highest density in the universe is found in collapsed stars? The forces in collapsed stars are so large that atoms are compressed into very small spaces. This material is called neutronium and has a density of 100 000 000 000 000 g/cm^3. One teaspoon of neutronium would have a mass of 500 million tonnes.

Floating and sinking

Look at the densities of some of the materials in the table. Compare their densities with the density of water. What do you notice about the densities of materials, such as wood, that float on water?

You can tell whether something will float or sink in water by comparing its density with that of water.

- If something is more dense than water, it will sink in water.
- If something is less dense than water, it will float in water.

Some objects, such as floats that are used in swimming pools, are designed to have a very low density. These objects are made from materials such as polystyrene, or they are hollow with only air inside.

Modern ships are built from steel that has a density of 8–9 g/cm^3. That is much more than the density of water, which is 1.0 g/cm^3. Some of the largest ships have a mass of over 500 000 000 kg. So, how do they float in water?

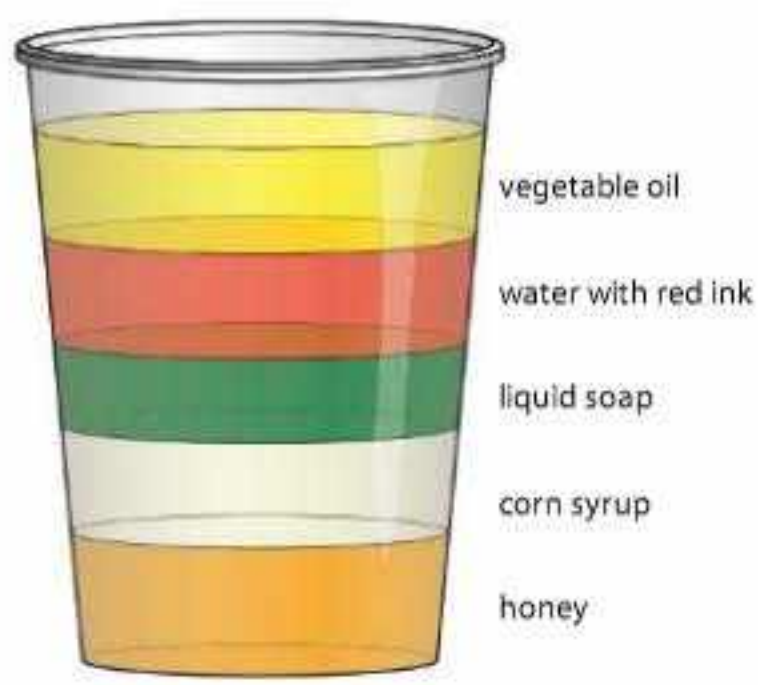
Ships are not solid blocks of steel. There are large spaces inside ships that contain only air. That means the ship has a very large volume, so the average density of the *whole* ship is less than the density of water. The average density is the mass of all the materials in the ship, including the air, divided by the total volume of the ship.

The density of a ship changes when its mass changes. Cargo, passengers and fuel all add mass to a ship, which increases its density. The density of the ship in the picture is too high, because of the mass of the cargo.

Liquids of different density

When liquids are added together carefully, the less dense liquids will float on the more dense liquids. The liquids that do not mix will form separate layers.

The picture shows what happens when some different liquids are added together.



Crude oil is less dense than water. So, when crude oil spills out of ships or out from oil wells, the oil floats on the water. The photograph shows black oil being washed up on a beach. Oil spilling from ships is a major source of water pollution.

Gases and liquids

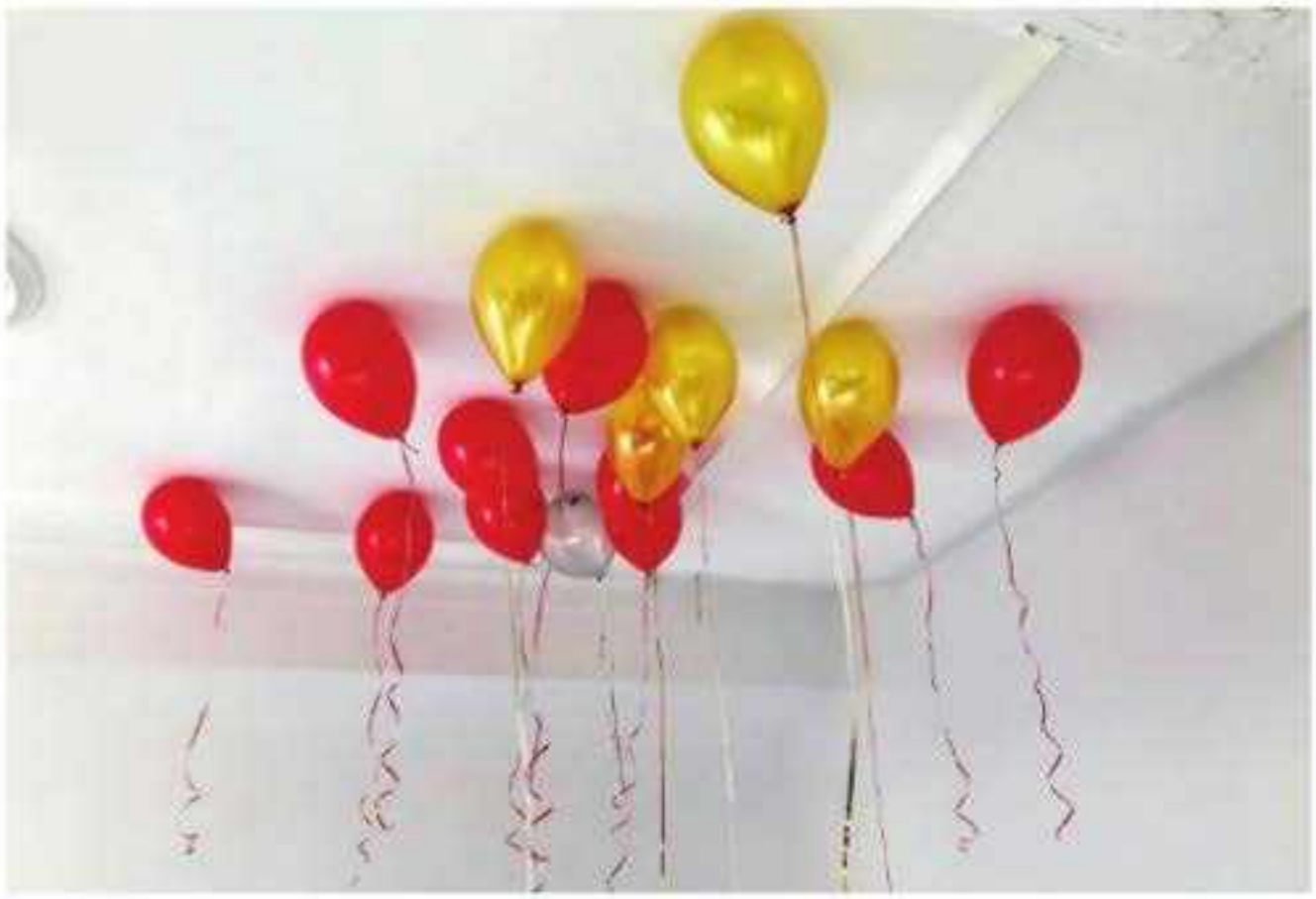
Gases are less dense than liquids because the particles in a gas are much further apart than in a liquid.

Drops of rain fall down because the water in the drops is more dense than air.

The gas in fizzy drinks is carbon dioxide. Carbon dioxide has a density of 0.002 g/cm^3. The liquid in most drinks has a density close to 1.0 g/cm^3, as the drinks are mostly water. This difference in density explains why the bubbles of gas in a fizzy drink rise to the top. The gas is a lot less dense than the liquid.

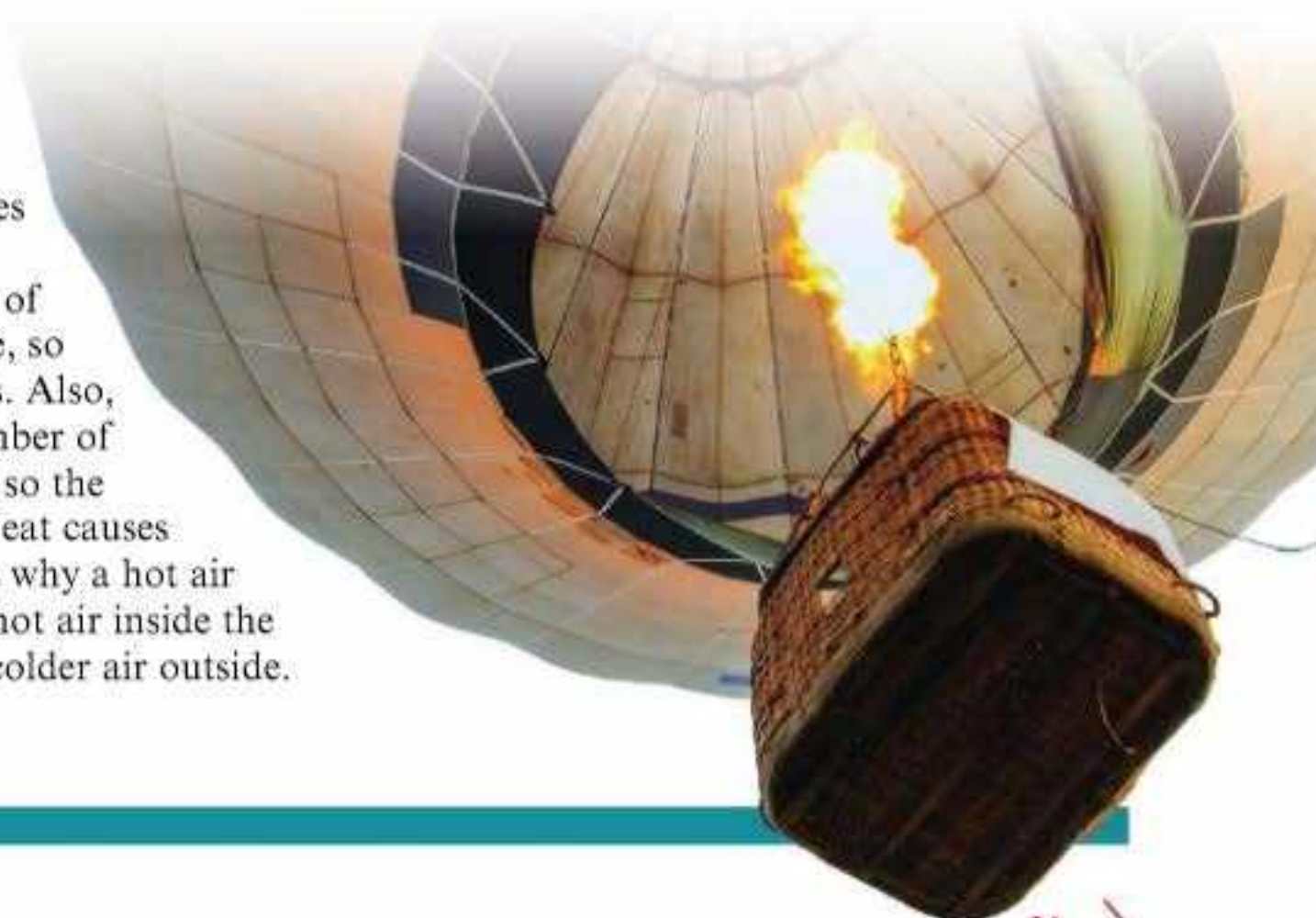
Gases of different density

Gases have lower densities than solids or liquids, but not all gases have the same density. Helium is one of the least dense gases. Helium is sometimes used to fill balloons. A balloon filled with helium will float in air because the balloon and gas is less dense than the air. The balloons in the picture have floated up through the air.



Hydrogen gas is even less dense than helium, but is not used to fill balloons because hydrogen forms an explosive mixture with air.

Solids and liquids are very diffi cult to compress because their particles are already in contact. Gases are easy to compress because their particles are far apart. When a gas is compressed, the same number of particles is in a smaller volume, so the density of the gas increases. Also, if a gas expands, the same number of particles is in a larger volume, so the density of the gas decreases. Heat causes a gas to expand. That explains why a hot air balloon can float because the hot air inside the balloon is less dense than the colder air outside.



Questions

1 Look at the densities of these materials:

- pine wood 0.41 g/cm^3
- polycarbonate 1.2 g/cm^3
- polyethene 0.95 g/cm^3
- water 1.0 g/cm^3

a Which of these materials has the lowest density?

b i Which of these materials will sink in water?

ii Explain why the material will sink in water.

2 a Copy and complete the equation for density.

density =

b A block of aluminium has a volume of 5.0 cm^3 and a mass of 13.5 g. Calculate the density of the aluminium. Give your answer in g/cm^3.

c Explain whether the block of aluminium will float or sink in water.

3 The diagram shows a block of wood.

a Calculate the volume of the block of wood. Give your answer in cm^3.

b The block of wood in the diagram has a mass of 54 g. Calculate the density of the wood. Give your answer in g/cm^3.

c Explain whether the block of wood will float or sink in water.

4 Sea water is placed in a tank. The volume of the sea water is 10 m^3. The mass of the sea water is 10 300 kg.

a Calculate the density of the sea water. Give your answer in kg/m^3.

b Pure water has a density of 1000 kg/m^3. Explain what will happen to a block of material with a density of 1020 kg/m^3 when placed into:

i sea water

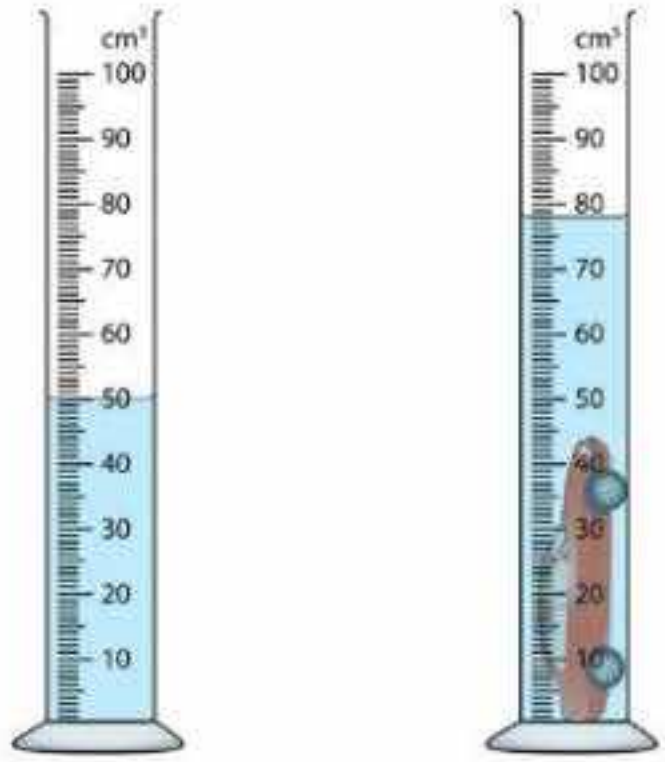
ii pure water.

5 Copper has a density of 8.96 g/cm^3.

a Calculate the mass of copper that has a volume of 20 cm^3.

b Calculate the volume of copper that has a mass of 4.5 g.

6 A toy car is placed into a measuring cylinder of water as shown in the diagram.



a Use the diagram to calculate the volume of the toy car.

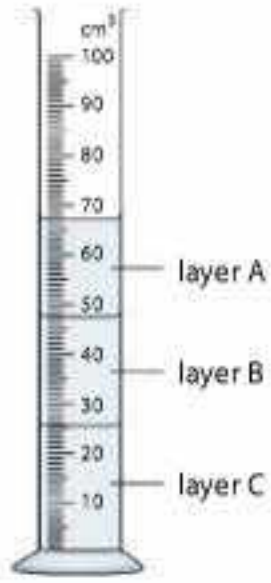
b The toy car in the diagram has a mass of 84 g. Calculate the density of the toy car. Give your answer in g/cm^3.

c The toy car in the diagram is made from steel and plastic. Steel has a density of 7.8 g/cm^3. Suggest **two** reasons for the difference between this value and the density you calculated in part **b**.

7 This table shows the densities of three liquids.

liquid	density in g/cm^3
kerosene	0.81
mercury	14.00
water	1.00

These three liquids are poured into a measuring cylinder and form three separate layers, as shown in the diagram.



Use information in the diagram and in the table to identify the liquids in the three layers, A, B and C.

8 Zara wants a party balloon that will float in air. She will hold the balloon on a string, as shown in the diagram.

State the property of the gas in the balloon needed to make the balloon float in air.

9 A hot air balloon floats in air because the density of air decreases as its temperature increases. Suggest why hot air balloons usually fly in the early morning and late evening and not in the middle of the day.

Activity 3.1.1

Densities of some regular objects

In this activity, you will calculate the densities of some different materials, using the mass and volume of regular objects.

You will need:

- a balance, a calculator, a ruler that can measure in millimetres, some regular objects made from different materials.

Method

1. Measure the length, width and height of each object. You should measure to the nearest 0.1 cm.
2. Calculate the volume of each object in cm^3.
3. Measure the mass of each object in grams. Remember to check that the balance is reading 0.0 g before you place the material on the balance.
4. Calculate the density of each material using the volumes and masses that you measured.
5. Record your results in a table.

Questions

1. The density of water is 1.0 g/cm^3. Use this value and your calculated densities to predict which materials will float and which will sink in water. If you have time, you could test these predictions.
2. Explain the importance of making sure the balance is reading 0.0 g before you place the material on the balance.
3. Some blocks of material may be old and slightly damaged, such as the one shown in the diagram.

   a. Explain why your calculated value for the volume of these damaged objects may not be correct.
   b. Explain whether the masses of these damaged objects will be correct.
   c. Suggest how any differences in volume and mass would affect the calculated value of density.

Think like a scientist

Densities of irregular objects

In this investigation, you will calculate the densities of irregular objects.

You will need:

- a balance, measuring cylinders of various sizes, water, a calculator, small irregular objects that will sink in water and will fit inside the measuring cylinders.

Safety

Do not drop heavy objects into glass measuring cylinders; either use a plastic measuring cylinder, or hold the glass measuring cylinder at an angle, so that the object slides down slowly.

Method

1. Measure the mass of each object in grams. Remember to check that the balance is reading 0.0 g before you place the object on the balance.
2. Use the displacement method to calculate the volumes of your objects in cm^3.
3. Calculate the density of each object using the volumes and masses that you measured.
4. Record your results in a table.

Questions

1. Explain why you should read the volume on a measuring cylinder with your eye at the same level as the surface of the liquid.
2. Explain how you would use the displacement method to calculate the volume of an object that floats in water. Remember that the displacement method only gives the correct volume of an object that is completely under the water.
3. Explain how you would use the displacement method to calculate the volume of an object that sinks in water but is too big to fit in a measuring cylinder.
4. Sofia and Zara are calculating the densities of irregular objects. Zara calculates the density of a small toy made from wood to be 5.27 g/cm^3. Sofia says this result is anomalous. Explain whether this result is likely to be correct or anomalous.

Continued

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 how to calculate the volume of a regular object.
- I understand how to calculate the volume of an irregular object.
- I know the equation for density.
- I can use density to predict whether an object will float or sink in water.

Summary checklist

- ☐ I can recall what is meant by density.
- ☐ I can recall the equation for density.
- ☐ I can use the equation for density and can calculate density, mass or volume.
- ☐ I know how to use density to predict whether an object will float or sink in water.

3.2 Heat and temperature

In this topic you will:

- understand the difference between heat and temperature.

Getting started

Work in groups to discuss answers to these questions.

1 Describe how you could increase the temperature of water in a beaker.

2 a Which of these needs more thermal energy to increase its temperature by 10 °C:
   - a glass containing 0.25 kg of water
   - 375 000 kg of water in a swimming pool?

   b Explain your answer.

Heat

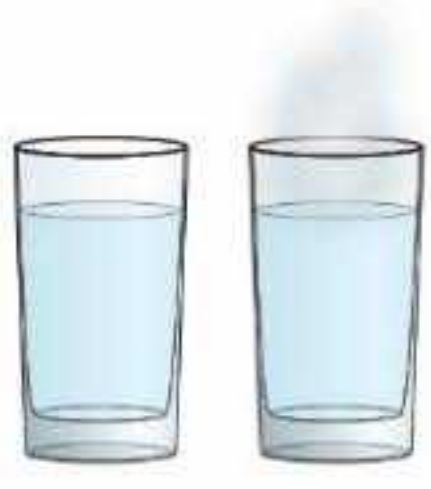
You will remember that we described thermal energy in Stage 7. Thermal energy can be transferred between objects. Thermal energy can be stored in an object, but the thermal energy that is stored will eventually dissipate into the surroundings. Thermal energy is measured in joules.

When the thermal energy of an object increases, the particles in the object start to vibrate faster. The energy of the particles increases.

Heat is a measure of the energy in the particles.

Heat is the total thermal energy of the vibrating particles in an object.

Look at the glasses of water in the pictures:



The volume of water is the same in both glasses. One has a higher temperature than the other, meaning that the thermal energy (heat) is greater. The water at the higher temperature contains particles that are moving faster. The number of particles in both glasses of water is the same, but the total thermal energy (heat) of the particles in the water with the higher temperature is higher.

The water in both glasses is at the same temperature. There is a larger volume of water in one glass, so it has more particles. As there are more particles, the total thermal energy (heat) of all these particles is greater than in the water with fewer particles. That means the larger volume of water has greater total thermal energy (heat) than the smaller volume, even when their temperatures are the same.

Temperature

Temperature is **not** the same as heat. Temperature gives us information about two things:

- the direction that thermal energy will be transferred
- the average energy of the particles in an object.

The ice cream in the picture is at a lower temperature than the surroundings.

The ice cream has been taken from a freezer at −20 °C. The air in the room is at 24 °C, which is a temperature difference of 44 °C (from −20 to 24 °C). Thermal energy is transferred from the air to the ice cream because of this temperature difference.

The larger a temperature difference between two objects, the faster the thermal energy transfer.

Temperature also gives us information about the energy of the particles.

Heat tells us about the *total* energy of the particles.

Temperature tells us the *average* energy of the particles.

This means temperature is a good way of comparing the particle energy between objects of different size or made from different materials.

Look at the picture of the hot soup and the cold water.

The soup is at a higher temperature than the water.

The soup and the water in the picture are made from different materials, so the types of particles are different. The mass and volume of the soup and the water are also different, so the numbers of particles are different.

When we say the temperature of the soup is higher than the temperature of the water, we mean the *average* energy of the soup particles is higher than the *average* energy of the water particles.

Another way to think of this is that 100 particles in the soup have more energy than 100 particles in the water.

Heat and temperature in a sparkler

A sparkler is a small hand-held firework.

When you hold a sparkler, some of the sparks may fall on your hand. The sparkler can be at a temperature of about 1000 °C, but one spark does not cause serious burns. Why not?

The reason is the mass of the spark is very small and the temperature difference between the air and the spark is very large.

As there are fewer particles in the spark than in the main part of the sparkler, the total particle energy is much smaller. Therefore, the total thermal energy or heat of the spark is very small.

As the temperature difference between the spark and the air is large, thermal energy will be transferred from the spark to the air quickly. In the short time the spark takes to fall to your skin, its temperature, and heat, have both decreased significantly.

How low can you go?

As the temperature of an object decreases, the particles move more slowly. A scientist called Kelvin in the 1800s predicted that particles would eventually stop moving if the temperature is low enough. Kelvin also predicted that if particles stop moving, this would be the lowest possible temperature.

Kelvin called this temperature absolute cold. We now call this temperature absolute zero. Absolute zero is −273 °C.

It is not actually possible to make particles stop moving completely, but scientists have created temperatures within billionths of a degree of absolute zero in laboratories!

Remember:

- heat is the *total* thermal energy in an object, which is the total energy of all the particles
- temperature is the *average* energy of the particles in an object.

Questions

1 a Which of these is the unit of heat?

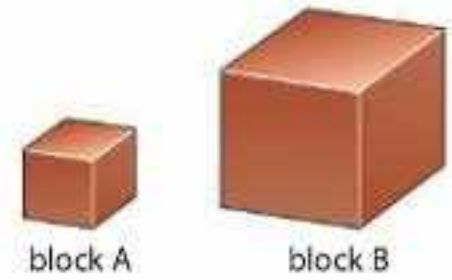
J **°C** **N** **m^3**

b Which of these is the unit of temperature?

J **°C** **N** **m^3**

2 The diagram shows two blocks of copper, A and B.

- block A has a mass of 10 g and a temperature of 25 °C
- block B has a mass of 80 g and a temperature of 25 °C.



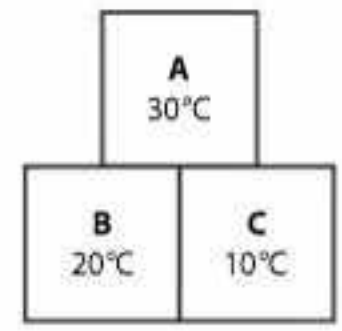
a Compare the temperatures of blocks A and B.

b Compare the heat of blocks A and B.

3 a Describe what is meant by the heat of an object.

b Describe what is meant by the temperature of an object.

4 The diagram shows three objects, A, B and C that are in contact with each other. The three objects are at different temperatures when they are first placed in contact.



In which direction will thermal energy be transferred?

A → B only

A → C only

A → B and A → C only

A → B and A → C and B → C

5 Zara makes this statement:

> If object X has a higher temperature than object Y, then X must always have more heat than Y.

Is Zara's statement true or false?

Explain your answer.

Activity 3.2.1

The Mpemba effect

In this activity, you will investigate how the temperature of water affects the time taken to freeze the water.

You will need:

- identical containers – such as plastic cups – to hold a small volume of water, access to a freezer, water, measuring cylinder, heat source, thermometer, permanent marker, timer.

Safety

If using plastic cups, do not use water at a temperature higher than 60 °C, so the cups do not melt.

Method

1. Prepare a range of cups by writing your chosen temperature on the side of each cup. For example, one cup each at 10 °C, 20 °C and 30 °C.
2. Add equal volumes of water at the chosen temperature to each cup. A volume of 10–20 cm^3 is enough.
3. Place the cups in the freezer and start the timer.
4. Check the water at equal time intervals for signs of freezing. Record the time taken for each sample to form ice across the surface of the water.

While waiting for the water to freeze, begin to answer the questions.

Questions

1. Draw a table to record your results.
2. Assume the temperature inside the freezer is −18 °C.

   Calculate the temperature difference between −18 °C and the temperature of each sample of water that you used. Remember that you will be subtracting a negative number from a positive number.
   For example, 40 °C − (−18 °C) = 58 °C.
3. What is the link between temperature difference and the speed of thermal energy transfer?
4. Describe any trends in your results.

Think like a scientist

Measuring heat and temperature

In this investigation, you will make measurements of both heat and temperature. Work in groups of three of four.

You will need:

- the apparatus shown in the diagram.

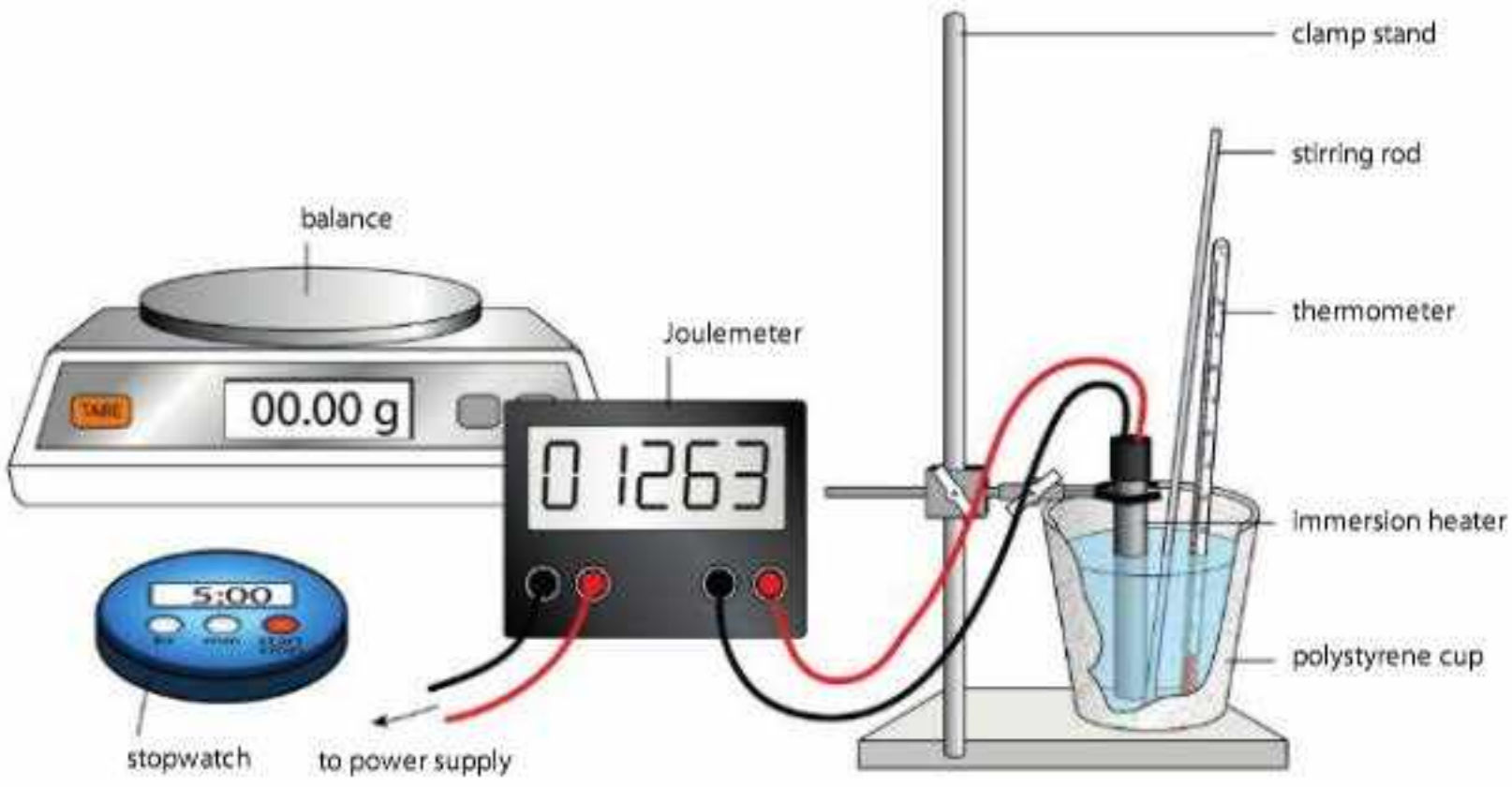
Safety

Do not touch the immersion heater while it is switched on.

Clamp the immersion heater so that it does not touch the bottom of the cup.

Method

Set up the equipment as shown in the diagram.



1. Put a known mass of water into the polystyrene cup.
2. Measure and record the temperature of the water at the start of the experiment.
3. Set the joule meter to zero or record the reading at the start.
4. Switch on the immersion heater and start the timer.
5. Use the stirrer to mix the water just before every minute and measure the water temperature every minute.
6. Record the reading on the joule meter every minute.

Continued

7 Continue with the temperature measurements until the temperature of the water has increased by 10 °C.

8 Switch off the immersion heater and allow it to cool.

Questions

1 Record your results in a table.

2 Plot a line graph with temperature on the *y*-axis and energy on the x-axis.

3 Describe the trend in the results.

4 If you were to repeat this experiment, list three variables that should be kept the same.

5 Most of the thermal energy from the immersion heater is transferred to increase the temperature of the water. List **three** other ways that thermal energy can be transferred in this investigation.

6 Suggest **two** ways to ensure that more thermal energy from the immersion heater is transferred to the water.

Self-assessment

Decide how well you did each of these things:

- making measurements at the correct time
- recording results in a table
- drawing the graph of the results.

Choose one thing that you could do better next time.

How will you do this better next time? What will you change?

Summary checklist

- ☐ I know what is meant by heat.
- ☐ I know what is meant by temperature.
- ☐ I know the difference between heat and temperature.

3.3 Conservation of energy

In this topic you will:

- learn that energy cannot be created or destroyed
- understand that because energy is conserved, there is no increase or decrease in energy
- understand that thermal energy is dissipated from hotter places to colder places.

Getting started

1 Thermal is an energy store. List as many other types of energy store as you can remember.

2 Choose two of your energy stores. Describe how the energy can be changed between these energy stores.

3 Describe what is meant by dissipated energy.

Key words

conserved
created
destroyed
system

Energy is conserved

People often talk about conserving energy when they mean using less energy. For example, you switch off a lamp when you leave the room.

In physics, saying that energy is **conserved** means something different from saying less energy is being used.

When we say that energy is conserved, we mean that the total quantity of energy stays the same. This happens when energy is stored, changed, transferred or even dissipated.

Look at the energy diagram for an electric lamp (extension material).

The energy diagram shows that every time 100 J of electrical energy is supplied to the lamp, 10 J of this is changed to light energy and 90 J is changed to thermal energy. The light energy is useful and the thermal energy is wasted.

The electrical energy is called the energy input and the light and thermal energy together are called the energy output.

The total energy input of 100 J is the same as the total energy output of 10 J + 90 J = 100 J.

This shows how energy is conserved in an electric lamp.

The energy diagram for the engine in a car has more energy outputs (extension material).

In the energy diagram for a car engine, the energy input and outputs are shown as percentages. Notice that the energy input is 100% and the total energy output adds up to 100%. Once again, energy is conserved.

In these examples, the electric lamp and the car engine are types of **system**. In physics, a system is something that has been chosen to be studied, especially in terms of energy changes.

The total energy output can never be greater than the total energy input in any type of system. This is because energy cannot be **created**. Created means to make something, or to bring something into existence.

Wasted energy, such as thermal energy, is dissipated. Dissipated means this energy spreads out into the surroundings and becomes less useful. Although this energy is dissipated, it is not **destroyed**. Destroyed is the opposite of created. Destroyed means to damage something or to end its existence.

The law of conservation of energy states that energy cannot be created or destroyed, only changed or transferred.

Questions

1 a Write down the law of conservation of energy.

b Decide whether each of these statements is true or false:

i The total energy input to a mobile phone is greater than the total energy output.

ii The total energy output of a washing machine is greater than the total energy input.

iii The total energy input to a wood fire is equal to the total energy output.

2 (Extension question) For each of these energy diagrams, calculate the missing energy value, **X**.

a An electric motor

b A television

c A bus engine

3 a In a wood fire, 70% of the chemical energy in wood is changed to thermal energy. The remaining energy is changed to light and waste chemicals.

Calculate the percentage of the chemical energy in the wood that is changed to light and waste chemicals.

b In an oil-burning power station, 55% of the chemical energy in the oil is changed to thermal energy and 10% is used in the power station. The remainder is changed to electrical energy.

Calculate the percentage of the chemical energy in the oil that is changed to electrical energy.

4 Sofia has an LED flashlight that uses 18 J of electrical energy. 7 J of the electrical energy is wasted as thermal energy. Sofia says that 12 J of the electrical energy is changed to light.

Explain whether Sofia is correct.

Activity 3.3.1

Conservation of energy

In this activity, you will observe energy being transferred from one moving object to another.

You will need:

- two identical plastic water bottles with lids, water, string, scissors, ruler, two strong supports – such as clamp stands – about 70–80 cm apart.

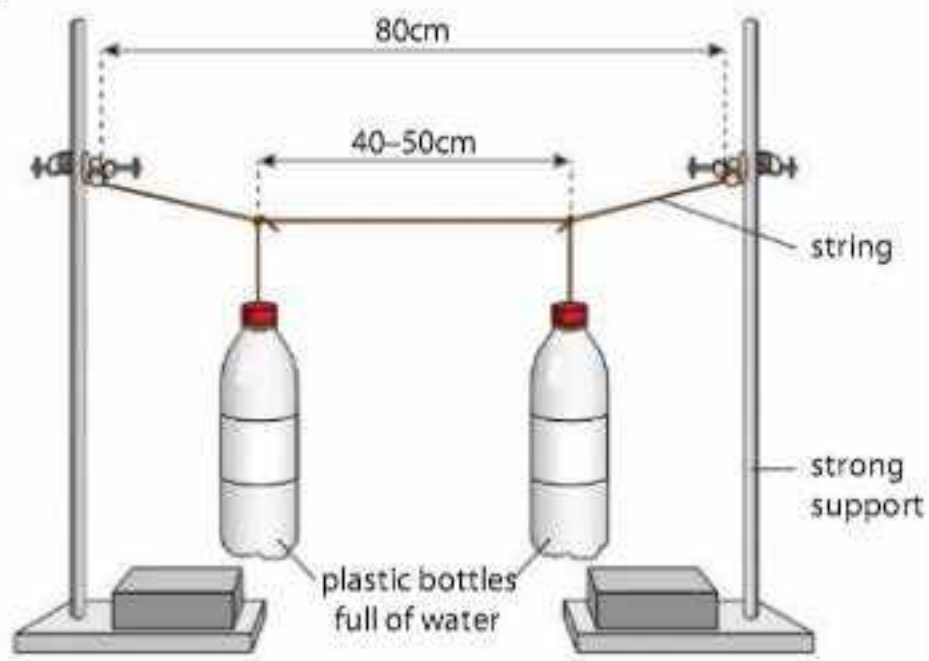
Method

1 Fill the two water bottles completely with water so there is no air inside. This is to make sure both bottles have equal mass.

2 Tie a piece of string about 10 cm long to the neck of each bottle.

3 Stretch a piece of string between the two supports and tie securely at each end. The string must be high enough for the water bottles to hang down without touching the surface below. This is the supporting string.

4 Tie the two bottles to the supporting string so they hang about 40–50 cm apart and hang down at equal heights, as shown in the diagram.



Continued

5 Looking at the equipment as shown in the diagram, pull the bottom of one bottle towards you so that it will swing at 90° to the supporting string.

6 Observe what happens to the two bottles.

Questions

1 Describe what you observe in the movement of the two bottles.

2 Explain this observation using the law of conservation of energy.

3 Explain why the bottles will eventually stop moving.

Activity 3.3.2

Bottle racers

In this activity, you will make household objects move using conservation of energy. Work in pairs.

You will need:

- empty plastic bottle with a small hole in the lid and another small hole in the base of the bottle, paperclip, elastic band, pencil or stick.

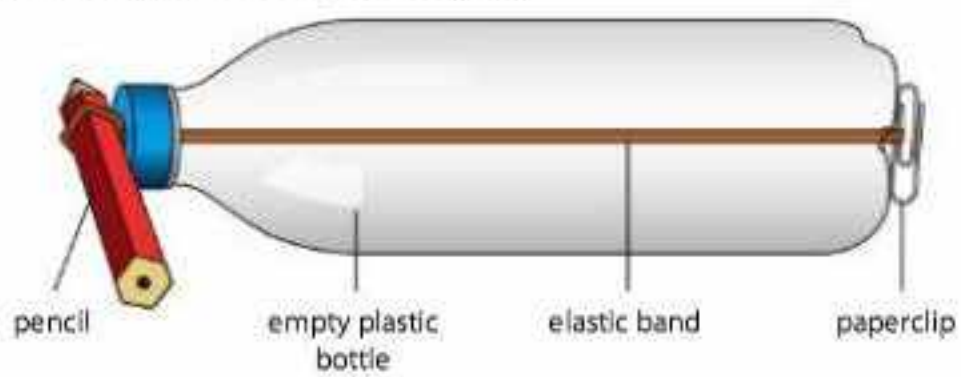
Method

1 Attach a paperclip to the elastic band and pass the other end of the elastic band into the bottle through the hole in the base.

2 Pull the elastic band out through the open top of the bottle and pass this end through the hole in the lid. Pass the pencil though this end of the elastic band.

3 Put the lid back onto the bottle.

4 The picture shows a completed bottle racer.



5 Rotate the pencil **once** so that the elastic band twists inside the bottle.

6 Place the bottle on its side on the floor.

7 Release the bottle. It should not move.

8 Find the number of times you need to rotate the pencil to make the bottle move.

Continued

Questions

1 State the part of the bottle racer that stores the energy.

2 Name the energy store in the bottle racer before it starts to move.

3 Name the energy that is transferred to the bottle to make it move.

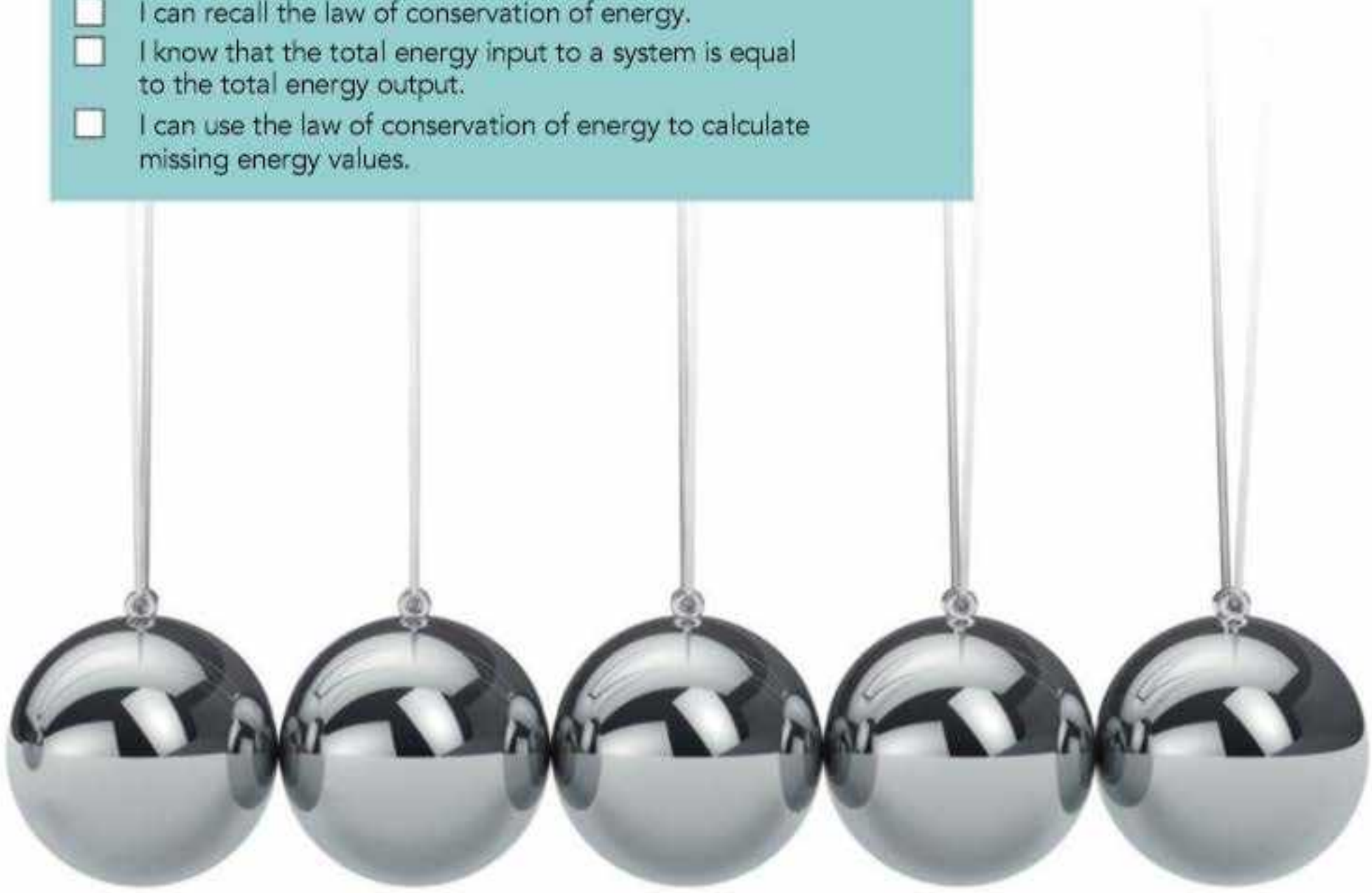
4 If you rotate the pencil more times, what happens to the movement of the bottle racer?

Explain these observations.

You could extend this activity by finding the number of times the pencil must be rotated to make the bottle move up a slope.

Summary checklist

- ☐ I can recall the law of conservation of energy.
- ☐ I know that the total energy input to a system is equal to the total energy output.
- ☐ I can use the law of conservation of energy to calculate missing energy values.



3.4 Moving from hot to cold

In this topic you will:

- discover that thermal energy always transfers from hotter places to colder places
- understand what is meant by heat dissipation.

Getting started

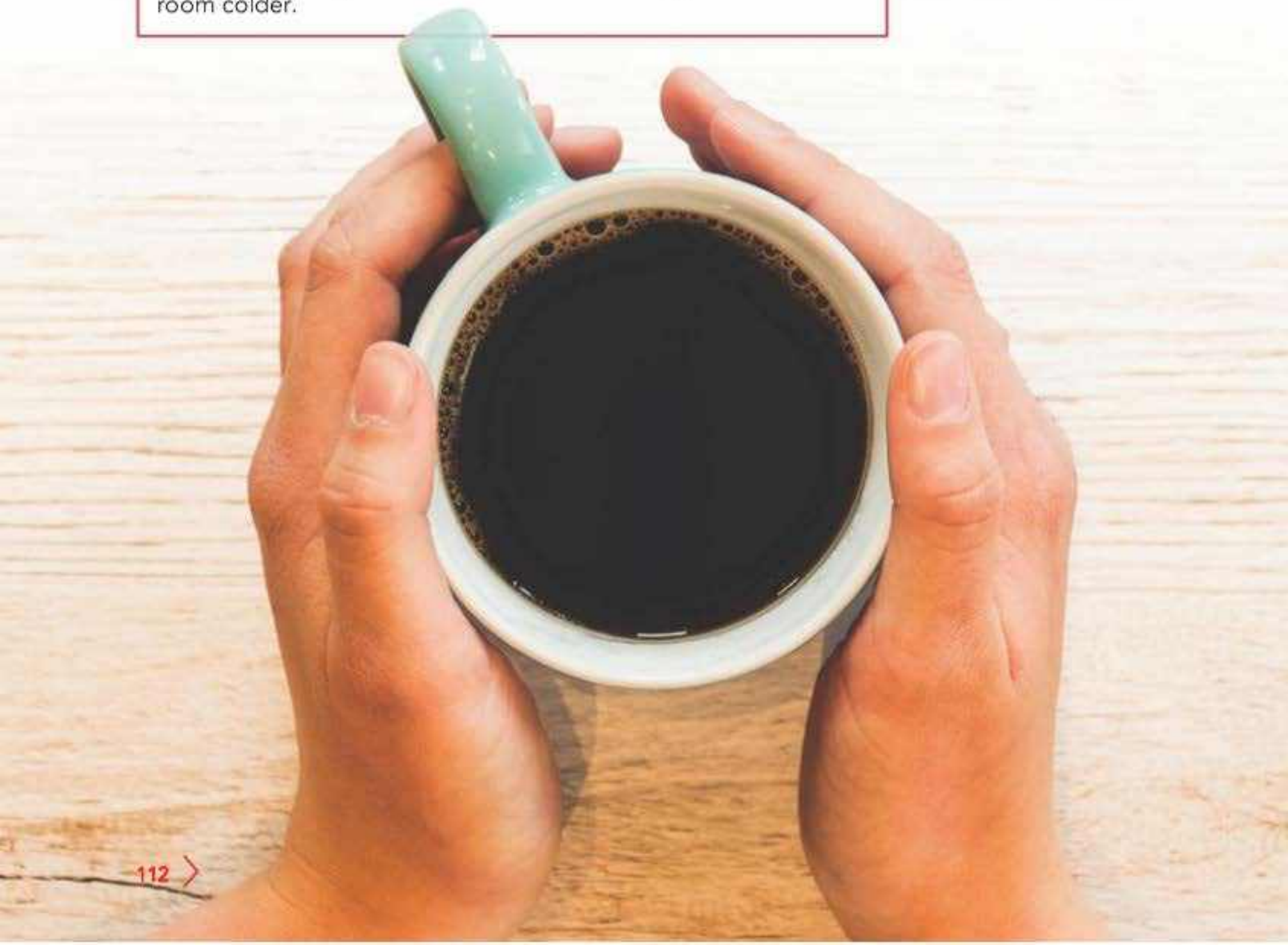
Work in groups.

Imagine you are in a hot room. It is colder outside than inside. When someone opens a window, the room feels colder.

Discuss what happens in terms of thermal energy to make the room colder.

Key words

colder
hotter



Feeling heat

When you put your hands around a hot drink, you can feel heat in your hands. This will only happen if the drink is **hotter** than your hands. Hotter means at a higher temperature.

Thermal energy moves from the drink, through the container and into your hands.

Thermal energy moves from the hotter drink to your colder hands.

Thermal energy always moves from hotter places to **colder** places. Colder means at a lower temperature.

We make use of this in many ways:

When you put food into a refrigerator, thermal energy transfers out of the food, and the food becomes colder.

There is water inside a car engine to remove thermal energy from the metal engine parts. This stops the engine overheating.

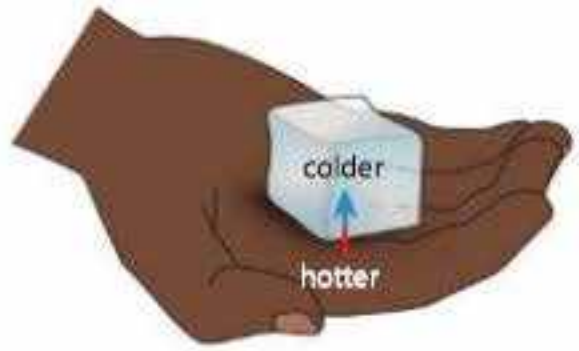
Animals sometimes go in water to cool down. Thermal energy moves from the animal's body into the colder water.

When thermal energy is removed from a hot object, we say that the thermal energy has dissipated.

Feeling cold

Imagine you are holding ice. The ice feels cold.

It is easy to think that the cold from the ice moves into your hand, but that does **not** happen. Cold is **not** an energy store and cold **cannot** move. Cold means there is less thermal energy.



When you hold the ice, thermal energy transfers away from your hand and into the ice. You feel cold because thermal energy has been transferred away from your hands. You can damage your skin by holding ice for too long, as your skin needs the correct quantity of thermal energy to function.

When it is colder outside and you open a window, the inside cools down. This is because thermal energy from the hotter inside moves to the colder outside. Cold *air* may enter the room, but thermal energy from the warmer air is still transferred to the colder air.

Dissipation

You met the word dissipation in Stage 7. Dissipation is used to describe energy that spreads out and becomes less useful.

When thermal energy moves from a hotter place to a colder place, we say that thermal energy has dissipated from the hotter place.

The rate, or speed, of thermal energy transfer increases when the temperature difference between the hot place and the cold place increases.

Remember that energy is always conserved, so the thermal energy has not disappeared or been destroyed, it has just spread out and moved to a colder place.

Some scientists think that, billions of years in the future, all the thermal energy in the universe will have dissipated. At that time, everything in the universe will be at the same low temperature and no more energy changes or transfers will be possible.

Questions

1 Copy and complete the sentence using the best words.

Thermal energy moves from ..... places to ..... places.

2 Marcus buys hot food and takes the food home.

a What will happen to the temperature of the hot food on the way home?

b Explain your answer using the words thermal energy.

3 Arun takes ice cream out of the freezer. The temperature of the ice cream is −18 °C when he first takes it from the freezer. The temperature of the air in the room is 22 °C.

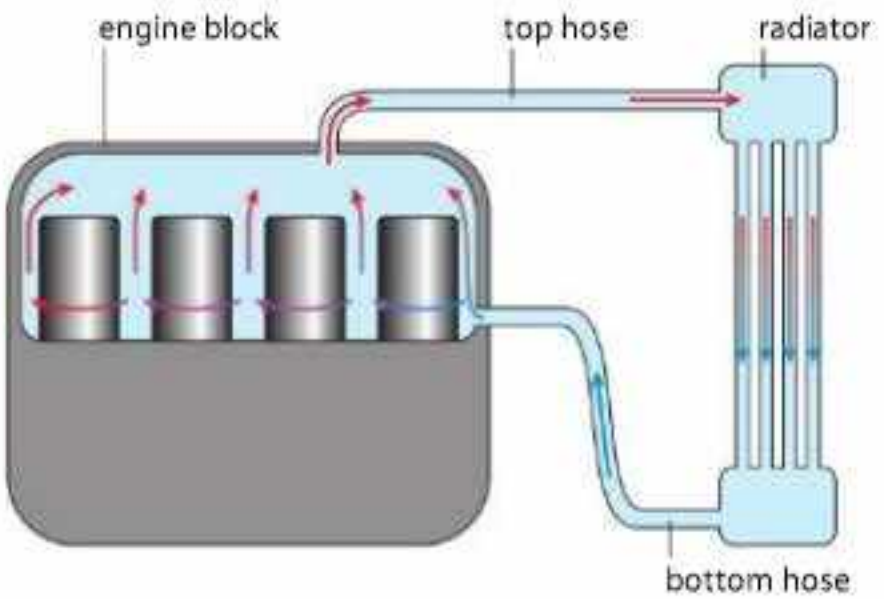
Explain what will happen to the temperature of the ice cream.

4 Sofia and Zara visit an indoor ski slope. The temperature of the air at the indoor ski slope is −2 °C. Both girls wear gloves.

Explain whether Sofia or Zara is correct.

5 This diagram shows a car engine.

The engine block gets hot. Water flows through the engine in the direction shown by the arrows. Cold water enters the engine block through the bottom hose.



a Explain how the water keeps the engine from getting too hot.

b Hot water comes out of the engine through the top hose. The water is cooled as it passes through the radiator. The radiator is exposed to air at the front of the engine.

Explain what happens to the thermal energy in the water as it passes through the radiator.

Activity 3.4.1

Hot coffee

In this activity, you will do a thought experiment.

Imagine you are making hot coffee for a friend. Your friend drinks hot coffee with a small volume of cold milk added. Your friend will arrive in five minutes. Your friend does not like cold coffee!

There are two methods, A and B, for preparing the coffee.

Method A: Pour the hot coffee into a cup. Leave the coffee for five minutes, and then add the cold milk.

Method B: Pour the hot coffee into a cup and add the cold milk. Then leave this mixture for five minutes.

In each case, think about what should happen. This is called a thought experiment.

Questions

1. Which method, A or B, will result in the coffee being hottest after 5 minutes, or will there be no difference?
2. Explain your choice.
3. Imagine you will do an experiment to compare methods A and B. Make a list of the variables you would need to keep constant to make the comparison fair.

Think like a scientist

Temperature change from heat dissipation

In this investigation, you will measure the temperature change in water caused by heat dissipation.

Work in groups of two or three.

You will need:

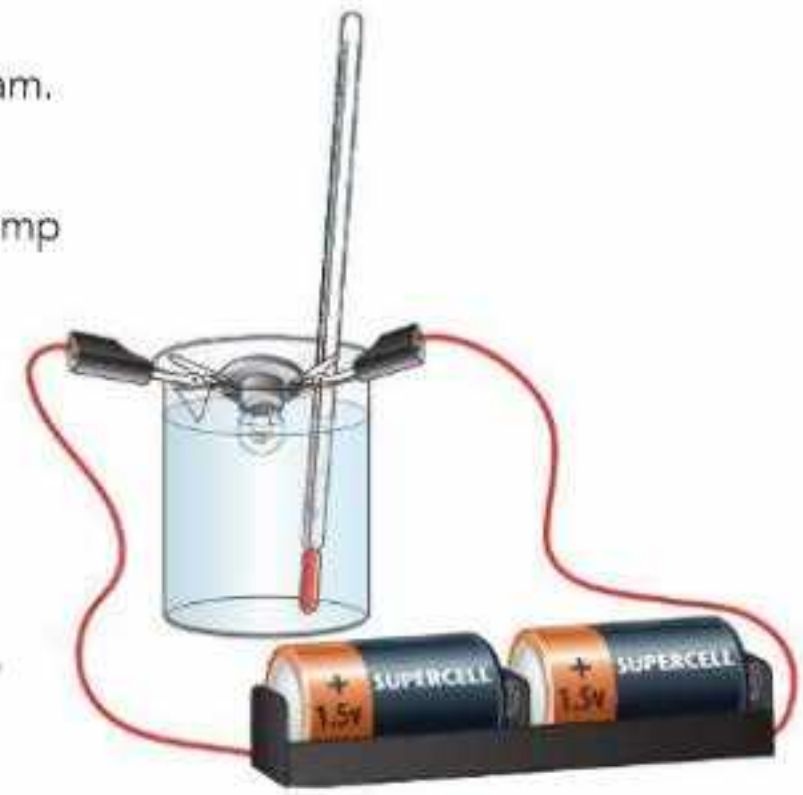
- 2 V or 6 V lamp, lamp holder, cells, wires and connectors, 50 cm^3 (or smaller) beaker, water, thermometer, timer.

Safety

This experiment must be carried out in the school laboratory. Make sure that **only** the glass part of the lamp is in the water. **Never** put a lamp in water at home!

Method

1. Set up the apparatus as shown in the diagram.
2. Use as small a volume of water as possible.
3. Make sure that **only the glass part** of the lamp is in the water.
4. Record the temperature of the water.
5. Switch on the lamp.
6. Record the temperature of the water every minute.
7. Continue to record the temperature of the water until the temperature stops changing.



Questions

1. Record your results in a table.
2. Plot a line graph of your results.
3. Explain the change in temperature of the water in the first few minutes after switching on the lamp.
4. Explain why the temperature of the water eventually stops increasing.
5. An LED is a device that changes electrical energy to light energy. LEDs change a bigger percentage of electrical energy to light energy than a lamp. Use this information to predict any differences in results if the experiment were repeated with an LED. Assume everything else in the experiment stays the same.

Summary checklist

- ☐ I know that thermal energy moves from hotter places to colder places
- ☐ I know that the spreading out of thermal energy is called dissipation.

3.5 Ways of transferring thermal energy

In this topic you will:

- describe how thermal energy can be transferred by conduction
- describe how thermal energy can be transferred by convection
- describe how thermal energy can be transferred by radiation.

Getting started

Work in groups to discuss the answers to these questions.

1 Describe how particles are arranged in:

a a solid b a liquid c a gas

2 Describe what happens to the particles when each of these substances is heated:

a a solid b a liquid c a gas

Key words

conduction
convection
convection current
emit
expand
radiation
vigorously

Heat and particle movement

When any substance is heated, the particles in that substance start to move faster.

In solids, the particles move by vibrating around fixed positions. This vibration gets faster when the solid is heated. As the particles vibrate more **vigorously**, they take up more space. Vigorously means with more energy, more speed and more force. That means solids **expand** when heated. Expand means to increase in size.

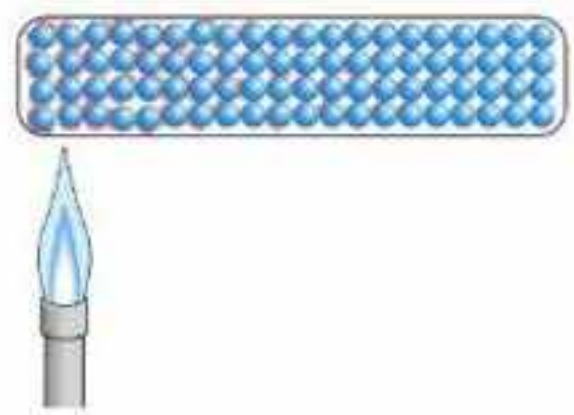
In liquids, the particles also vibrate, but the particles are not in fixed positions. When the liquid is heated, the particles vibrate faster and move around faster. Again, as the thermal energy increases, the particles take up more space. That means the liquid expands when heated.

In gases, the particles are far apart and move in straight lines until they collide with another particle or the walls of the container. When the gas is heated, the particles move faster and collide with more force and more frequently. The particles will take up more space in a heated gas, so gases also expand when heated.

Conduction

When particles are vibrating, they will push against the particles beside them. The faster and more vigorous the vibration of the particles, the greater the push. This will cause the particles beside to vibrate more vigorously as well.

This is how thermal energy is transferred by **conduction**. Conduction of thermal energy works best in solids where the particles are close together and can only move by vibrating. The diagram shows how thermal energy is transferred by conduction through a solid.



Metals are the best conductors of heat because of the way the particles are arranged. The electrons that are free to move in a metal help to pass along the vibrations.

Wood, plastics and fabrics, such as wool and cotton are poor conductors.

Just as with electricity, the opposite of a conductor is an insulator. We say that poor conductors of thermal energy are good thermal insulators.

Some objects are made from materials that are chosen because of their ability to conduct thermal energy.

Look at the pan in the picture. The pan is made from metal because metal is a good conductor of thermal energy. That helps the food to heat faster. The handle is made from plastic because plastic is a good thermal insulator. That makes the handle comfortable to touch. The spoon is made from wood, which is also a good insulator.

Clothes for cold weather are made from materials that are good insulators. That slows the conduction of thermal energy away from the body.

Conduction does not work well in liquids because the particles move around more when heated, rather than just vibrating.

Conduction also does not work well in gases because the particles are far apart and the collisions are not very frequent.

Conduction cannot happen in a vacuum as there are no particles to vibrate in a vacuum.

Convection

When liquids and gases are heated, the particles move faster and take up more space.

Taking up more space means the volume increases. The number of particles does not change, so the mass of the liquid or gas does not change.

You will remember from Topic 3.1 that density $= \frac{\text{mass}}{\text{volume}}$

From this equation, you can see that when volume increases and mass stays the same, then density will decrease.

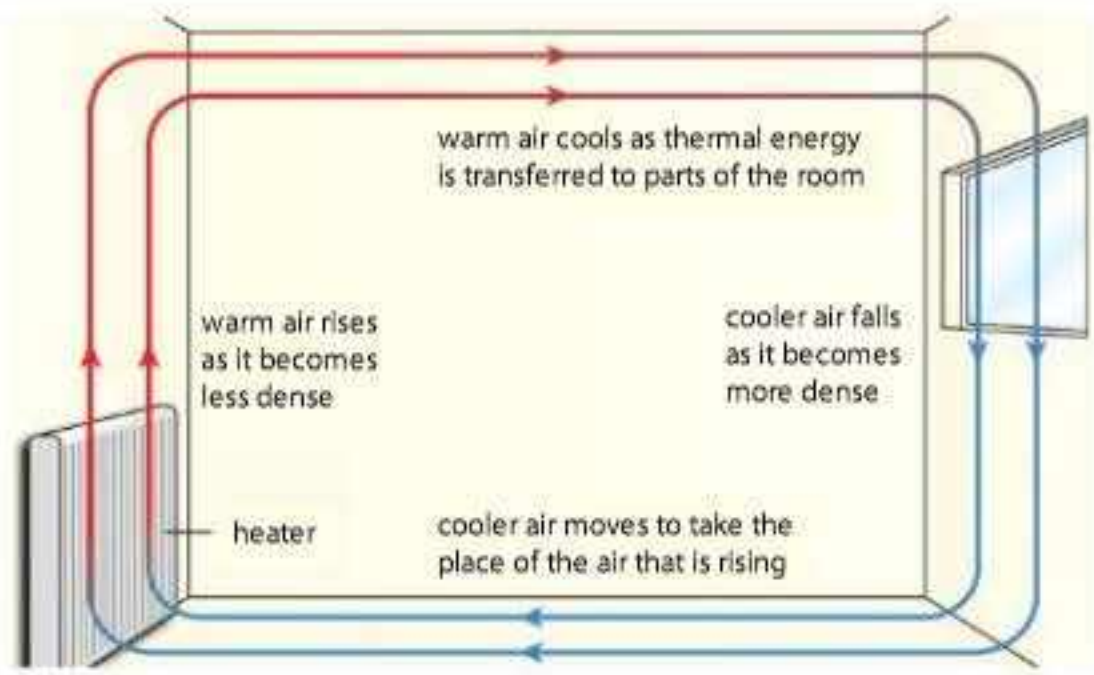
You will also remember from Topic 3.1 that less dense substances float in more dense substances.

Imagine a gas or liquid that is heated at the bottom. The particles at the bottom will start to move faster and take up more space. This part of the liquid or gas will become less dense and start to float up through the colder, more dense parts. This upward movement of warmer liquid or gas is called **convection**.

Colder, more dense parts of the liquid or gas then sink down to occupy the space. These colder parts are then closer to the source of heat and they get heated. The particles in these parts then occupy more space and start to float.

This movement around the heated liquid or gas is called a **convection current**. The convection current causes all of the liquid or gas to eventually become heated.

The diagram shows how a convection current heats all the air in a room.

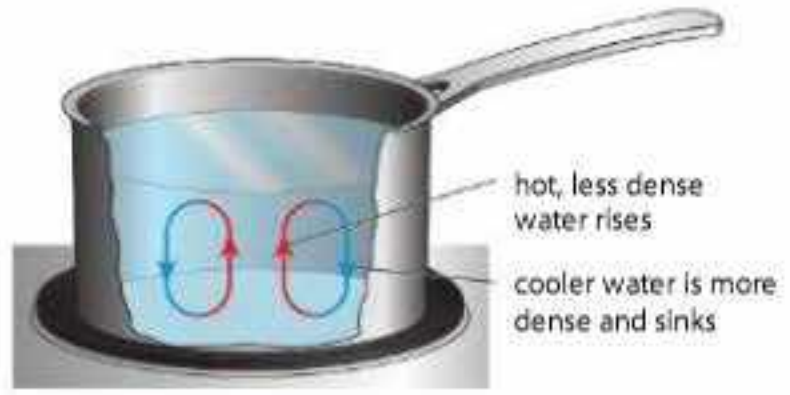


The next diagram shows how a convection current heats all the water in a cooking pan.

Convection can happen in liquids and gases because the particles are free to move.

Convection cannot happen in a solid because the particles are not free to move. The particles in a solid can only vibrate about fixed positions.

Convection cannot happen in a vacuum as there are no particles to move.



The cooking pan is heated only at the bottom, but convection currents in the water heat all of the water.

Radiation

There is a vacuum in the space between the Sun and the Earth, so conduction or convection would not transfer thermal energy from the Sun to Earth. That means thermal energy must be transferred in a different way.

This different way is called **radiation**. Radiation is a type of wave that we cannot see. Thermal energy can be transferred by radiation very quickly. The thermal energy from the Sun only takes aboutnine minutes to reach Earth!

All objects give out thermal energy through radiation. The hotter the object, the more radiation it will **emit**. Emit means to give out.

The Sun and other hot objects emit thermal energy by radiation. Cooler objects absorb thermal energy by radiation from hotter ones.

Radiation can pass through a vacuum because radiation does not need particles.

Radiation can also pass through transparent solids, liquids and gases.

The colour and texture of an object affects its ability to emit or absorb thermal energy by radiation.

The best emitters and absorbers of radiation:

- are dull
- are black
- have a large surface area.

The worst emitters and absorbers of radiation:

- are shiny
- are white or silver
- have a small surface area.

Shiny, white or silver surfaces reflect radiation away.

Penguins have black feathers on their backs to absorb as much thermal energy from radiation as possible.

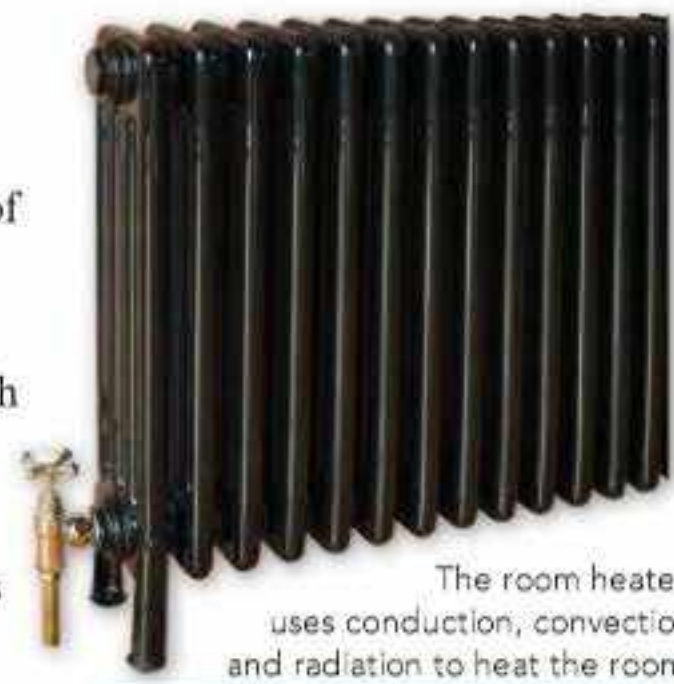
Buildings in many hot countries are painted white so they absorb less thermal energy from radiation.

Conduction, convection and radiation

Most objects gain or lose thermal energy by a combination of conduction, convection and radiation.

Look at the picture of the room heater.

The room heater in the picture has hot water flowing through the inside. Thermal energy from the hot water is transferred to the metal of the heater by conduction. Thermal energy from the metal is transferred to the air, also by conduction. When the warm air expands, this warm air rises, which heats the air above by convection. The metal surface of the heater also emits thermal energy by radiation.



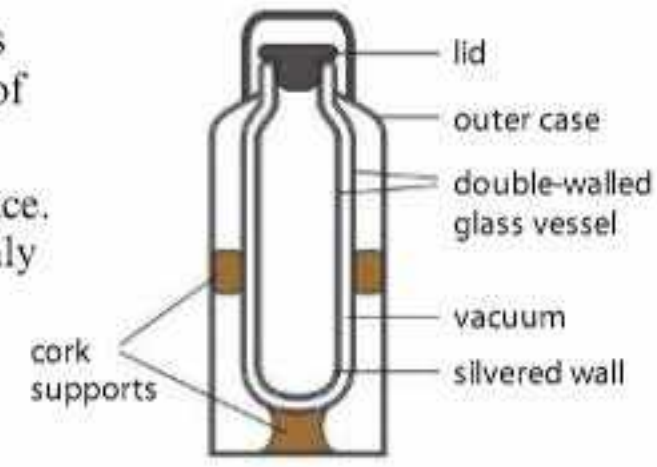
The room heater uses conduction, convection and radiation to heat the room.

Some objects are designed to reduce the effects of conduction, convection or radiation.

Vacuum flasks are containers used to store hot liquids such as tea, coffee or soup. The flask is designed to slow the transfer of thermal energy by reducing conduction and radiation.

Inside a vacuum flask there is a glass bottle with a silver surface. The glass bottle is surrounded by a vacuum, and the bottle only makes contact with the outside of the flask at the top, as shown in the diagram.

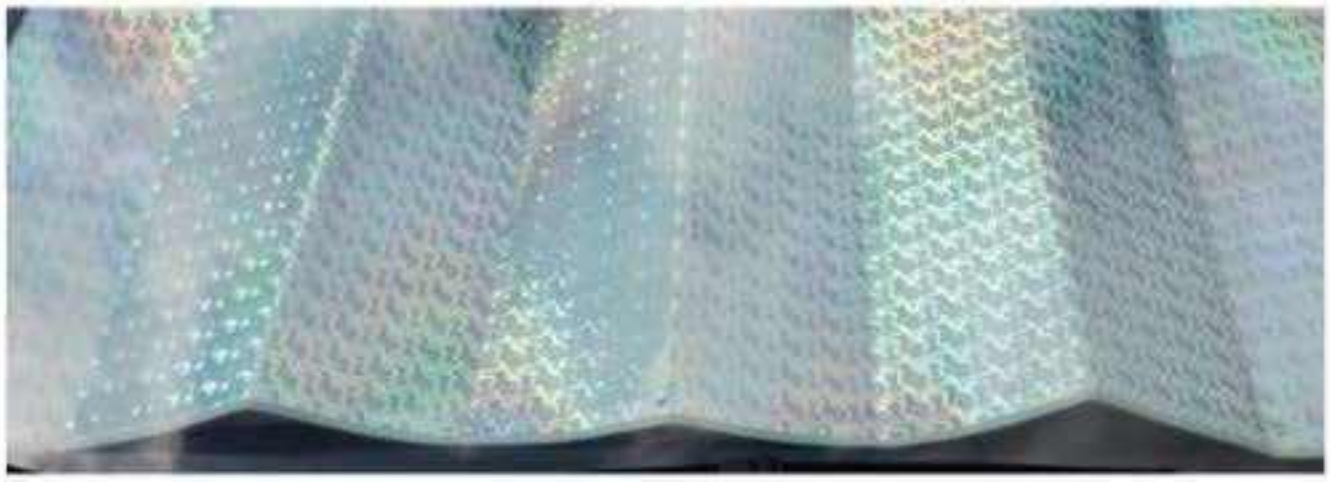
The silver surface of the bottle reflects thermal energy in the form of radiation back into the hot drink. The vacuum surrounding the bottle prevents conduction of thermal energy from the drink to the outside.



Inside a vacuum flask

Double-glazed windows reduce thermal energy transfer into or out of buildings. The picture shows double-glazed windows. There are two layers of glass separated by a thin layer of argon gas. Argon is a poor conductor of heat. In the picture, you can also see insulation inside the

wall of the house. There is a space between the two layers of the brick wall that is filled with foam. The foam is a poor conductor and also fills the space to prevent convection currents from forming inside the wall.



Car windows can be covered with silver material to reflect radiation from the Sun away from the inside of the car. This helps to stop the car becoming too hot inside when parked on a sunny day.

Questions

1 a List the three ways that thermal energy can be transferred from one place to another.

b Explain which two of these ways cannot occur in a vacuum.

c Explain which one of these ways occurs best in solids.

2 Marcus and Arun go out on a sunny day. Marcus wears a white T-shirt and Arun wears a black T-shirt. Their T-shirts are the same apart from the colours.

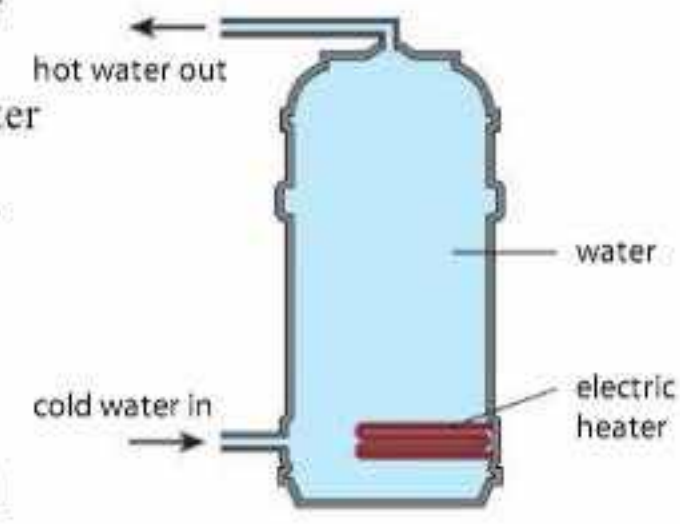
Explain any difference in the heat that the two boys will feel when they spend the same time in the Sun.

3 Which method transfers thermal energy:

a through a metal cooking pan

b from the Sun to Earth.

4 The diagram shows a water tank with an electric heater to heat the water.



a Explain how the electric heater heats all of the water in the tank.

b Explain why hot water is removed from the top of the tank and not from the bottom.

c The total volume of water in the tank does not change. Some tanks have a second electric heater that can be used when not all of the water in the tank needs to be heated. Suggest where the second electric heater would be positioned in the tank.

Think like a scientist

Conduction of thermal energy in different materials

In this investigation, you will compare how different materials conduct thermal energy.

Work in groups of two or three.

You will need:

- rods about 30 cm long made from different metals, candle wax, paperclips, a heat source – such as a candle – that can be used to heat one end of the rod, clamp stands.

Safety

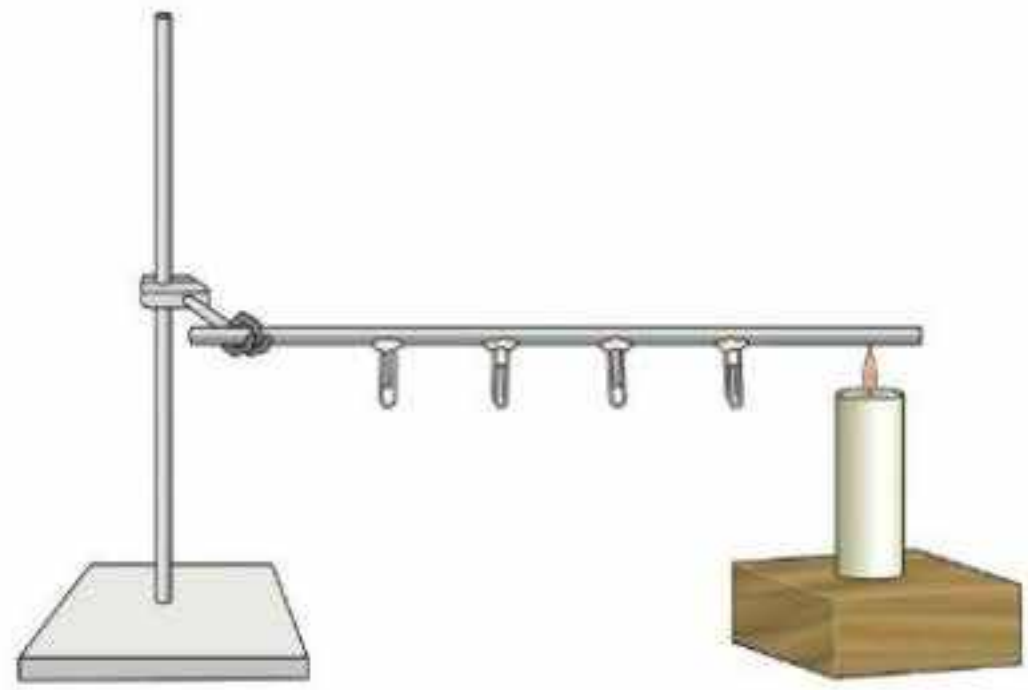
Write a risk assessment for this investigation. Check it with your teacher before carrying out the investigation.

Method

1 Melt the candle wax and use the soft wax to attach paperclips to each rod at intervals of about 5 cm.

2 Clamp one rod so that one end of the rod can be heated, as shown in the diagram.

3 Heat one end of each rod and observe what happens to the wax and the paperclips.



Questions

1 To make the comparison a fair test, list the variables that must be kept constant for each rod.

2 List any of these variables that you could not control in your experiment.

3 Describe your observations.

4 Explain your observations using ideas about thermal energy, particles and conduction.

5 This investigation cannot be used to test conduction of thermal energy in substances such as wood or plastic. Explain why.

Activity 3.5.1

Observing convection

In this activity, you will observe a convection current in water.

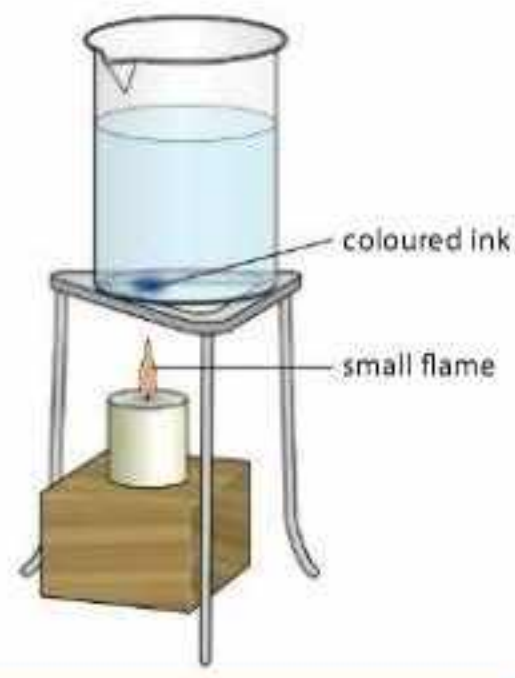
Work in groups of two or three.

You will need:

- large glass beaker, tripod without gauze, cold water, heat source – such as a candle – coloured ink or water-based paint, pipette.

Method

1. Fill the beaker with cold water to about three-quarters full.
2. Use the pipette to place a small volume of coloured ink at one side of the bottom of the beaker. Take care not to mix the coloured ink with the water.
3. Place the heat source under the beaker below the position of the coloured ink as shown in the diagram.
4. Do not stir the water while heating.
5. Observe what happens to the coloured ink.



Questions

1. Record your observations in a series of labelled drawings.
2. Add a written explanation of what is happening in your drawings. Use ideas about particles and density.

Think like a scientist

Emitting thermal energy by radiation

In this investigation, you will compare how different colours emit radiation.

Work in groups of two or three.

You will need:

- three or more identical empty food or drink cans, paint (matt/dull black, white and silver – other colours optional), three or more thermometers, hot water, measuring cylinder, funnel, timer, graph paper.

Method

1 Paint three identical cans dull black, white and silver. Allow the paint to dry until the next lesson.

Question

1 You will be placing hot water in each can and investigating how long the water takes to cool in each can. Write a prediction for this investigation, explaining any differences between the three cans.

Method (continued)

2 Measure the volume of water that will be needed to fill one of your containers to within about 1 cm from the top.

3 Heat enough water to fill four cans (or one more than the number of cans you will use).

4 Stop heating the water when the temperature is about 60 °C.

5 Measure an equal volume of water into each can. Use the funnel to help get all of the water into the cans.

6 Place a thermometer in each can and record the temperature of the water every two minutes.

Questions

2 Record your results in a single table with separate columns for each colour of can.

3 Plot a line graph of your results. Draw the lines for each colour of can on the same graph. Use a key to identify each line.

4 Describe the trends in your results.

5 Explain whether your results matched your prediction.

6 Explain how you could recognise any anomalous results in this investigation.

Continued

7 Make a list of the variables that must be kept the same in this investigation.

8 This investigation was to compare how the colours emitted thermal energy by radiation. Describe an investigation to compare how these coloured cans would absorb thermal energy by radiation.

Summary checklist

- ☐ I know that thermal energy can be transferred by conduction, convection or radiation.
- ☐ I know how conduction and convection happen using a particle model.
- ☐ I know that radiation does not require particles.
- ☐ I know why conduction works best in solids and cannot happen in a vacuum.
- ☐ I know why convection happens best in liquids and gases and cannot happen in solids or a vacuum.
- ☐ I know which colours and textures are the best emitters and reflectors of radiation.

3.6 Cooling by evaporation

In this topic you will:

- understand how evaporation causes cooling.

Getting started

Work in groups to discuss the answers to these questions.

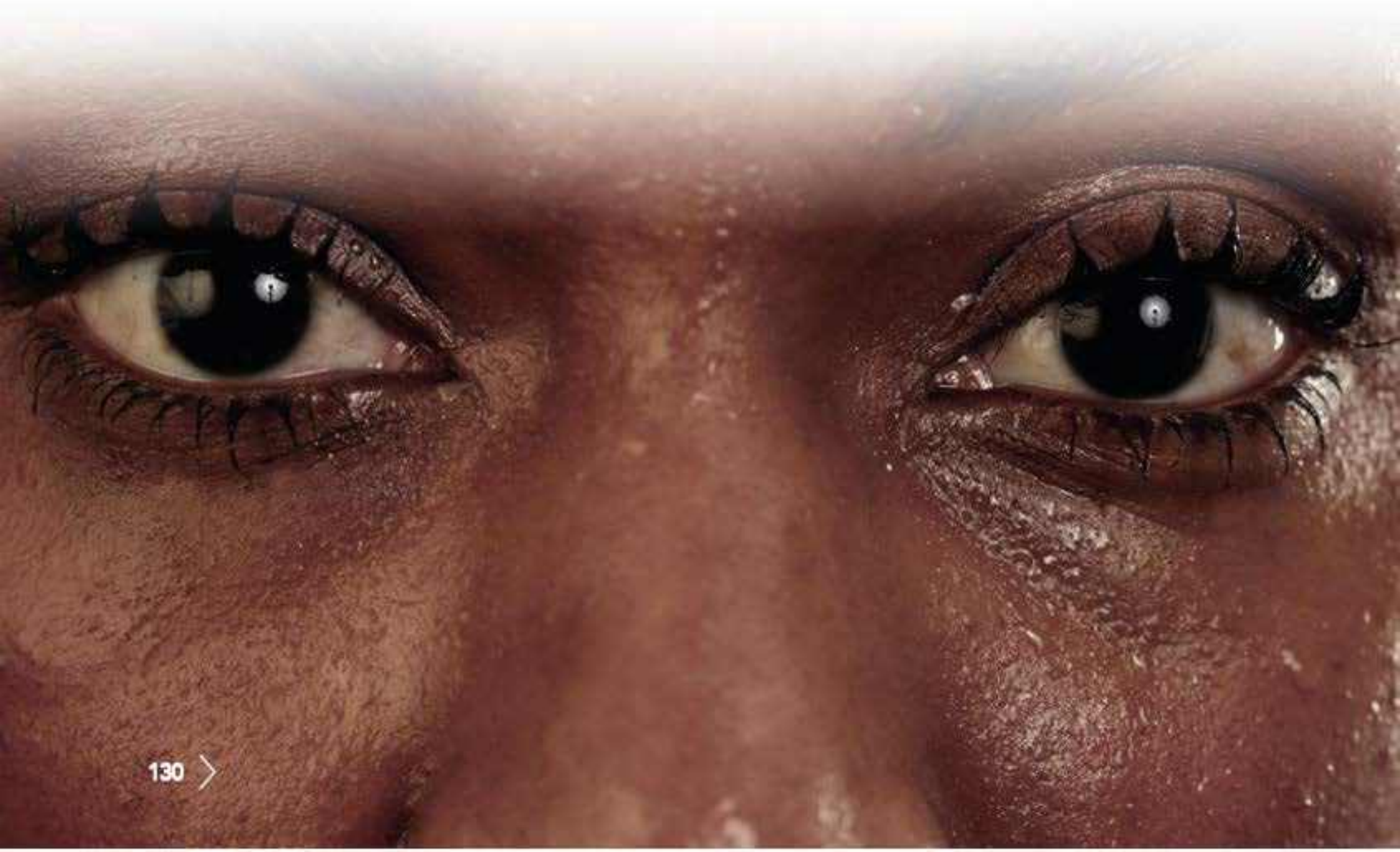
The boiling point of water is 100 °C. Water can evaporate at much lower temperatures, such as 15 °C.

1 Explain the difference between boiling and evaporation.

2 Explain how evaporation at temperatures lower than boiling point occurs. Use ideas about particles and energy in your answer.

Key words

porous
random

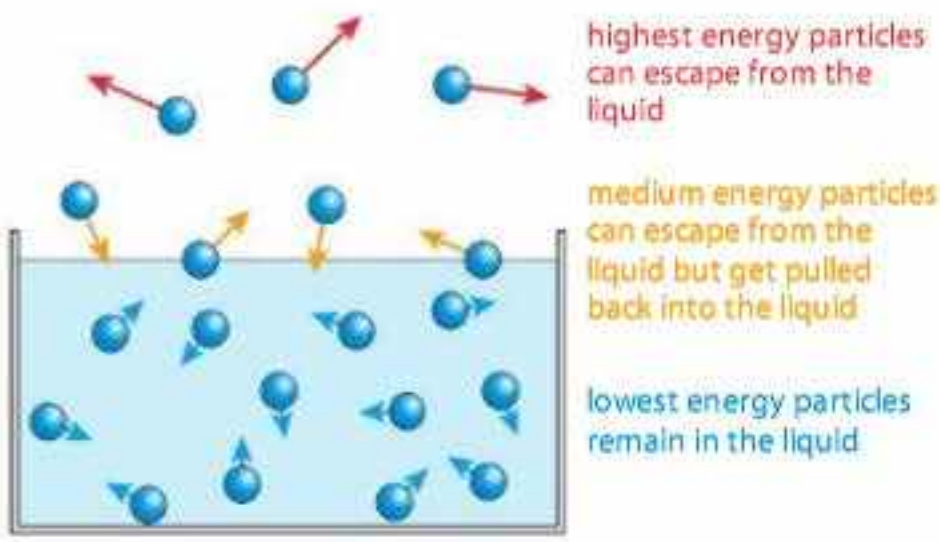


Evaporation

Evaporation is the change of state from liquid to gas.

Think of a liquid such as water at room temperature. The particles in the water are moving around in **random** directions. Some of these particles move faster than others, and the speed of the particles is also random. The word random means unpredictable.

The particles in the water that are moving faster have more energy. Some of these particles have enough energy to escape from the surface of the liquid and become particles of a gas. Some of these are pulled back into the liquid, but others have sufficient energy to leave and not get pulled back. This is summarised in the diagram.



Not all of the particles in the liquid are shown. Remember, particles in a liquid are in contact with each other.

Evaporation and cooling

You will recall from Topic 3.2 that temperature is a measure of the average energy of particles.

Think about the water again. Remember that the particles in the water have different energies.

When the particles with the highest energy escape from the water, this will lower the average energy of the particles that remain. Therefore, the temperature of the water will decrease, so evaporation causes cooling.

You can feel the effect of this when you get out of a swimming pool.

When the water on your skin evaporates, the particles with the highest energy escape causing the water to cool. The thermal energy in the water droplets on your skin comes from your skin. Therefore, the energy provided to change the state of the water from liquid to gas comes from your skin. As your skin loses thermal energy, this causes cooling.

When we are too hot, our skin produces sweat. Many people think that the liquid on the skin alone causes cooling, but since the sweat was produced in the skin, it is at the same temperature as the skin.

When the sweat evaporates, its temperature drops. Thermal energy from the skin is then transferred to the cooler sweat and the process continues to lower the skin temperature.

Some animals that do not sweat very much cover themselves in water to cool down. The evaporation of the water gives the cooling effect.

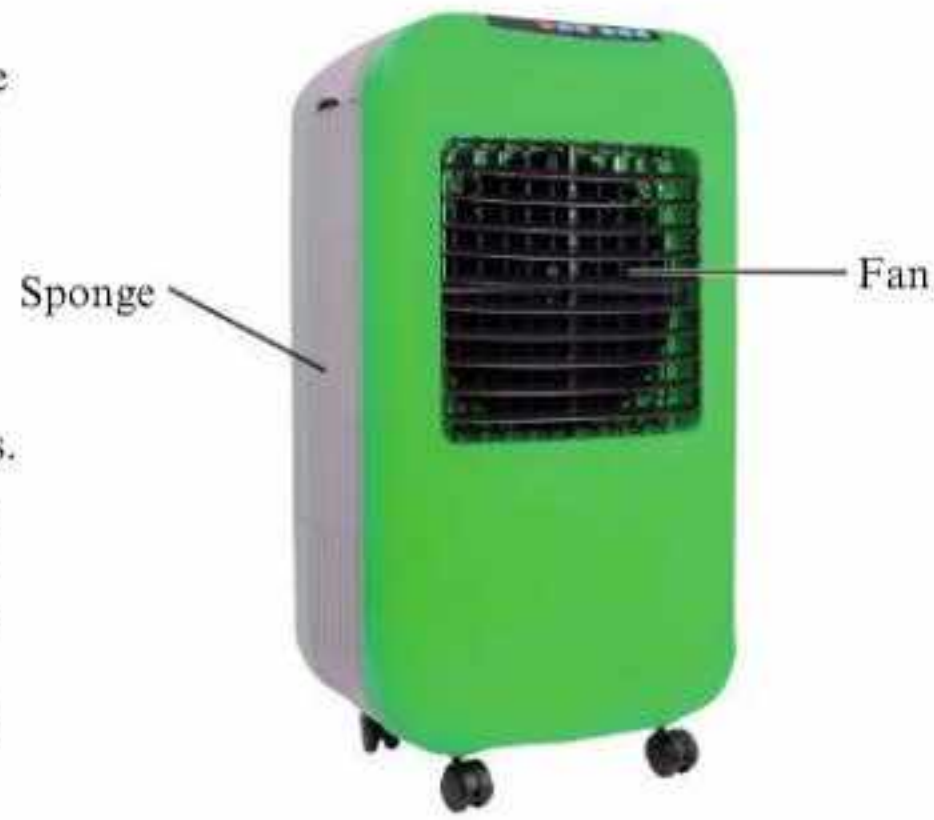
In very humid conditions, sweat may not be able to evaporate. This can be dangerous, as body temperature can increase without this cooling effect.

The picture shows a type of water cooler.

The water cooler is made from **porous** clay. The word porous means that water can slowly soak through the clay. When filled with water, some water soaks through the clay to the outside. This water evaporates into surrounding air, cooling the water inside the water cooler.

Some air coolers use evaporation of water to cool air. The picture shows one of these coolers.

The air cooler contains a sponge that is soaked in water. A fan blows warm air from the room through the sponge. The warm air provides the thermal energy to evaporate the water, and so the thermal energy of the air decreases, cooling the air.



Evaporation and cooling of other liquids

Different liquids have different forces holding the particles together. Some liquids have forces between particles that are weaker than those in water and some are stronger.

Some liquids, such as perfumes, have weaker forces between the particles. Perfumes are designed to evaporate quickly and easily so you can smell them.

If you put equal volumes of perfume and water at the same temperature on your skin, the perfume will feel colder. Perfume evaporates faster than water, so removes thermal energy faster.

Other liquids, such as liquid soap, have stronger forces between the particles. Liquid soap evaporates much more slowly than water. If you put equal volumes of liquid soap and water at the same temperature on your skin, the water will feel colder. Water evaporates faster than liquid soap, so removes thermal energy faster.

Safety note: Do not put any liquid on your skin apart from water, soap or perfume. Soap should be washed off skin using plenty of water.

Questions

1 The boiling point of water is 100 °C.

Copy and complete these sentences about water using words from the list. Each word can be used once, more than once or not at all.

least **most** **different** **the same**
evaporate **condense** **freeze**

The energies of the particles in water at 25 °C are ..... .

Particles with the ..... energy stay in the liquid.

Particles with the ..... energy can leave the liquid.

When liquid water turns to gas, the water is said to ..... .

2 Hot water at 80 °C is placed in a beaker and left in a room temperature of 20 °C. Most of the cooling of the water is caused by radiation and conduction. Which of these also causes the temperature of the water to decrease? Write **one** letter.

A freezing B condensation C evaporation D boiling

3 a Explain what happens to the average energy of particles in a liquid during evaporation.

b What happens to the temperature of a liquid during evaporation?

Explain your answer.

4 a Explain how sweat can cool the skin.

b Explain why skin can become too warm when sweat cannot evaporate.

5 Isopropanol is a liquid that can be applied to the skin to reduce the chance of cuts becoming infected. Isopropanol evaporates quickly. Isopropanol at room temperature feels cold when applied to the skin. Explain why.

Think like a scientist

Making an air cooler

In this activity, you will make an air cooler that works by evaporation.

You will need:

- an old towel, frame to hang towel, tray that can hold water and is long enough to contain one edge of the towel, water, desktop fan, thermometer, stand for thermometer.

Safety

You will be using an electric fan and water in this activity. Keep the water away from electric cables, wall sockets and the fan itself. Keep the fan as far from the wall socket as possible. Make sure the fan can be switched off at the socket immediately if water spills. Only operate switches with dry hands.

Method

1 Make sure the thermometer is dry. Place the thermometer in the stand or clamp the thermometer for all air temperature measurements.

Question

1 Explain why you should **not** hold the thermometer in your hand when measuring the temperature of the air.

Method (continued)

2 Measure the temperature of the air in the room.

3 Switch the fan on and measure the temperature of air coming from the fan.

4 Soak the towel in water and hang the wet towel on the frame.

5 Fill the tray with water and position the wet towel so the bottom edge is in the water.

6 Move the fan to about 10 cm from the wet towel and switch it on, so air is blowing at the wet towel.

7 Measure the temperature of the air between the fan and the wet towel.

Questions

2 Explain any differences in temperature that you measured in steps 2, 3 and 7.

3 Explain any other differences that you would predict if a dry towel were used in place of the wet towel.

Activity 3.6.1

Feeling the effects of evaporation

In this activity, you will feel the effects of cooling by evaporation.

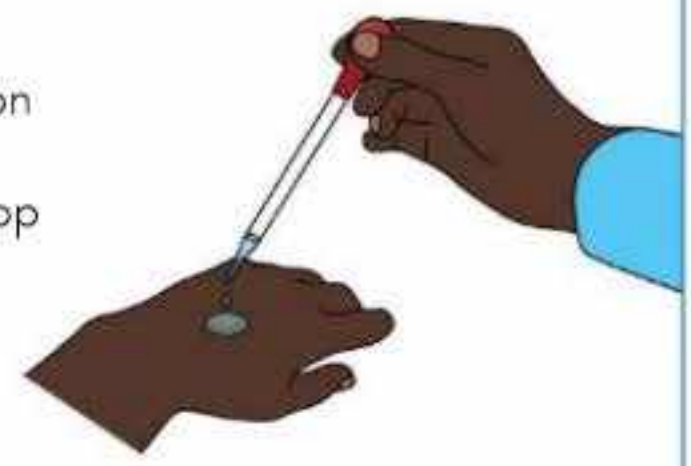
You will need:

- water, liquid soap, ethanol or isopropanol (also known as isopropyl alcohol or rubbing alcohol), dropper pipette, paper towels, access to hand-washing facilities or running water.

Safety

No other liquids should be used in this activity except ones that are intended for use directly on the skin.

Method



1. Use the dropper pipette to put one drop of water on the back of your hand, as shown in the diagram.
2. Use a finger from your other hand to spread the drop of water thinly on your skin.
3. Gently blow on the wet skin.
4. Remember how this feels.
5. Dry your hand using a paper towel.
6. Repeat steps 1–4 with the liquid soap. This time wash your hand with plenty of water to remove the soap before drying.
7. Repeat steps 1–4 with the ethanol or isopropanol. Wash your hand to remove any ethanol or isopropanol before drying.

Questions

1. Explain why you spread each liquid thinly in step 2.
2. Write a description of what you feel on your skin with each liquid.
3. Use your answer to question 2 to suggest
   a. which of the liquids evaporates fastest
   b. which of the liquids evaporates slowest.
4. Explain why it would be difficult to present the results of this activity in a bar chart.
5. Suggest how you could change this activity to get results that could be presented in a bar chart.

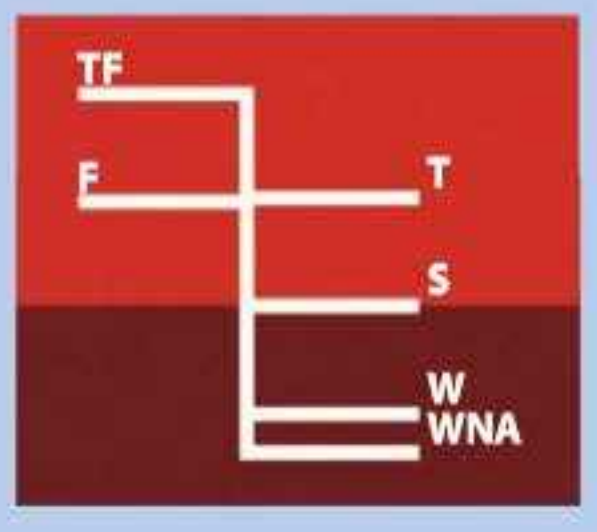
Summary checklist

- ☐ I know how evaporation can lower the average energy of particles in a liquid.
- ☐ I know how evaporation can cause cooling effects.

Project: Load lines

Background

Load lines, sometimes called Plimsoll lines, are painted on the sides of many ships. The picture shows an example of load lines.



The load lines are on the side of a ship, half way between the front and the back.

When cargo or passengers go onto a ship, the ship goes further down into the water. The load lines show how far down a ship can be in water and still be safe. The letters stand for different types of water and different conditions.

Your task

Find out what the letters on the load lines stand for.

Use a block of wood to model a ship. You will prepare different water conditions and test how your model floats in each. Your water conditions will model those shown on the load lines on a ship.

You can then mark load lines on your model.

You will also explain how the different water conditions affect how the ship floats.

Work in groups.

You can use equipment such as:

- a large bucket or deep sink to hold water
- a large block of wood to model your ship
- salt to add to the water
- a balance to weigh the salt
- a thermometer to measure the temperature of the water
- a method of heating water.

Continued

To give the best results, a block of wood that floats with a minimum of 10 cm of wood below the water surface is suggested.

Fresh water is water such as in rivers and lakes. You can model fresh water by using pure water with no added salt.

Sea water contains salt. Find out how much salt (sodium chloride) you will need to add to water to make your own sea water.

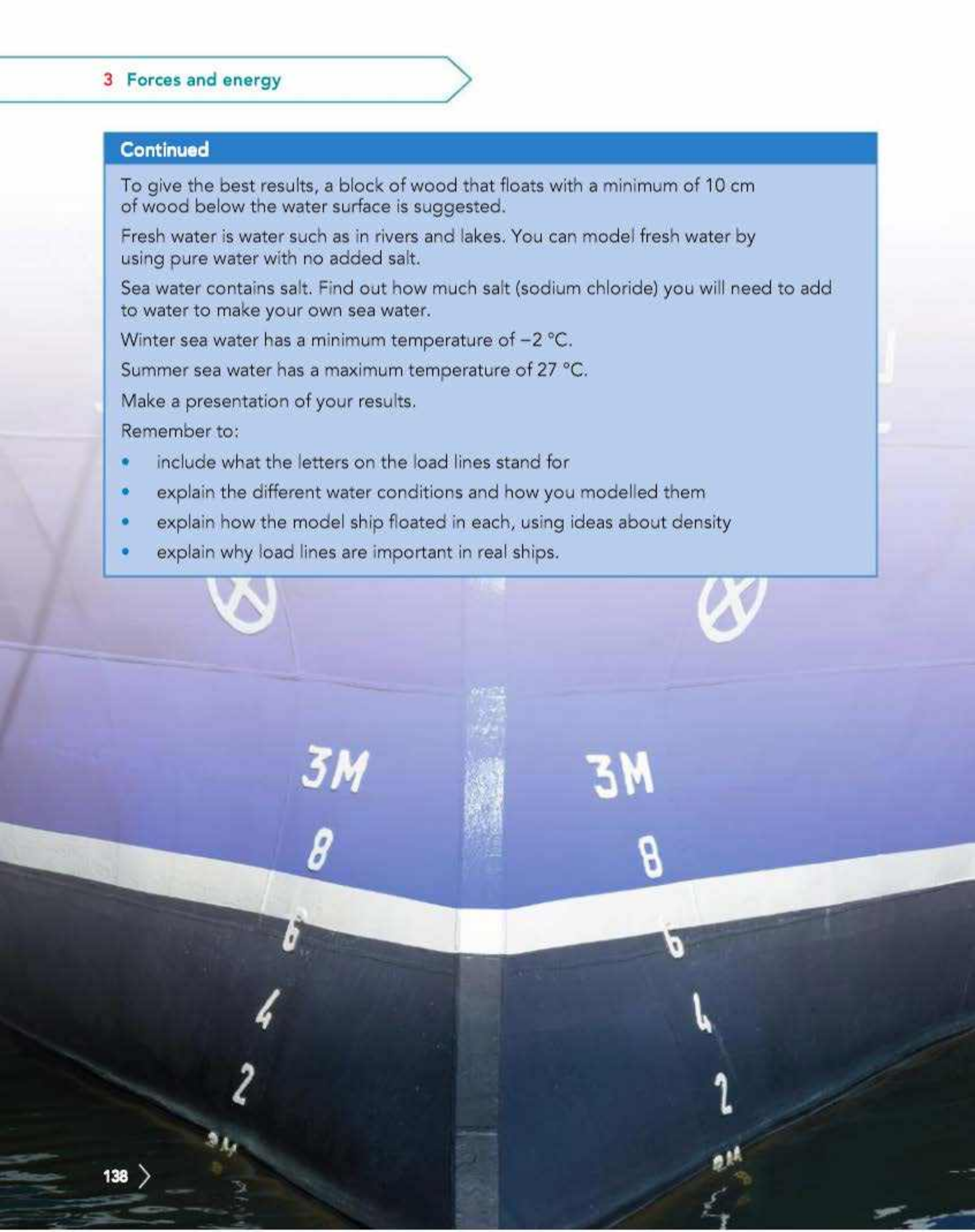
Winter sea water has a minimum temperature of −2 °C.

Summer sea water has a maximum temperature of 27 °C.

Make a presentation of your results.

Remember to:

- include what the letters on the load lines stand for
- explain the different water conditions and how you modelled them
- explain how the model ship floated in each, using ideas about density
- explain why load lines are important in real ships.



Check your progress

3.1 Which of these is the correct equation to calculate density?

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

A density = weight × volume

B $\text{density} = \frac{\text{mass}}{\text{volume}}$

C $\text{density} = \frac{\text{volume}}{\text{mass}}$

D $\text{density} = \frac{\text{weight}}{\text{volume}}$

3.2 Which statements are true about the density of air?

Give **two** letters. **[2]**

A The density of air is 0 g/cm^3 because air has no mass.

B The density of air is less than that of solids because the particles in air are further apart.

C The density of air is more than that of liquids because the particles in air are closer together.

D The density of air is more than that of a vacuum because a vacuum has no particles.

3.3 An object has a mass of 60 g and a volume of 50 cm^3.

a Calculate the density of this object. Show your working and give the unit with your answer. **[3]**

b The density of water is 1.0 g/cm^3. Explain whether this object will float or sink in water. **[1]**

3.4 Two beakers, X and Y, contain water at the same temperature.

Beaker X contains 50 cm^3 water.

Beaker Y contains 100 cm^3 water.

a Explain how the average energy of the particles in beakers X and Y compare. **[2]**

b Explain how the heat of the water in beakers X and Y compare. **[2]**

3.5 **a** State the unit of temperature. **[1]**

b State the unit of heat. **[1]**

3.6 Copy and complete the law of conservation of energy.

Energy is always ..... , meaning that energy cannot be ..... or ..... . [2]

3.7 An electric lamp uses 50 J of electrical energy.

5 J of energy is changed to light energy. The remainder is wasted as thermal energy.

Calculate the quantity of wasted energy. Give the unit. [2]

3.8 A small metal ball is heated to a temperature of 200 °C. The heated ball is dropped into water, which is at 4 °C.

a Explain what happens to the temperature of the ball **and** the temperature of the water just after the ball enters the water. [2]

b After a few minutes, the temperature of the ball and the temperature of the water stop changing. Which statement is true when these temperatures have stopped changing?

Give **one** letter. [1]

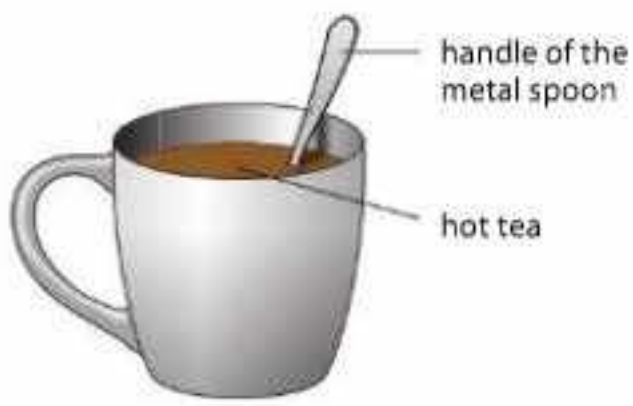
A The temperature of the water will be higher than the temperature of the ball.

B The temperature of the ball will be higher than the temperature of the water.

C The temperatures of the water and the ball will be the same.

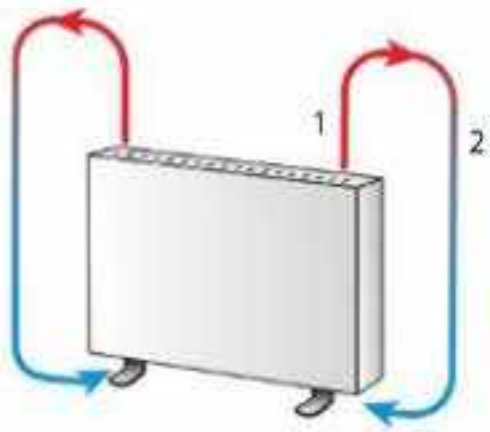
D The temperatures of the water and the ball will be lower than 4 °C.

3.9 A metal spoon is initially at room temperature. The metal spoon is placed in a cup of hot tea.



Explain why the handle of the metal spoon increases in temperature. [3]

3.10 The diagram shows the convection currents in the air around a heater.



a Explain what is happening to the air at position 1 in the diagram. **[3]**

b Explain what is happening to the air at position 2 in the diagram. **[3]**

3.11 Two cars are parked in the sun on a warm day. They are identical except that one is black and the other is white.

Both cars are parked for three hours.

Explain whether there is any temperature difference inside the black car and the white car after three hours. **[3]**

3.12 Explain how sweat can cool the skin, even when the sweat is at the same temperature as the skin. **[3]**

4 Maintaining life

> 4.1 Plants and water

In this topic you will:

- find out how plants absorb water
- discover how water moves from a plant's roots to its leaves.

Getting started

All living things need water to stay alive.

For example, living things need water to dissolve chemicals inside their cells, so that chemical reactions (such as respiration) can happen.

With a partner, think of as many sentences as you can that start with:

Living things need water ..... .

Try to include some good scientific information in each of your sentences. When everyone is ready, take turns with other pairs to share one of your sentences with the rest of the class. Build up a collection of all the different ideas on the board.

Key words

root hairs
xylem vessels

How root hairs absorb water

Plants, like all living things, are made mostly of water. Plants need to absorb water almost all of the time. They do this through their roots. The roots absorb water from the soil.

Soil is made up of tiny particles of rock. The particles are usually irregularly shaped, and all sorts of different sizes. They do not pack together tightly. There are spaces between them, which are filled with air and water.

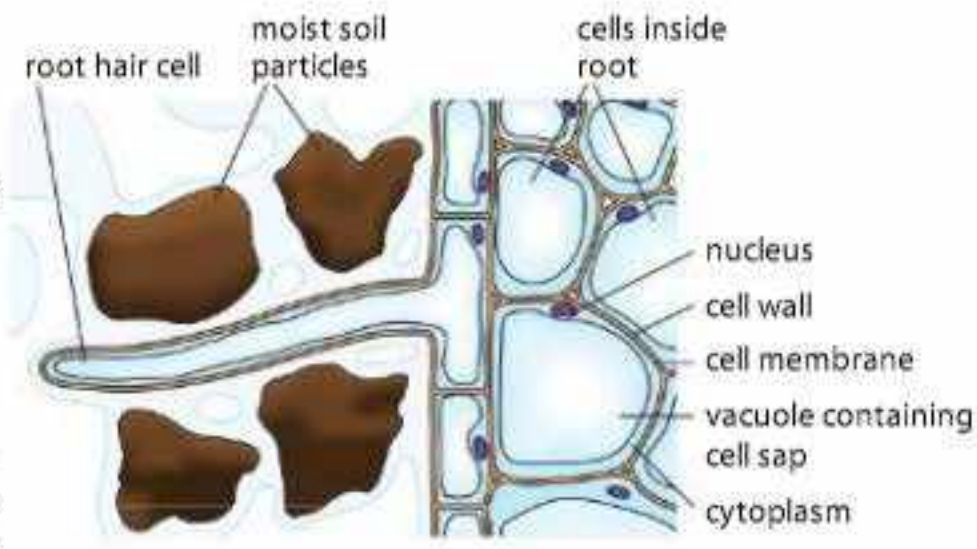
You may remember that special cells called **root hairs** grow out of the surface of roots. Root hair cells provide a really big surface through which water and mineral ions can be absorbed into the plant.

This photograph of root hairs was taken with a microscope. Root hairs are very tiny, but you can just see them without using a lens.

This diagram shows a root hair growing in between soil particles. Each root hair is part of a single cell.

Water moves into the root hair cell from the soil. It passes through the cell wall and the cell membrane of the cell, and into the cytoplasm.

Minerals, including magnesium and nitrate, also move into the root hair cell, along with the water. Magnesium and nitrate are in the form of ions (see Topic 2.4), dissolved in the water between the soil particles.



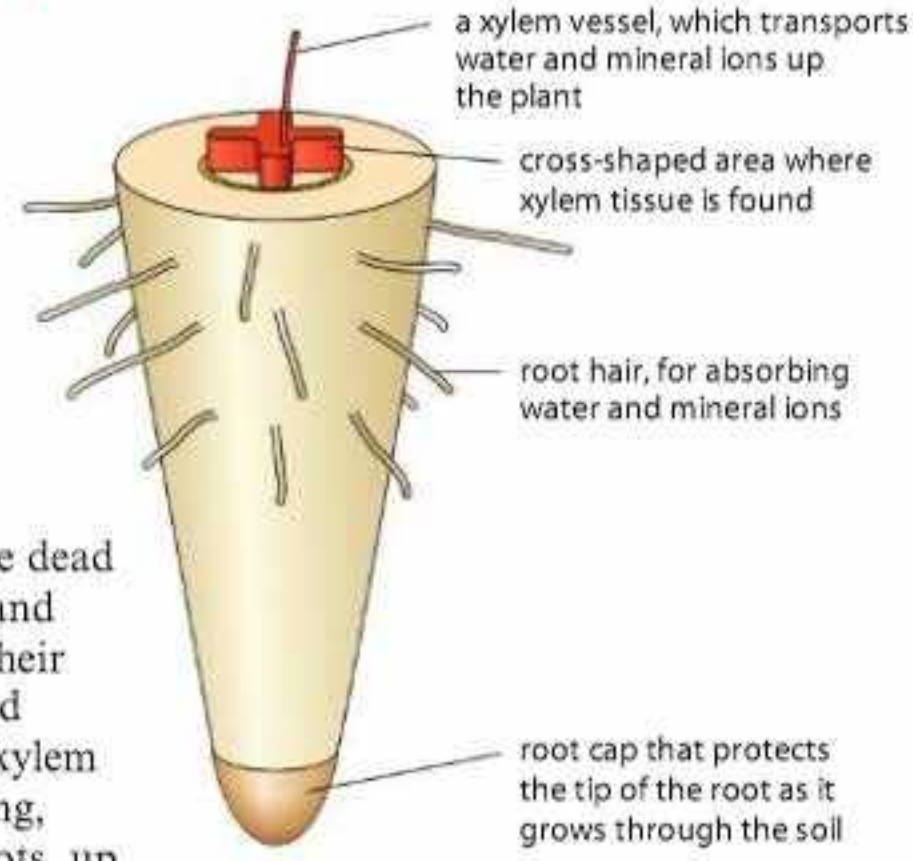
Questions

1 Root hair cells are different from other plant cells. Describe how the structure of a root hair cell helps it to carry out its function.

2 Why do plants need nitrate ions and magnesium ions?

How water moves up the plant

This diagram shows what a root looks like if you cut it across. You can see the root hairs on the outside of the root. In the centre, there are some very special cells called **xylem vessels**. These are the water transport system of the plant.

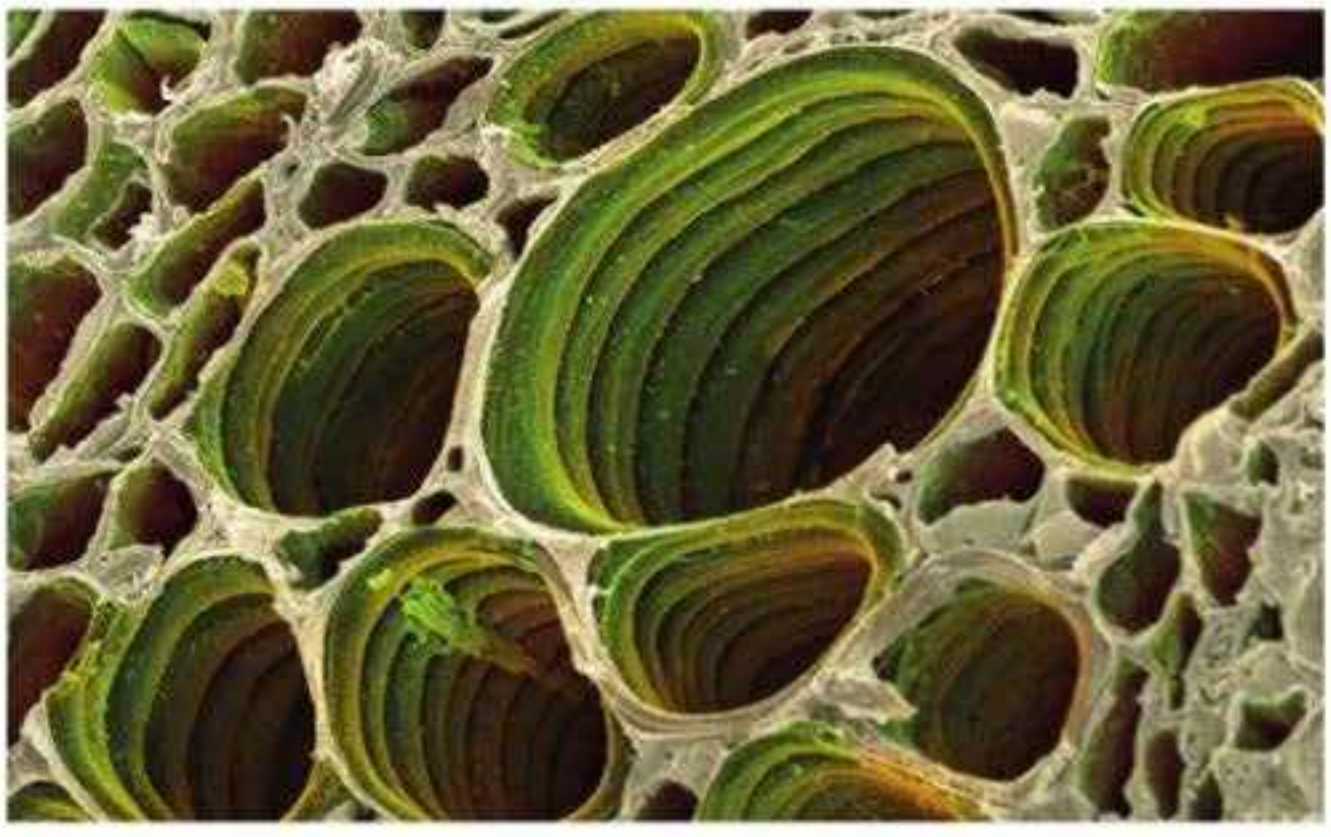


After water has been absorbed into a root hair cell, it moves from the outside of the root towards the inside. It goes into the xylem vessels in the centre of the root.

Xylem vessels are long, tube-like cells. They are dead cells – all of their contents, such as cytoplasm and a nucleus, have disappeared. All that is left is their cell walls, with an empty space inside. Their end walls have completely disappeared too. Many xylem vessels stack on top of one another, making long, empty tubes that reach all the way from the roots, up to the highest parts of the plant.

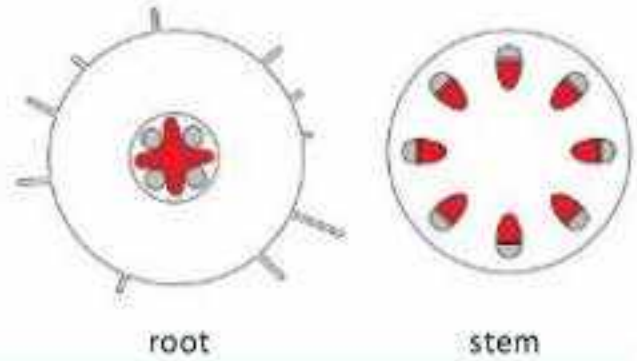
The wood in a tree trunk is made up of xylem vessels. They carry water from the roots all the way to the top of the tree.

This photograph shows some xylem vessels. It has been taken with a microscope. The actual diameter of a xylem vessel is only about 0.05 mm – although, as you can see in the photograph, they come in a range of different sizes.



Xylem in roots and stems

These two diagrams show the position of xylem in the roots (left) and stems (right) of a plant. They are cross-sections – you are looking down on a cut surface across a root and across a stem. The xylem vessels are shown in red.



Activity 4.1.1

Annotating a diagram

Work with a partner, or in a group of three, for this activity.

On a large sheet of paper, make a big copy of the unlabelled, circular diagram showing the position of xylem vessels in a root. Make sure that you leave enough space around your drawing to add some writing.

Use the information on the three-dimensional diagram on the previous page, and in the text on this page, to add annotations to your diagram.

The annotations should describe what each part does, so that someone looking at your diagram can understand how water is absorbed by the root, and how it is transported upwards from the root.

Self-assessment

Put your completed diagram onto the wall, alongside other learners' diagrams.

How do you think that your diagram and annotations compare with theirs?

What features make one diagram better than another?

Think like a scientist

Investigating transport in a celery stalk

In this experiment, you will try to follow the path of water as it moves up through a stalk.

You will need:

- a stalk of celery, pak choi or another plant that has a thick stalk – it works best if there are leaves at the top of the stalk, a small container, such as beaker or Petri dish, some water mixed with a coloured dye (e.g. blue ink, or methylene blue stain).

Safety

Be sure to put the stalk onto a non-slip surface before you try to cut it.
Cut away from you, so that if the blade slips, it does not hit your hand.

Continued

Method

1 Put some of the coloured water into your small container. You need no more than 1 to 2 cm depth.

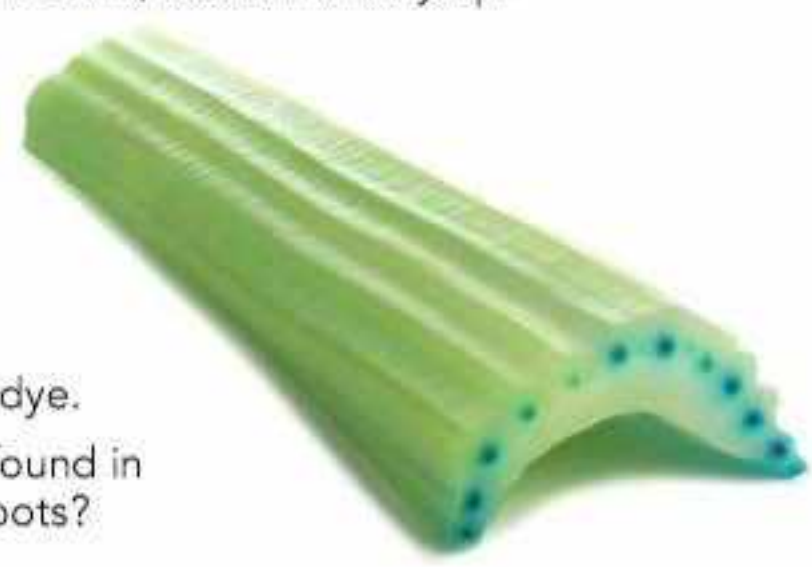
2 Cut across the lower end of the stalk (not the leaf end), making sure that the cut end is clean and is not blocked or damaged.

3 Stand the stalk in the coloured water. Make sure you stand the cut end in the water.

4 Every five minutes or so, look at the stalk. You may be able to see the blue dye moving up through it. This can sometimes happen very quickly, or sometimes very slowly – so be prepared!

5 When the dye has reached the top of the stalk, take the stalk out of the container. Rinse the blue dye off the end of the stalk, using tap water.

6 Put the stalk down onto a cork board or other non-slip surface. Use a knife to cut across the end of the stalk, about half way up. You should see something like this:



Questions

1 Make a drawing of the cut end of the stalk after it has been in the blue dye.

2 Which kind of cells do you think are found in the places where you can see blue spots? Choose from:

palisade cells root hair cells xylem cells

Label your drawing with the name of these cells.

3 Suggest why it was important to do each of these things, as you carried out your experiment.

a putting no more than 2 cm of water in the container at the start of your experiment

b washing the stalk before cutting across it, at the end of your experiment

4 In your experiment, there were no roots on the plant. Try to imagine how the stalk that you used would connect with the roots on a complete plant. Then write a sentence or two to explain how – in a complete plant – water would get to the stalk.

Think like a scientist

Planning an experiment

Method

Now that you have done the experiment to see how coloured water moves up a stalk, you are going to think about how you could modify this method to test a hypothesis. After you have had your plan checked, you may be able to do your planned experiment.

Questions

1. Think about what effect temperature might have on the speed at which the water moves up a stalk. If the temperature increases, do you think the water would move upwards faster, or more slowly? Why do you think that?
2. Write down your idea as a hypothesis.
3. Now think about how you could modify the experiment that you did with the stalk, to test your hypothesis. Discuss your ideas with a partner.
4. Write a description of your planned experiment. Make sure that you include:
   - a list, or drawings, of the apparatus that you will need
   - which variable you will change (your independent variable)
   - what you will measure (your dependent variable), how you will measure it and when you will measure it
   - which variables you will keep the same
   - a risk assessment for your planned investigation – what risks are there, and how will you control them?

In this topic, you have used photographs, a three-dimensional diagram, two-dimensional diagrams (the circular ones showing the xylem in stems and roots) and part of a real plant, to help you to understand how water moves into and up a plant.

How easy do you find it to link these different ways of thinking about a topic together? If you do have any difficulties, what might you be able to do to get better at it?

Summary checklist

- ☐ I can describe how water and mineral salts are absorbed from the soil into root hair cells.
- ☐ I can describe how water and mineral salts cross the root to reach the xylem vessels.
- ☐ I can suggest a hypothesis about the rate of movement of water in a stalk.
- ☐ I can plan an experiment to test my hypothesis.
- ☐ I can carry out a risk assessment for my experiment.

4.2 Transpiration

In this topic you will:

- find out how water vapour is lost from plant leaves
- summarise why plants need water.

Getting started

When we think of water, we usually think of a liquid. But water can also be a solid and a gas.

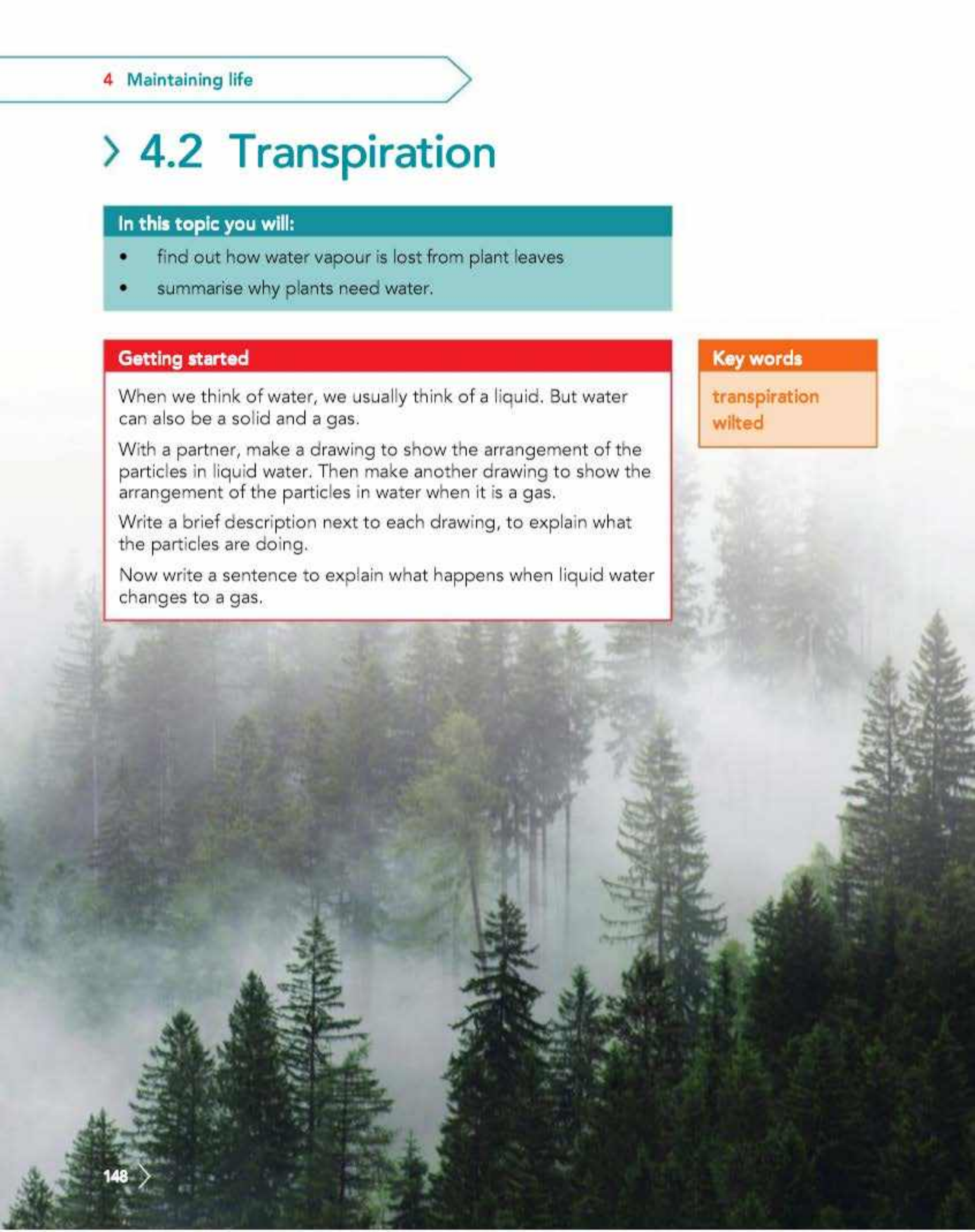
With a partner, make a drawing to show the arrangement of the particles in liquid water. Then make another drawing to show the arrangement of the particles in water when it is a gas.

Write a brief description next to each drawing, to explain what the particles are doing.

Now write a sentence to explain what happens when liquid water changes to a gas.

Key words

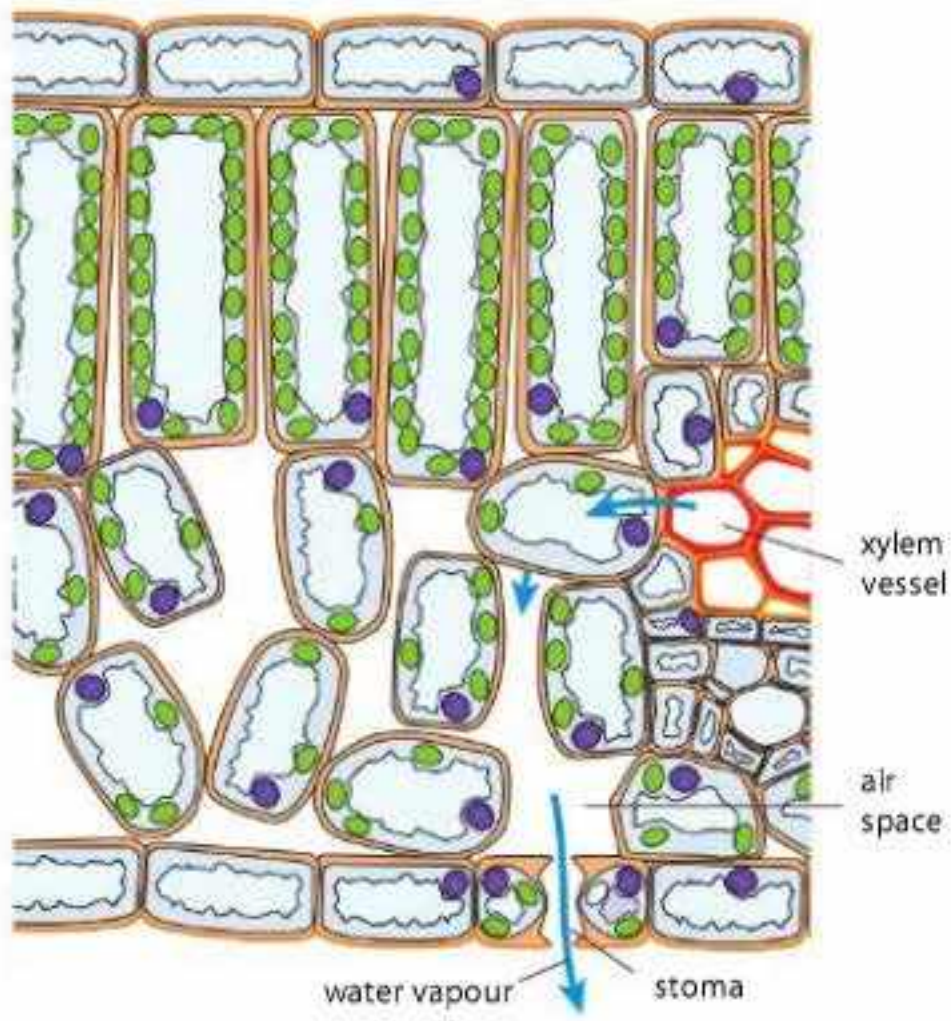
transpiration
wilted



How water moves through leaves

In the last topic, we saw how water goes into a root, across the root to its centre, and then up through the root and stem towards the leaves. Now we will think about what happens to the water when it reaches the leaves.

This diagram shows a section through part of a leaf. The arrows show how water moves out of the xylem vessels, and into the leaf.



When water arrives at a leaf, it moves out of the xylem vessels and into the leaf cells. The cells that have chloroplasts use some of the water for photosynthesis. But they do not need very much water for that, and most of the water does not stay in the cell. The liquid water in the cell soaks into the cellulose cell wall, and then changes to water vapour – it evaporates. The water vapour diffuses into the air spaces between the cells.

These air spaces connect with the air outside the leaf through tiny holes in the underside of the leaf – the stomata. The water vapour can diffuse through these holes and into the air.

The loss of water vapour from leaves is called **transpiration**.

Questions

1 Look at the diagram of the inside of a leaf in Topic 1.2. Use the information on that diagram to identify these parts on the diagram on this page

- the upper epidermis
- the palisade layer
- the spongy layer.

2 Most transpiration happens from the underside of a leaf, not the top. Why is this?

Think like a scientist

Investigating transpiration

In this experiment, you will investigate water loss from a plant growing in a pot.

You will need:

- two very similar plants, both growing in the same size pots
- two big, transparent polythene bags
- a balance for measuring the mass of the plants in their pots.

Method

1 Check that the soil in both plant pots is moist. If not, give both of them the same volume of water. Leave the pots for about five minutes, so that any excess water can drain away.

2 Take the first plant, and completely cover the plant and the pot with a plastic bag. Tie the bag very firmly at the top.

3 Take the second plant, and cover the pot and soil, but not the leaves of the plant, with a plastic bag. Tie the bag tightly around the plant stem – but take care not to damage the stem.

4 Measure the mass of both plants in their pots. Record the masses.

5 Each day for at least a week, measure the masses of both plants. Record all of your readings in a results table. (You could put the date in the first column, and the masses of the two plants in the next two columns. Remember to include the units in the column headings.)

Continued

6 Use your results to draw a line graph. You can draw two lines on the same graph – one line for each plant.

Questions

1 What was the variable that you changed (your independent variable) in this experiment?

2 What variables did you keep the same?

3 Compare the changes in mass for the two plants. Use comparative words in your answer, such as 'more' and 'faster'.

4 Explain why one plant lost mass faster than the other. Use the word 'transpiration' in your answer.

Think like a scientist

Which side of a leaf loses most water?

In this experiment, you will hang a number of leaves up to dry. The leaves will be treated differently, so that the surfaces that can lose water vapour are not all the same.

When the leaves lose water, they lose mass. You can compare the mass lost from each leaf to find out which treatment is best at helping the leaf to conserve (keep) its water.

You will need:

- eight leaves, all from the same kind of plant, and all roughly the same size
- some petroleum jelly
- at least eight paperclips, or another way of fixing the leaves to your 'washing line'
- a 'washing line' that you can hang your leaves from; you may be able to hang some string across the whole room for the whole class to share, or you can set up your own personal washing line with some string held between two retort stands
- a balance to measure the mass of the leaves (it needs to be quite sensitive, because leaves have only a small mass)
- some filter paper or other paper to put on the balance when you measure the mass of the leaves, so that you do not get petroleum jelly on the balance.

Method

1 Choose eight leaves that are as similar to each other as possible.

2 Line the leaves up on a piece of paper. Write a letter next to each leaf, in order: A, B, C, D, E, F, G and H. Make sure each leaf stays next to its letter.

Continued

3 Collect some petroleum jelly. Apply it to some of the leaves like this:
Leaves A and B : no petroleum jelly
Leaves C and D: a thin layer of jelly smeared on the upper surface only
Leaves E and F: a thin layer of jelly smeared on the lower surface only
Leaves G and H: a thin layer of jelly smeared on both surfaces.

4 Measure the mass of each leaf, and record it. Take care not to get petroleum jelly on the balance!

5 Now hang all eight leaves on your washing line. You cannot actually label the leaves, so make sure that you keep them in exactly the same order as on the paper (see the diagram below).

6 While the leaves are hanging up, make a prediction about which ones you think will lose mass most quickly. Write it down and explain your prediction.

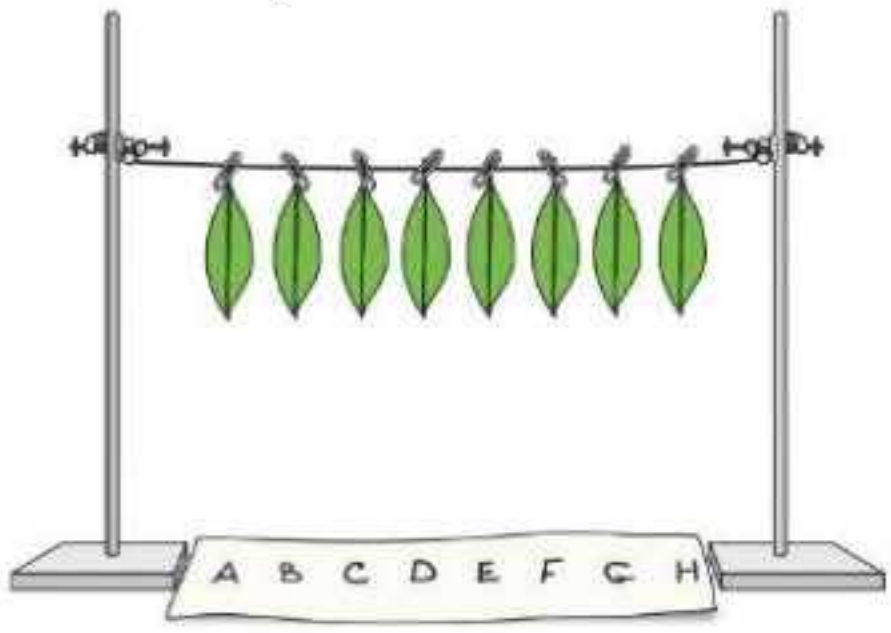
7 Allow the leaves to dry for at least one day. Then take them off the washing line and measure their masses again.

8 Record all of your results in a results table.

9 Identify any anomalous results. If you have any, decide what you will do about them.

10 Calculate the change in mass for each leaf and add this to your table.

11 Where two leaves had the same treatment, calculate the mean change in mass for those two leaves, and add this to your table.



Questions

1 List, in rank order, the treatments that best helped the leaves to conserve (keep) their water.

2 Use your knowledge of leaf structure and transpiration to explain the reasons for the order that you have described in your answer to question 1.

Continued

3 Did the two leaves that had the same treatment both lose exactly the same mass? If not, suggest why.

4 Suggest why you used two leaves for each treatment. Would it have been better to use more leaves for each treatment? Explain your answer.

5 Imagine that you are asked to do this experiment again. Suggest two improvements you would make (other than using more leaves for each treatment). For each of your suggestions, explain why this would improve the strength of the evidence you collect.

Self-assessment

How well did your results chart work? Do you think you designed it well? Was it easy to write your results into it?

Activity 4.2.1

Conserving water in the desert

Work with a partner for this activity.

In Stage 8, you studied the different habitats in a desert ecosystem.

Think about the kind of plants that live in a desert, where it is very hot and dry.

How are these plants adapted to:

- get as much water as possible from the soil
- reduce the amount of water that they lose through transpiration?

Be ready to share your ideas with the rest of the class.

Why plants need water

In this topic and the previous one, you have learnt how plants absorb water and transport it to their leaves. But why do plants actually need all this water?

Water for support

The photograph shows one reason why plants need water – it helps them to stand upright.

The plant on the left has been given plenty of water. The plant on the right has not been watered for several days.

Plant cells contain a lot of water, especially inside their vacuoles. A plant cell that has plenty of water is strong and firm. When all the cells in a plant are like this, they press on one another and make the whole plant firm and well supported.

When a plant cell doesn't contain enough water, it becomes soft and floppy. When all the cells in a plant are like this, the plant collapses. We say that it has **wilted**.

Water for transport

As water moves through the xylem vessels, it carries dissolved mineral salts. This is how these mineral salts are transported from the roots to all the other parts of the plant.

Water for cooling

When water evaporates, it takes heat away with it. So when water evaporates from the cell wall of a cell in a leaf, it cools the cell. This is important for plants that live in very hot places.

Water for photosynthesis

Water is one of the reactants in photosynthesis. In photosynthesis, plants change water and carbon dioxide to glucose and oxygen.

Summary checklist

- ☐ I can describe how water moves from xylem vessels to the outside of a leaf.
- ☐ I can describe where in a leaf water changes from liquid water to water vapour.
- ☐ I can explain that transpiration is the loss of water vapour from the surface of leaves.
- ☐ I can explain why plants need water.
- ☐ I can measure small masses accurately and precisely, and record my measurements in a results chart.
- ☐ I can evaluate how strong the evidence I collect in my experiment is, and suggest improvements to my experiment.

4.3 Excretion in humans

In this topic you will:

- find out what substances humans excrete
- study the structure of the human excretory system
- learn how the kidneys help with excretion.

Getting started

In the previous topic, you looked at why plants need water.

Discuss these questions with a partner.

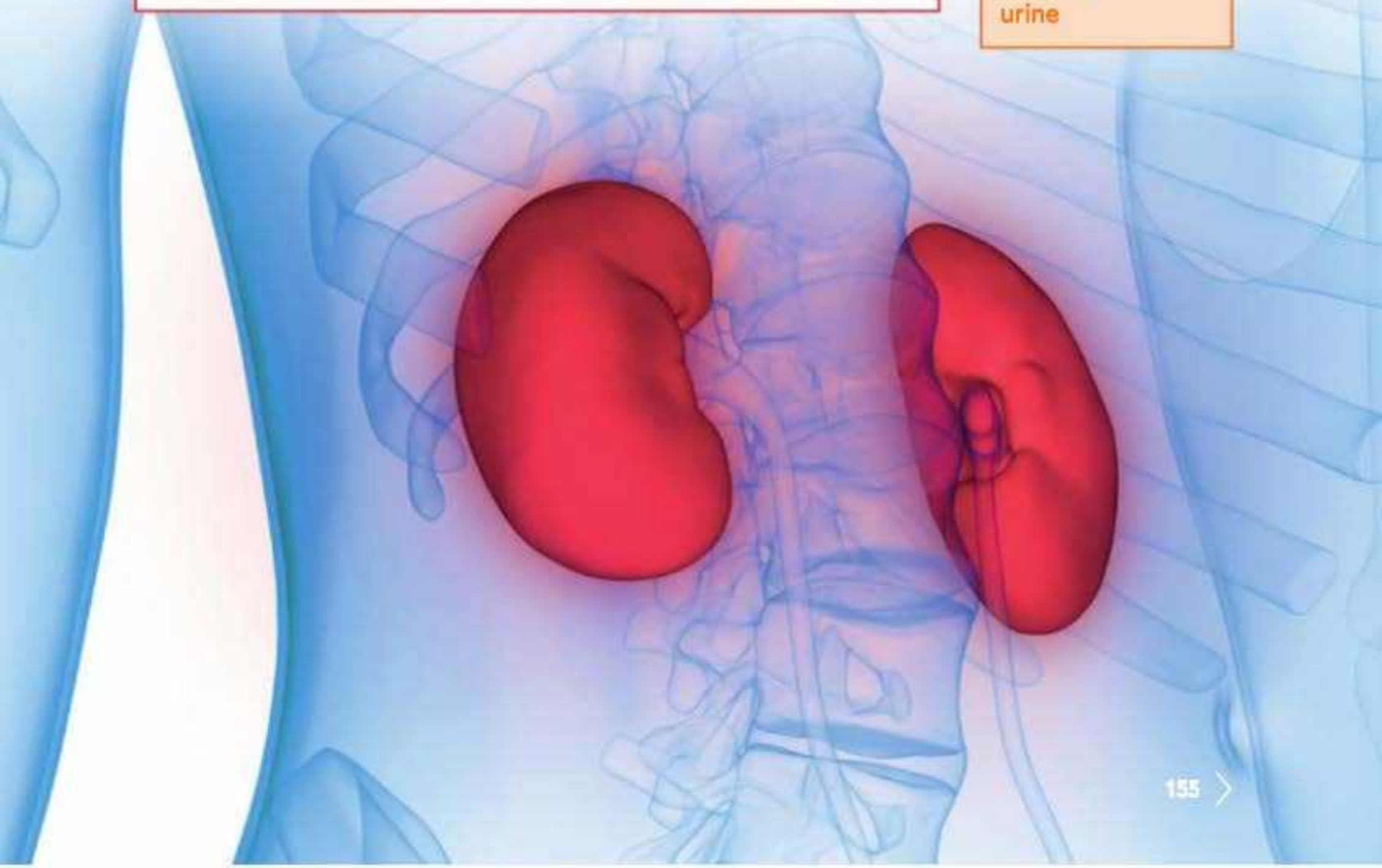
1 Are any of the reasons why plants need water the same as for humans?

2 Can you think of any reasons why humans need water that are not the same as for plants?

3 Are there any reasons why plants need water that are not the same as for humans?

Key words

bladder
excretion
excretory system
kidneys
renal
urea
ureter
urethra
urine



What is excretion?

In Stage 7, you learnt that **excretion** is one of the characteristics of all living things. Excretion means getting rid of waste materials.

In fact, this does not include *all* waste materials. Excretion really only applies to waste materials that have – even for only a short while – been truly inside the body.

Think about what happens when a person eats food. It travels down, along the long tube that takes it from the mouth to the anus. It is a strange idea, but actually the food that travels all the way through this tube has never really been part of their body. Only things that move out of the digestive system, and into the person's blood or their body cells, are really part of their body.

This means that the waste from the digestive system, which animals (including humans) get rid of as faeces, does not count as excretion. It has never been part of the body.

So, if getting rid of faeces is not excretion, what *does* excretion include?

Excretion includes all the waste substances that organisms make in their cells, plus any substances that they have too much of, that have been part of their body. For animals, including humans, these include:

- carbon dioxide, which body cells make in respiration
- **urea**, a waste substance that is made in liver cells
- excess water that is not needed by the body.

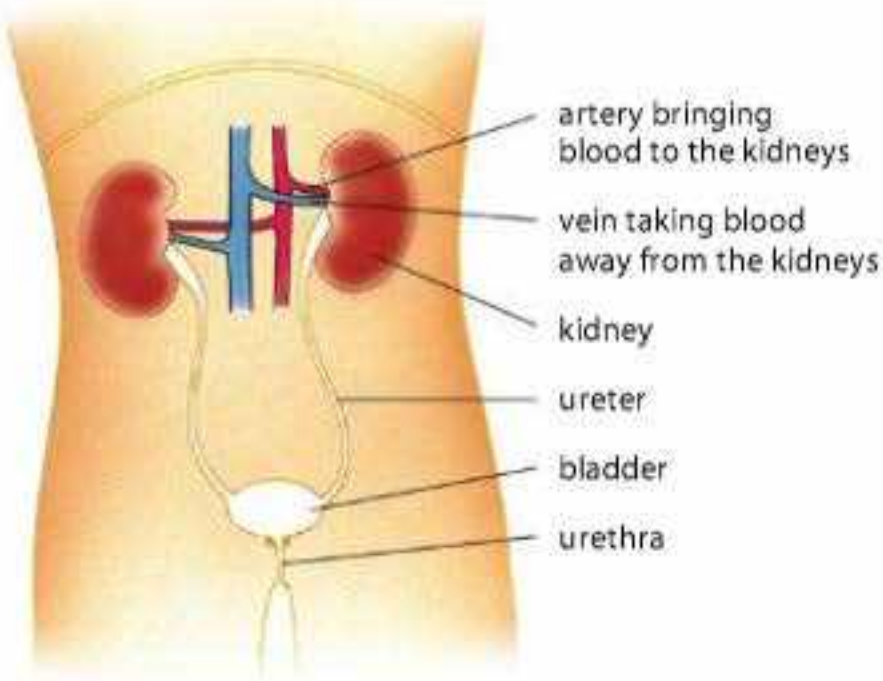
Excreting urea

When we eat food, any proteins in the food are broken down to smaller molecules inside the digestive system. These small molecules go into the blood. The blood transports them to the liver.

If we have more protein than we need, the liver changes the smaller molecules into urea. Urea is a poisonous substance. If it builds up in the body, it makes a person ill.

As soon as urea is made in a liver cell, it is taken away from the liver in the blood.

The urea is removed from the blood by the **kidneys** in the **excretory system**. This system is also known as the **renal** system. 'Renal' means 'to do with kidneys'.



As the blood flows through the kidneys, the kidneys filter the blood. They remove all of the urea from it. The kidneys also remove excess water from the blood. The urea dissolves in the excess water. The solution made of urea dissolved in water is called **urine**.

The urine made in each kidney flows down a tube called a **ureter**. This carries it to the **bladder**, which can store it for a while. The urine can flow out of the bladder to the outside world through another tube, called the **urethra**.

Activity 4.3.1

Excretory system words and meanings

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

You need eighteen identical pieces of card.

On nine of the cards, write one of the words in the Key words list at the start of this topic.

On the other nine cards, write the meanings of the Key words. Discuss this in your group first, to make sure that everyone agrees that the meaning is correct.

Shuffle the cards. Place them all face down.

One person picks up two cards. If they are a word and its meaning, they keep the cards and have another turn. If they do not match, they replace them face down and the next person has a turn.

Keep going until all the cards have been claimed. The winner is the person with the most cards.

This topic has a lot of new words beginning with u.

People often get mixed up between urea and urine. They also confuse ureter and urethra.

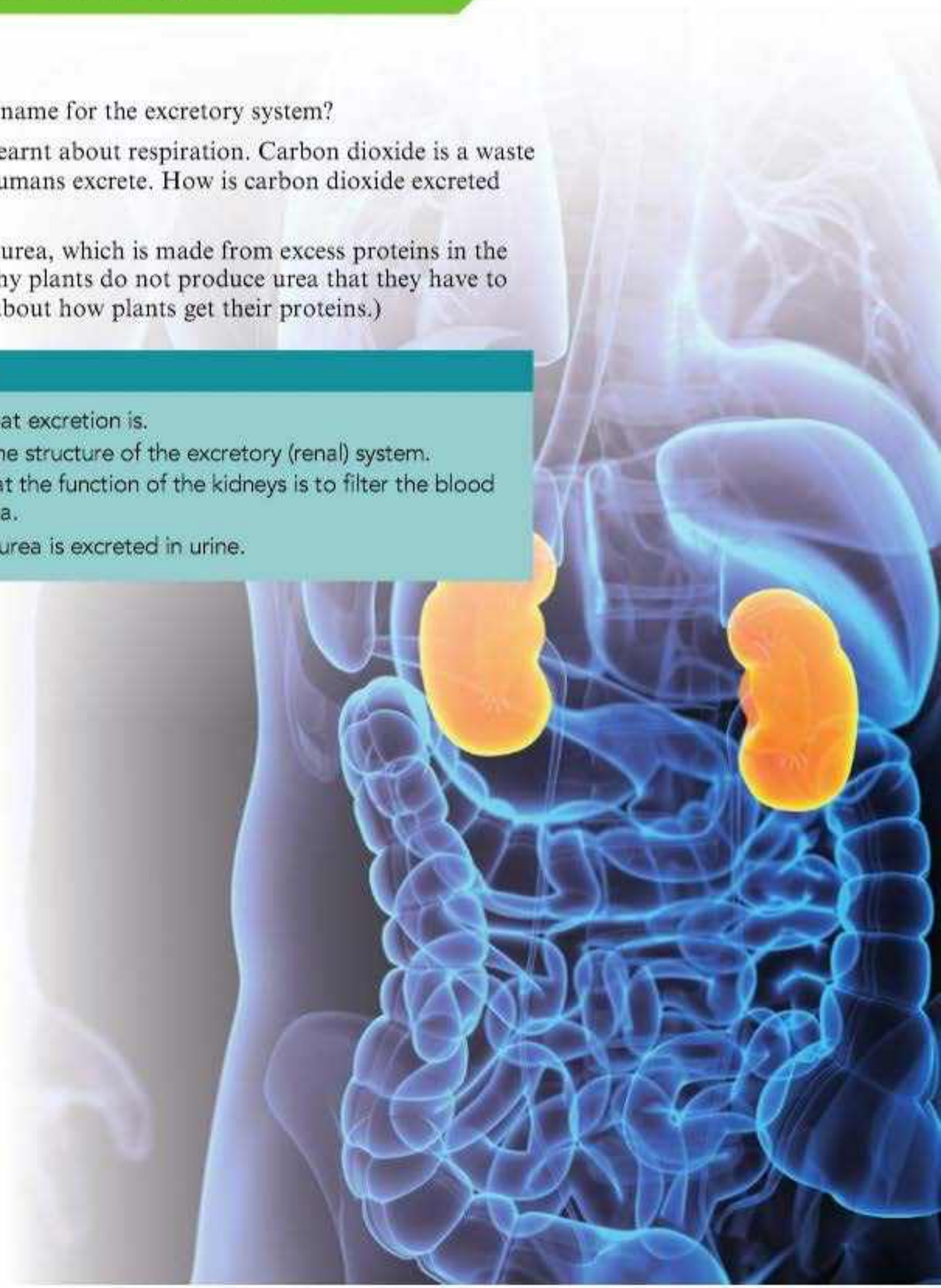
What have you done to help you to remember how to spell each of these words, and avoid mixing them up?

Questions

1 What is another name for the excretory system?

2 In Stage 8, you learnt about respiration. Carbon dioxide is a waste substance that humans excrete. How is carbon dioxide excreted from the body?

3 Humans excrete urea, which is made from excess proteins in the body. Suggest why plants do not produce urea that they have to excrete. (Think about how plants get their proteins.)

Summary checklist

- ☐ I can explain what excretion is.
- ☐ I can describe the structure of the excretory (renal) system.
- ☐ I can explain that the function of the kidneys is to filter the blood and remove urea.
- ☐ I can state that urea is excreted in urine.