6 States of matter

Almost all substances on Earth can be grouped as solids, liquids or gases. By comparing the properties of solids, liquids and gases, you can begin to answer questions such as 'What are substances made of?' This question has fascinated people for thousands of years, and scientists are still looking for more answers.

Think about particles

- Why does ice melt?
- What is dry ice and why doesn't it melt?
- Why do car windows fog up in winter?
- What are clouds made of?
- What is the difference between hail and snow?
- Why are there small gaps in railway lines?

In this chapter:

YOUR QUEST

Bathroom science

1 Why does the mirror fog up in the bathroom after someone has had a hot shower?
2 On really hot days, you may have a cold shower to cool down. Does the bathroom mirror fog up when you do this?
3 Some showers have shower curtains rather than glass shower screens. When people have warm showers, the curtain tends to move in towards the person and stick to them. Give possible explanations for why this happens.
4 When you have a hot shower, the bathroom fills with water vapour. Is this water vapour a gas or a liquid or both? Explain your reasoning.
5 How hot does water have to be before it can burn you?
6 Does water vapour always rise?
7 Are water vapour and steam the same thing?
8 Can you see water vapour or steam?

What is water vapour — a gas, a liquid, or both?

Ranking substances

1 Working in small groups, rank the following substances in order from most solid-like to most liquid-like to most gas-like.
- a brick
- jelly
- sugar
- Vegemite®
- orange cordial
- steam
- plasticine
- tomato sauce
- air
- green slime

2 Compare your rankings with those of other groups. Comment on any differences between the rankings.
3 Which substances were most difficult to classify as solid, liquid or gas? Explain why they were difficult to classify.
4 Draw a three-column table, like the one below, and separate the substances into three categories: solid, liquid or gas.

Solid	Liquid	Gas

Green slime — is it solid or liquid? How do you know?

States of matter

Every substance in the universe is made up of matter that can exist in a number of different forms called states. Almost all matter on Earth exists in three different states: **solid**, **liquid** and **gas**. These states of matter have very different **properties**. That is, they are different in the way they behave and appear.

Iodine diffusing in a fume cupboard

INVESTIGATION 6.1

Comparing solids, liquids and gases

AIM To compare the properties of solids, liquids and gases

Materials:
ice cube
balloon
plastic syringe
beaker of water
spatula

METHOD AND RESULTS

- Pick up an ice cube and place it on the bench. Using a spatula, try to squash it or compress it to make it smaller.
- Take the beaker of water and draw a small amount up into the syringe. Place your finger over the opening at the end of the syringe and press down on the plunger.
- Partially inflate a balloon with air and hold the opening tightly closed. Try to squeeze the balloon.
- Release your hold on the opening of the balloon.

1 Copy the table below and use your observations to complete it.

Properties of solids, liquids and gases

Substance	State of substance	Can the shape be changed easily?	Does it take up space?	Can it be compressed?
Ice	Solid			
Water	Liquid			
Air	Gas			

DISCUSS AND EXPLAIN

2 Where did the air in the balloon go when you released the opening?

Solids

Solids such as ice have a very definite shape that cannot easily be changed. They take up a fixed amount of space and are generally not able to be compressed.

Most solids cannot be poured, but there are some, such as salt, sand and sugar, that can be.

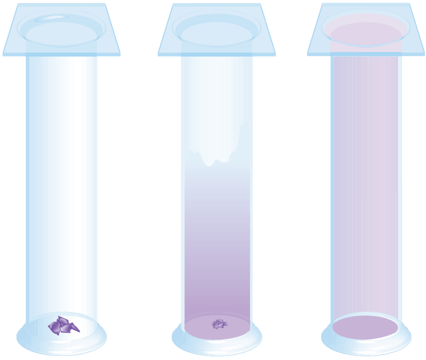
Liquids

Water is a liquid and its shape changes to that of the container in which it is kept. Like solids, liquids take up a fixed amount of space.

If a liquid is poured into a glass, it will take up the shape of the glass. If you continue to pour, it will eventually overflow onto the bench or floor.

Gases

Gases spread out and will not stay in a container unless it has a lid. Gases move around, taking up all of the available space. This movement is called **diffusion**. In the illustration below, iodine gas is being formed and is spreading, or diffusing, throughout the gas jar.



The purple iodine gas diffuses, taking up all of the available space. What will happen to the gas if the lid is removed?

Gases, unlike solids and liquids, can be compressed, making them take up less space. An inflated balloon can be compressed by squeezing it.

Measuring matter

The amount of matter in a substance, whether solid, liquid or gas, is called **mass**. The most commonly used unit of mass is the kilogram (kg), which is equal to 1000 grams (g). Mass is measured with an electronic scale or beam balance.

The amount of space taken up by a substance is called its **volume**. The volume of solids is usually measured in cubic metres (m^3) or cubic centimetres (cm^3). The volume of fluids is measured in millilitres (mL). One millilitre occupies the same volume as 1 cm^3. A **fluid** is a substance that can flow. All liquids and gases are fluids.

INVESTIGATION 6.2

Measuring the volume of an irregular-shaped solid

AIM To measure the volume of an irregular-shaped solid

Materials:

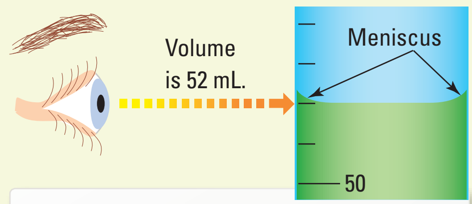
100 mL beaker
100 mL measuring cylinder
stone or pebble that will fit into the measuring cylinder

METHOD AND RESULTS

- Half-fill (approximately) a 100 mL beaker with water.
- Carefully pour the water into the measuring cylinder.
- Carefully place the pebble into the measuring cylinder. Take care not to spill any water.

DISCUSS AND EXPLAIN

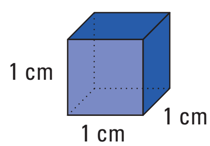
1. Read and record the volume of water in the measuring cylinder using the technique shown in the diagram below.
2. Read and record the new volume.
3. What was the volume of the solid in mL?
4. What was the volume of the solid in cm^3?



Reading the volume of a liquid in a measuring cylinder. The curved upper surface is called the meniscus. Your eye should be level with the flat part in the centre of the meniscus.

5. Suggest another way of measuring the volume of the solid object.

$$1 \text{ mL} = 1 \text{ cm}^3$$
$$1 \text{ L} = 1000 \text{ cm}^3$$
$$1000 \text{ L} = 1 \text{ m}^3$$



This cube has a volume of 1 cm^3 and can hold 1 mL of a fluid.

UNDERSTANDING AND INQUIRING

REMEMBER

1 List as many as you can remember of the solids, liquids and gases you came into contact with before leaving for school today. Organise them into a table under three headings, ‘Solids’, ‘Liquids’ and ‘Gases’, or into a cluster, mind or concept map.

2 (a) Write down three properties that most solids have in common.
(b) Would liquids have the same three properties? If not, what differences might be expected?

3 Which properties of gases are different from those of liquids?

4 What is the unit used for measuring small volumes such as for liquid medicines? How could you measure such a volume?

THINK

5 Both steel and chalk are solids. What properties of steel make it more useful than chalk for building bridges?

6 Are plasticine and playdough solids or liquids? Explain why.

7 What is diffusion? Give two examples of this occurring around your house.

8 Is it possible for a solid to behave like a fluid? Explain your answer.

9 At the petrol station, the safety sign asks for the car engine to be switched off before you fill the petrol tank. Why is this necessary?

INVESTIGATE

10 There is a fourth state of matter known as plasma, which is not very common on Earth. Research and report on:
(a) how plasma is different from solids, liquids and gases
(b) where plasma can be found
(c) how plasma can be used on Earth.

11 Different liquids pour or flow in different ways. Test this by pouring honey, shampoo, cooking oil and water from one container to another. Time how long they take to pour. Make sure it is a fair test. Record the results in a table and write a conclusion based on your observations and results.

Changing states

Water is the only substance on Earth that exists naturally in three different states at normal temperatures. It is in the oceans, in the polar ice and in the air as water vapour. Water is constantly moving and changing states. You can observe water changing states in the kitchen. To change the state of any substance, including water, it must be heated or cooled, or the pressure changed.

Unfortunately, the ice sculpture in the photograph won't last for very long. Even as the sculptor works, it is melting as heat moves into it from the warmer air around it.

Melting point and boiling point

The state of matter of any substance depends on its temperature. The temperature at which a substance changes from a solid into a liquid (melts) is called its **melting point**. A liquid changes into a solid (freezes) at the same temperature. Water has a melting point of 0 °C, so to melt ice it has to be heated to a temperature of 0 °C. To freeze water it has to be cooled to a temperature of 0 °C.

The **boiling point** is the temperature at which a substance boils. At this temperature, the substance changes from liquid into gas (evaporates) quickly. At the same temperature, a gas changes into a liquid (condenses). The boiling point of water is 100 °C. The melting and boiling points of some common substances are shown in the table on the next page.

Evaporating
Evaporation occurs when a liquid changes to a gas. When water evaporates at temperatures less than 100 °C, it forms water vapour. When it evaporates at temperatures greater than 100 °C, it forms steam. Water vapour and steam cannot be seen.

Melting
The change of state from solid to liquid is called melting. A solid melts when heat is transferred to it.

Freezing
The change of state from a liquid to a solid is called freezing. A liquid turns into a solid when heat is transferred away from it.

Condensing
Condensation is the opposite of evaporation. If a gas comes into contact with a cold surface, it can turn into a liquid.

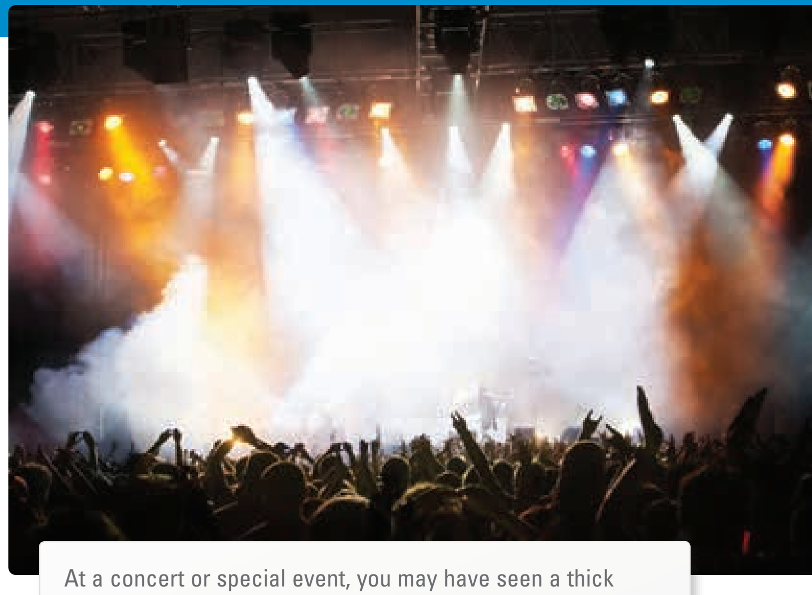
Boiling
During boiling, the change from liquid to gas (evaporation) happens quickly. The change is so fast that bubbles form in the liquid as the gas rises through it and escapes. During boiling, the entire substance is heated. A liquid remains at its boiling point until it has all turned into a gas.

HOW ABOUT THAT!

Melting and boiling points change with the height above sea level. This is because the air gets thinner as you move away from the Earth's surface. If you were climbing Mount Everest and made a cup of coffee near its peak, you would find that the water boiled at about 70 °C instead of 100 °C.

Melting and boiling points of some common substances at sea level

Substance	Melting point (°C)	Boiling point (°C)
Water	0	100
Table salt	804	1413
Iron	1535	2750
Aluminium	660	1800
Oxygen	–218	–183
Nitrogen	–210	–196

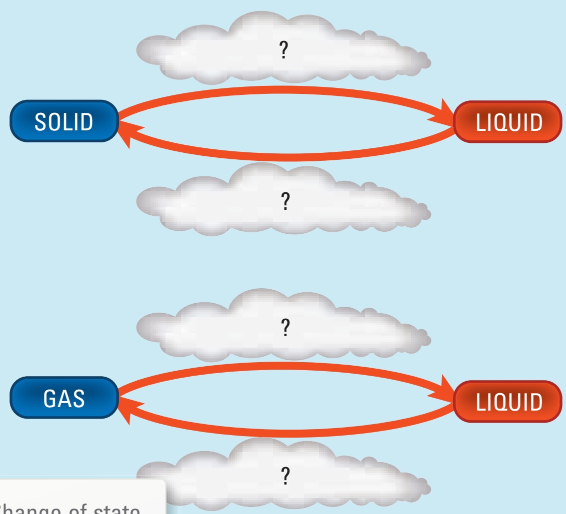


At a concert or special event, you may have seen a thick 'smoke' used for effect. This smoke is produced when solid carbon dioxide, called 'dry ice', changes state from a solid directly to a gas. This very unusual change of state is called **sublimation**. The 'smoke' is actually tiny droplets of water that condense from the air as the cold dry ice sublimes. Dry ice sublimes at a temperature of –78.5 °C. Iodine also sublimes. Diamonds sublime at a temperature of 3550 °C.

UNDERSTANDING AND INQUIRING

REMEMBER

1 (a) Copy and complete the diagram below, labelling the changes of state.
(b) Use a labelled arrow to add 'sublimation' to your diagram.



Change of state

2 What is the name given to the change of state from liquid water to steam? What happens to make this occur?

3 What happens to liquid water when it is cooled below 0 °C? Has heat moved into or out of the liquid?

4 When water evaporates it can change state from liquid to a gas in the form of either steam or water vapour. Explain the difference between steam and water vapour.

ANALYSE

Use the table above to answer these questions.

5 At what temperature would you expect table salt to melt? At what temperature would it freeze?

6 Would you expect aluminium to be found as a solid, liquid or gas at:
(a) 200 °C? (b) 680 °C? (c) 1900 °C?

7 Which substance — oxygen or nitrogen — would freeze first if the temperature were gradually lowered?

THINK

8 Explain the difference between evaporation and boiling.

9 Why is dry ice useful to produce a 'smoke' effect? What other uses are there for dry ice?

INVESTIGATE

10 Dry the outside of a very cold can of soft drink or carton of milk and allow it to stand on a table or bench for about ten minutes. (Don't forget to put it back in the fridge afterwards.)
(a) What change occurred on the outside of the can?
(b) Where did the water come from?
(c) What change of state has occurred?

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work sheet 6.1 Changing the boiling point of water

The state of the weather

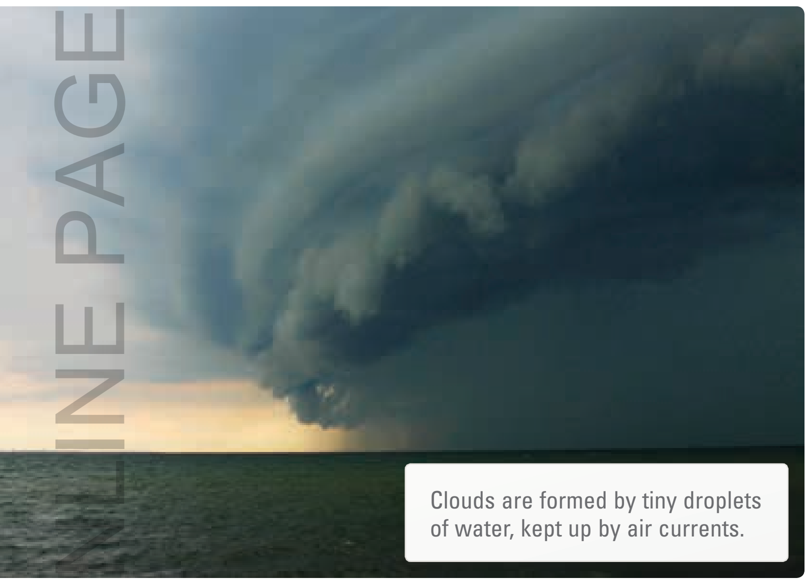
Rain, hail, snow and sleet are all types of **precipitation**. Precipitation is falling water, whether in solid or liquid form. All precipitation occurs because energy from the sun melts ice and causes liquid water to evaporate to become water vapour in the atmosphere. When the temperature in the atmosphere gets low enough, the water vapour condenses or freezes. That's when we get rain, hail, snow or sleet.

Water and the weather

The type of precipitation we get depends mostly on the temperature in the clouds and the air around them. It also depends on the amount of water vapour in the air and air pressure.

Rain

Rain forms when water vapour condenses in cold air, forming tiny droplets of water. These droplets are so small that they are kept up by moving air, forming clouds.



Clouds are formed by tiny droplets of water, kept up by air currents.

As the droplets join together they become too heavy to remain in the air. They fall to the ground as rain. When air currents are low, very tiny drops of rain may fall as a fine mist known as drizzle.

Hail

If drops of rain freeze, they may form hailstones. Air currents within clouds move raindrops from the bottom of the cloud upwards to the top of the cloud. The top of the cloud is much colder than the bottom and the rising raindrops freeze very quickly. The frozen raindrops fall back towards the bottom of the cloud.

In summer, warm rising air helps to keep the hailstones in the clouds for longer, forming even more layers than usual. These hailstones can reach masses of over one kilogram before they fall.

If the air currents are strong enough, the frozen raindrops rise again, adding a new layer of ice. They fall again, then rise again to form another layer of ice. This can happen over and over again, each time adding a new layer of ice. When the ice has built up many layers, it gets heavy enough to fall to the ground as a hailstone. Hailstones can be extremely large and cause extensive damage.

Snow

Snow consists of crystals of ice that have frozen slowly in clouds. Many different shapes and patterns can be found in snowflakes. The shape and size depend on how cold the cloud is, its height and the amount of water vapour it holds. Crystals of ice form when clouds have temperatures below −20 °C. The crystals join together and fall. As they fall, they become wet with moisture but then refreeze as snowflakes.

If the air between the cloud and the ground is colder than 0 °C, the snowflakes fall as very powdery, dry snow. If the air is warmer, the ice crystals melt and fall as rain or sleet.

Snowflakes form many different shapes and patterns but always have six 'sides'.

Sleet

Sleet is snow that is melting or raindrops that are not completely frozen. Sleet forms when the air between the clouds and the ground is warm enough to melt ice.

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Understanding a weather forecast

Interpret weather maps for yourself and find out how isobars indicate air pressure.

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Predicting the weather

The scientists who predict, or forecast, the weather are **meteorologists**. Meteorology is the study of the atmosphere and includes the observation, explanation and prediction of weather and climate. Numerous observations of temperature, precipitation, wind speed, air pressure, humidity and more are needed to make weather forecasts. Humidity is a measure of the amount of water vapour in the air.

Before the first weather balloon was launched in 1882, observations with instruments such as thermometers, barometers and rain gauges could be made only on land or ships. Not long after the invention of the first 'flying machine' in 1903, weather instruments were attached to the wings of planes, allowing them to be taken higher in the atmosphere.

As new technology becomes available, the number and quality of observations improve. Improved weather balloons, together with radar, satellite images and computer modelling, allow meteorologists to make predictions further ahead and more accurately than ever before.

A meteorologist releases a weather balloon in Antarctica.

UNDERSTANDING AND INQUIRING

REMEMBER

1 What are clouds made of?

2 Using words or a labelled diagram, explain how hailstones are formed.

3 How can hailstones get as large as the one in the photograph on the previous page?

4 Explain the difference between snow and sleet.

5 What is meteorology concerned with?

6 What is humidity a measure of?

THINK

7 Suggest why extra-large hailstones are more common in summer than winter.

8 Ski resort operators suffer a shortage of snow in some years. What conditions would they look for to predict coming snowfalls?

INVESTIGATE

9 Make a list of leisure activities that rely on predictions about the weather.

10 In which occupations do each of the following types of weather prevent activity?
(a) Extreme heat
(b) Heavy rain
(c) Thunderstorms

11 Record the predictions of the maximum temperature of your nearest capital city made in a 7-day forecast. For each day of the 7-day period, also record the maximum temperature predicted on the day before. These forecasts can be found online on the Bureau of Meteorology website (www.bom.gov.au), on the TV news or in daily newspapers.

Then record the actual maximum temperature for each day as reported on the evening news or www.bom.gov.au. Use a table like the one below to record your data.

Daily maximum temperatures (°C)

	Day 1	Day 2	Day 3	Day 4	Day 5	Day 6	Day 7
Prediction in 7-day forecast							
Forecast the day before							
Actual maximum temperature							

(a) How does the accuracy of the 7-day forecast compare with the accuracy of the previous day's forecast?
(b) State your opinion about the accuracy of the forecast made on the day before.
(c) Apart from temperature, what other aspects of the weather forecast are reported in newspapers and on the TV news?

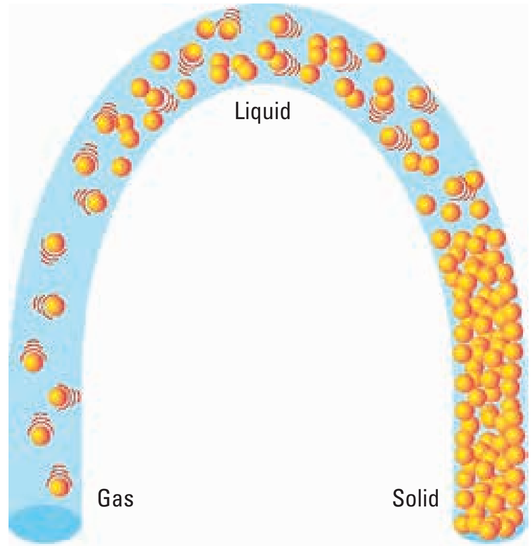
12 Find out what relative humidity is and with which instrument it is measured.

13 Research and report on what a hydrologist does.

14 Find out the difference between weather and climate.

Matter and energy: The particle model

How do you explain why ice has properties that are different from those of water or steam? Scientists use a model to explain the different properties of solids, liquids and gases. This model is called the **particle model**.

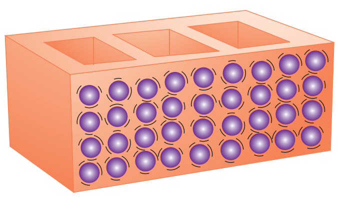


A particle model for different states

According to the particle model:
- all substances are made up of tiny particles
- the particles are attracted towards other surrounding particles
- the particles are always moving
- the hotter the substance is, the faster the particles move.

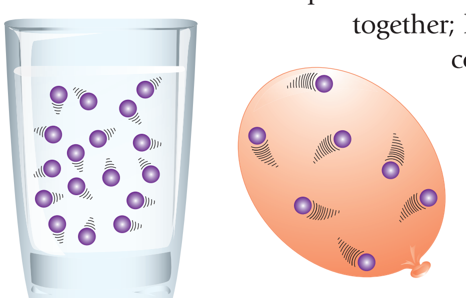
Particles in a solid

In solids the particles are very close together, so they cannot be compressed. The attraction between neighbouring particles in a solid is usually strong. Because there are such strong bonds between the particles, solids usually have a fixed shape and a constant volume. The particles in solids cannot move freely; instead they vibrate in a fixed position.



Particles in a liquid

In liquids the particles are held together by attraction, but the bonds between them are not as strong as those in solids. The weak particle attraction allows the particles to roll over each other, but they can't 'escape'. For this reason, liquids have a fixed volume but the rolling motion of the particles allows them to take up the shape of their container. As in solids, the particles in liquids are still very close together; liquids cannot be compressed into smaller spaces.



Particles in a liquid and a gas

WHAT DOES IT MEAN?

The word *particle* comes from the Latin word *particula*, meaning 'part'.

Particles in a gas

The particles in a gas have much more energy than those in solids or liquids, and they are in constant motion. The attraction between the particles in a gas is so weak that they are able to move freely in all directions. They spread out to take up any space that is available. This means that gases have no fixed shape or volume. Because of the large spaces between particles, gases can be compressed.

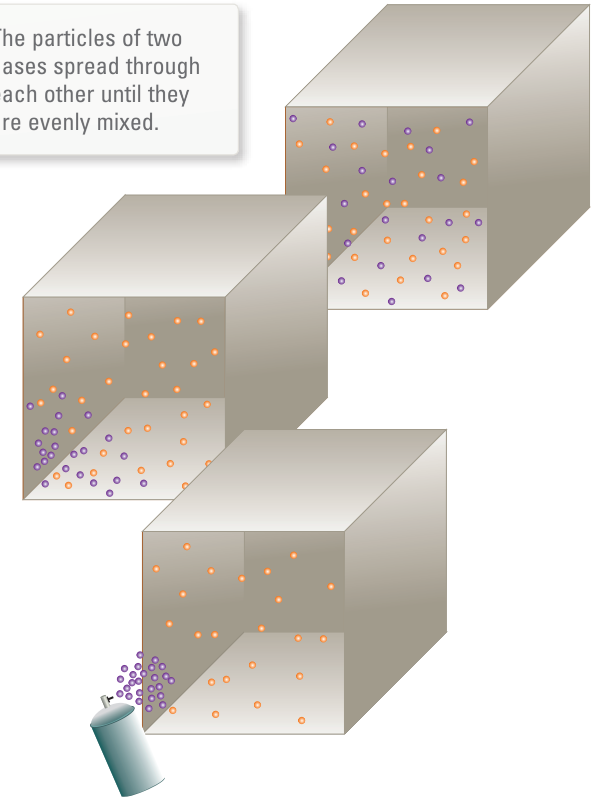
Spreading out

The spreading of one substance through another is called diffusion. This can happen only when the particles of one substance can spread through the particles of another substance. Diffusion is possible in liquids and gases because the particles move around. You would expect diffusion to happen faster in gases than in liquids because the particles move faster. Particles in a solid vibrate in a fixed position, so diffusion can't occur.

The particle model and balloons

The particle model can be used to explain what happens to a balloon when you inflate it. Particles of air inside the balloon constantly move in all directions. They collide with each other and with the

ONLINE PAGE PROOFS



The particles of two gases spread through each other until they are evenly mixed.

inside wall of the balloon. But the wall is not rigid. It can stretch as more particles are added. The balloon **expands** until it can't stretch any more. When you let some of the air out of the balloon, fewer particles collide with the inside wall of the balloon. It gets smaller or **contracts**.

Heating solids, liquids and gases

When a substance is heated, the particles gain energy, move faster, become further apart and take up more space and substance expands as the temperature increases.

The tyres on a moving car get quite hot. This makes the air inside expand and may even cause a blowout in extreme circumstances. Heating usually causes gases to expand much more than solids or liquids. Gases expand easily because the particles are spread out and not attracted to each other strongly. Solids, liquids and gases contract when they are cooled because the particles lose energy, slow down, need less space to move in and become more strongly attracted to each other.

Hot air balloons rise when the air inside them expands. The particles in the heated air move faster and take up more space. This makes each cubic centimetre of air inside the balloon lighter than each cubic centimetre of air outside the balloon, so the air inside the balloon rises, taking the balloon with it.

INVESTIGATION 6.3

Investigating diffusion

AIM To compare diffusion of liquids and gases

Materials:
250 mL beaker
water
food colouring
eye-dropper
fragrant spray

METHOD AND RESULTS

- Place a drop of food colouring into a beaker of water and record your observations for several minutes, making sure the beaker is not moved.
- Release some of the fragrant spray in one corner of the classroom. Move away and observe by smell.

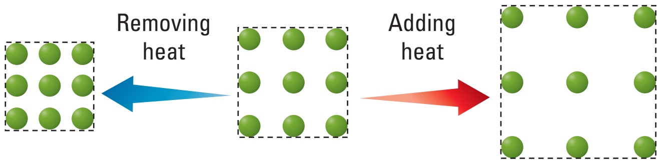
1. Draw a diagram to show the movement of the food colouring through the water.

DISCUSS AND EXPLAIN

2. Explain how the fragrant spray moved through the air.
3. This investigation shows diffusion in a liquid (water) and in a gas (air).
   (a) In which state does diffusion occur faster?
   (b) Why do you think this is so?

These hot air balloons rise when the air inside them expands. How do they get back down to the ground?

Architects and engineers allow for expansion and contraction of materials when designing bridges and buildings. Bridges have gaps at each end of large sections so that in hot weather, when the metal and concrete expand, they will not buckle. Railway lines also have gaps to allow for expansion. Electrical wires are hung from poles loosely so that when the weather



Contraction
- Particles move more slowly.
- Distance between particles gets smaller.
- The attraction between the particles increases.

Expansion
- Particles move faster.
- Distance between particles increases.
- The attraction between the particles decreases.

The volume of a substance changes when it is heated or cooled.

cools, they will not become too tight and break as they contract. The amount by which a structure will expand or contract depends on the material it is made from; so when choosing a material, it is important to find out how much that material will expand or contract. The table on page 221 shows how much some commonly used materials expand when the temperature increases by 10 °C.

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Priestley and the Law of Conservation of Mass
Watch a video from *The story of science* about the states of matter.
eles-1767

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INVESTIGATION 6.4

Explaining gases

AIM: To observe and explain the expansion and contraction of a gas

Materials:

balloon	*piece of string*
ruler	*small conical flask*
2 large beakers	*ice cubes*
hot and cold water	

METHOD AND RESULTS

1 Copy the table below right into your workbook.
- Inflate the balloon to its maximum size. Then deflate it. This makes it easier to stretch.
- Inflate the balloon again, to a size slightly larger than an orange. Fit the neck of the balloon over the conical flask to seal it.
- Wrap the string once around the widest part of the balloon to find its circumference. With a ruler, measure the length of the string that encircled the balloon.

2 Record the measurement in your table.
- Half-fill one of the beakers with ice cubes and a small amount of cold water.
- Place the conical flask in the ice-water beaker and observe the balloon. After a few minutes, use the string to measure the circumference of the balloon again.

3 Record your measurement in your table.
- Put some hot water into the second beaker. Take the conical flask from the ice-water and place it into the hot water.

4 Leave for a few minutes, then measure and record the balloon's circumference.

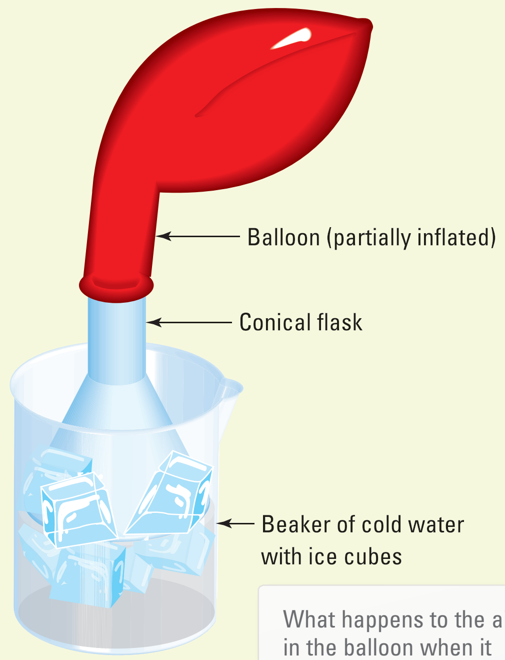
DISCUSS AND EXPLAIN

5 Was any air added to or removed from the balloon after it was placed over the conical flask?

6 After being in ice-water and hot water, were there any changes in the size of the balloon?

7 Using the particle model, try to explain what might have made the balloon contract and expand.

8 What quantity was varied or changed in this experiment? What things were kept the same?



What happens to the air in the balloon when it gets cold?

Effect of temperature on air

Temperature of surroundings	Circumference of balloon (cm)
Room temperature	
Cold (ice-water)	
Hot (hot water)	

An exception to the model

According to the particle model, the spaces between the particles in a liquid get smaller as the liquid is cooled, and the particles are closest once the liquid has become a solid. However, water is one of the few substances that do not behave exactly as the particle model predicts.

While the temperature of water is cooled from 100 °C to 4 °C, the particles behave as expected, with the spaces between them growing smaller. As water temperature drops below 4 °C, however, something strange happens—the spaces between the particles start to get larger again. By the time water freezes at 0 °C, the particles are further apart than they were at 4 °C! In general, the volume taken up by water particles increases by nearly 10 per cent when it becomes ice; you may have noticed this if you have ever put a full bottle of water in the freezer!

Oops! The reason why you shouldn't put a bottle full of water in the freezer.

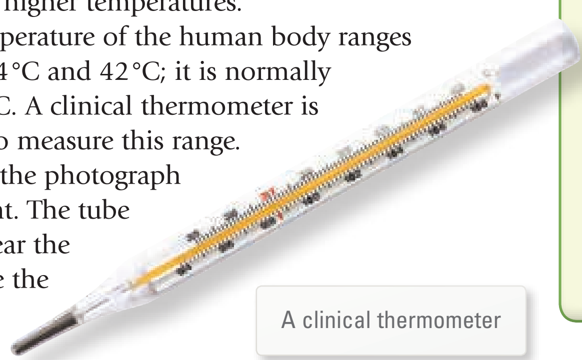
Thermometers

Bulb thermometers, like the one pictured below, use the expansion of liquids when they are heated to measure temperature. Most bulb thermometers consist of thin tubes and a bulb that contains a liquid. As the temperature rises, the liquid expands, moving up the tube, which is sealed at the top.

The two most commonly used liquids in thermometers are mercury and alcohol. Mercury has a low freezing point (–39 °C) and a high boiling point (357 °C). Alcohol, however, is much more useful in very cold conditions because it does not freeze until the temperature drops to –117 °C. On the other hand, alcohol boils at 79 °C, so it cannot be used for measuring higher temperatures.

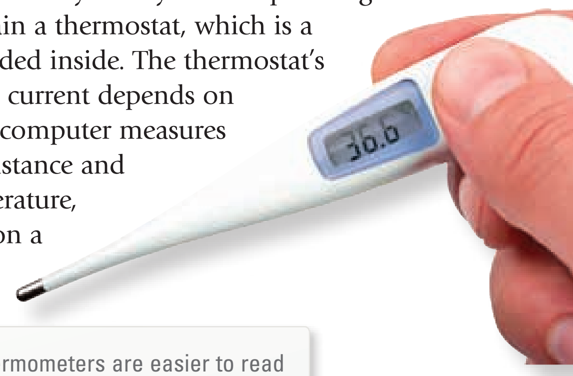
The temperature of the human body ranges between 34 °C and 42 °C; it is normally about 37 °C. A clinical thermometer is designed to measure this range.

Look at the photograph on the right. The tube narrows near the bulb. Once the mercury has expanded, this narrowing prevents the mercury contracting and moving back into the bulb before the temperature can be read. Once a reading has been taken, the mercury has to be shaken back into the bulb before the thermometer can be reused.



A clinical thermometer

Bulb thermometers are gradually being replaced by digital thermometers, which don't rely on expansion and contraction of mercury or any other liquid. Digital thermometers contain a thermostat, which is a sealed solid, embedded inside. The thermostat's resistance to electric current depends on temperature. A tiny computer measures the thermostat's resistance and calculates the temperature, which is displayed on a small screen.



Digital thermometers are easier to read than bulb thermometers.

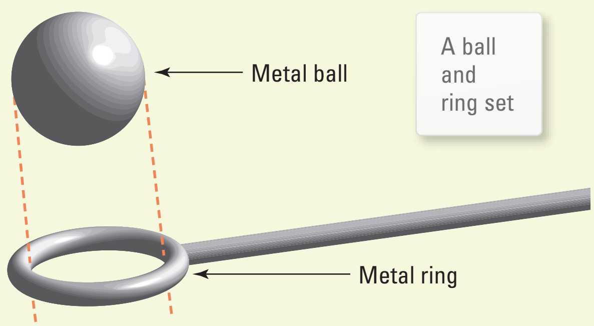
INVESTIGATION 6.5

Expansion of solids

AIM: To observe and explain the expansion of a solid

Materials:

metal ball and ring set
Bunsen burner and heatproof mat
tongs



A ball and ring set

METHOD AND RESULTS

- Try to put the ball through the ring.
- Use the Bunsen burner to heat the ring and use tongs to try to put the ball through it. Take care not to touch the hot metal.
- Let the ring cool and try to put the ball through the ring again.

DISCUSS AND EXPLAIN

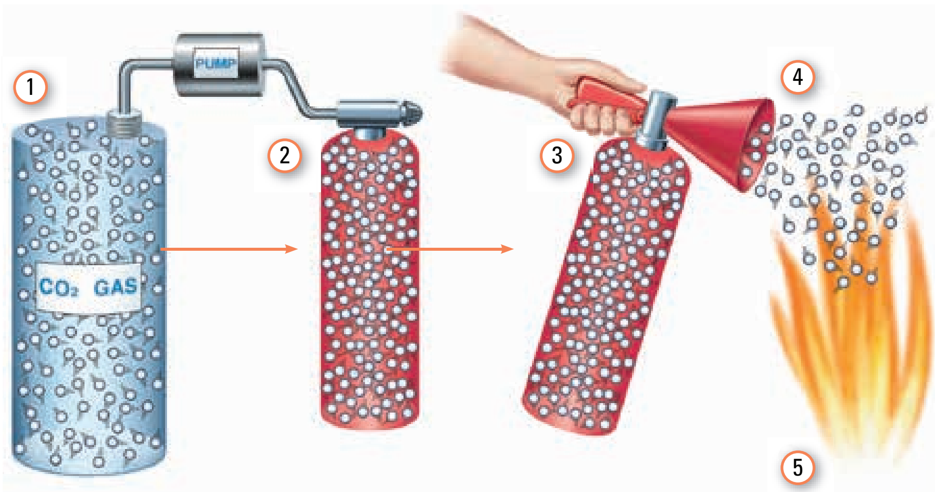
1. What happened to change the size of the ring?
2. Use the particle model to explain the change that took place in the ring.

Gases under pressure

The fire extinguishers used to put out electrical fires are filled with carbon dioxide gas. Carbon dioxide can be used in this way only because huge amounts of it can be compressed, or squeezed, into a container. Gases can be compressed because there is a lot of space between the particles. Gases compressed into cylinders are used for barbecues, scuba diving, natural gas in cars and aerosol cans.

> **eBook plus** eLesson
> **Under pressure**
> Learn about the factors that affect the pressure of a gas and how compressed gases are used to make fire extinguishers and aerosol cans.
> eles-0058

1. Gases, including carbon dioxide, have lots of space between their particles.
2. Carbon dioxide is compressed into a cylinder. The particles are squashed closer together.
3. The carbon dioxide particles are now under increased pressure. This means that the particles in the gas collide frequently with the walls of the cylinder and push outwards. The particles are trying to escape, but are held in by the container.
4. When the nozzle is opened, the pressure forces the carbon dioxide gas out very quickly through the opening.
5. The particles of gas quickly spread out over the fire. The gas smothers the fire, stopping oxygen from the air getting to it. Fires cannot burn without oxygen, so the fire goes out.



INVESTIGATION 6.6

Expansion of liquids

AIM To observe and explain the expansion of a liquid

Materials:

500 mL conical flask
tripod and gauze mat
eye-dropper
narrow glass tube
food colouring
marking pen
rubber stopper with one hole to fit the tube
Bunsen burner, heatproof mat and matches

METHOD AND RESULTS

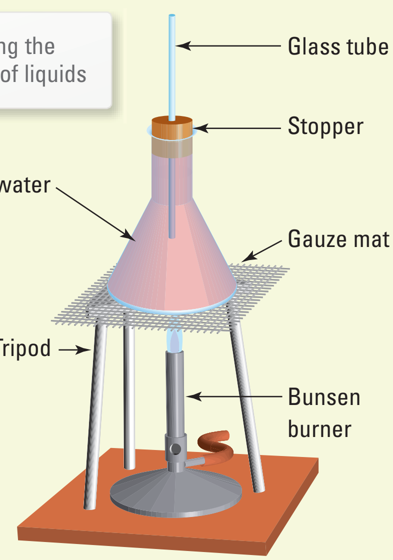
- Use an eye-dropper to place two or three drops of food colouring in the flask, then fill it with water right to the top.
- Place the stopper in the flask with the glass tube fitted. Some coloured water should rise into the tube. Mark the level of the liquid in the tube with the marking pen.
- Place the flask on the tripod and gauze mat, light the Bunsen burner and gently heat the liquid. Observe what happens to the liquid level in the tube.
- After about five minutes of heating, turn off the Bunsen burner and watch what happens to the liquid level in the tube.

1. What happens to the level of the liquid while it is being heated?
2. What happens to the level of the liquid while it is cooling down?

DISCUSS AND EXPLAIN

3. Use the particle model to explain why liquids expand.

Investigating the expansion of liquids



UNDERSTANDING AND INQUIRING

REMEMBER

1 Explain why a model is needed to explain the properties and behaviour of different states of matter.

2 List the four main ideas of the particle model.

3 What is diffusion?

4 Explain why solids generally expand when they are heated.

5 The following statements are incorrect. Rewrite them correctly.
  (a) Heating a liquid might make its particles stick closer together.
  (b) Solids have a definite shape because their particles are free to move around.
  (c) You can compress a gas because its particles are close together.

6 When a substance is heated, its temperature increases. What other change might be observed?

7 (a) Describe what change you expect to see when hot metal objects are cooling.
  (b) Why does this happen? Explain, using the particle model.

8 List two examples of structures that contain gaps to prevent them buckling in hot weather.

9 Give one reason why overhead electric power lines are not hung tightly.

10 What happens to the particles in carbon dioxide gas when they are compressed into a fire extinguisher?

ANALYSE

Expansion of materials

Substance	Expansion (mm) of 100 m length when temperature increases by 10 °C
Steel	11
Platinum	9
Concrete	11
Glass — soda	9
Glass — Pyrex	3
Lead	29
Tin	21
Aluminium	23

Use the table above to answer the following questions.

11 If a steel rod of 10 metres in length was heated so that its temperature rose by 10 °C, how long would the rod become?

12 Why is Pyrex, rather than soda glass, used in cooking glassware such as casserole dishes and saucepans?

13 Concrete is often reinforced with steel bars or mesh to make it stronger. Why is steel a better choice than another metal, such as aluminium or lead?

THINK

14 Describe an everyday example of diffusion.

15 Use the particle model to explain why:
  (a) perfume can be smelled from a few metres away
  (b) steam can be compressed while ice cannot
  (c) water vapour takes up more space than the same amount of liquid
  (d) solids do not mix well, but gases and liquids mix easily in most cases.

16 Use the particle model to predict what will happen to the length and width of a solid substance if it is heated (without melting).

17 A jar with the lid jammed on tightly can be hard to open. If hot water is run over the lid, it becomes easier to open. Why?

18 Hot air balloons have a gas heater connected to them.
  (a) What happens to the particles inside the balloon when the heater is turned on?
  (b) Explain why the balloon rises.

19 Under what conditions might you use an alcohol thermometer rather than a mercury thermometer?

20 List the advantages of digital thermometers over mercury bulb thermometers for measuring human body temperature.

21 Use the particle model to explain what keeps car or bicycle tyres in the right shape when they are pumped up to a high air pressure.

INVESTIGATE

22 The mercury thermometer was invented by a German named Gabriel Fahrenheit (1686–1736). A different set of markings is used to scale Fahrenheit thermometers. At what temperatures does water boil and freeze on this scale?

23 Why do icebergs float in Arctic and Antarctic waters? Do you think much of the iceberg is under the water, or is it mostly above? How could you test your hypothesis? Design a suitable experiment.

24 Use the internet to investigate the safe storage of gas cylinders. Make a list of requirements and state the reason for each of them.

25 Use the **States of matter in containers** weblink in your eBookPLUS to watch how solids, liquids and gases behave differently within a container.

eBook*plus*

26 All materials expand when heated and contract when cooled, right? Use the **Mystery expansion** weblink in your eBookPLUS to learn about a substance that breaks all the rules.

work sheet
6.2 Fire! Fire!
6.3 Expansion of liquids
6.4 Particles in our lives

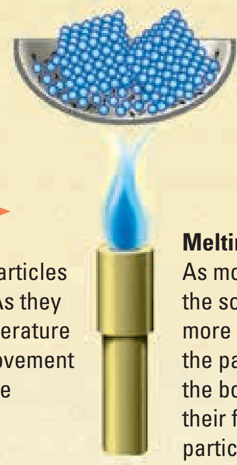
Energy in, energy out

A change of state involves the heating or cooling of matter. As a substance is heated, energy is transferred to it. When a substance cools, energy moves away from it to another substance or to the environment. The change in energy causes the particles in the substance to move at different speeds.

An increase in the energy of the particles of a substance results in an increase in the temperature of the substance. A decrease in the energy of particles results in a decrease in the temperature of the substance.

The flowchart below shows what happens to the particles that make up a substance when it changes from a solid state into a gas state. When a gas is cooled, the direction of the flowchart can be reversed as the substance changes from a gas state into a solid state.

Solid
When a solid is heated, its particles start to move more quickly. As they move more quickly, the temperature increases. The increased movement of its particles also makes the solid expand.



Melting
As more heat is transferred to the solid, its particles vibrate more violently. Eventually the particles move so much that the bonds holding them in their fixed positions break. The particles start to roll over each other. Melting continues until the entire solid becomes a liquid.

Liquid
As a liquid is heated, its particles move and roll over each other faster and faster. The temperature of the liquid increases and it expands.

Evaporating
If the liquid continues to be heated, the particles will eventually have enough energy to break the bonds holding them together. The particles can break away from the liquid and begin to move around freely. This process is called evaporation. The liquid boils until the entire liquid has evaporated to become a gas.

Gas
As in solids and liquids, the particles in gases move faster and faster when they are heated and the temperature of the gas increases. The increased movement of the particles means that they take up more space and the gas expands. If the gas is heated in a closed container, the increased movement of the particles means that they collide more often with the sides of the container and with each other.

Foggy mirrors

Have you noticed how the mirror in the bathroom 'fogs up' after a hot shower? The 'fog' is actually formed by invisible water vapour in the air cooling down when it contacts the cold glass. It condenses to become water.

Fog in the air
Some of the energy of the particles in the water vapour is transferred away from the vapour to the air. The transfer of energy leaves the water vapour with less energy — so much less energy that its particles slow down. The transfer of energy away from the water vapour means it cools down and turns into tiny droplets of water. These tiny droplets form clouds. This process is called condensation.

Invisible gas
Water vapour forms when particles in the hot water gain enough energy to escape from each other and become a gas. You can't see water vapour. The particles in the water vapour move around freely. They have more energy than the particles in the liquid water.

Fog on the mirror
The energy from some of the particles in the water vapour is transferred to the cold mirror. This causes the water vapour to condense on the mirror.

UNDERSTANDING AND INQUIRING

REMEMBER

1 Describe the motion of the particles in a liquid.

2 When a substance changes state from a solid into a liquid:
(a) what happens to the bonds between the particles?
(b) how does the motion of the particles change?

3 Describe what happens to the movement of particles as a substance changes its state from a gas to a liquid.

THINK

4 Describe two changes in the properties of a substance when its particles move faster.

5 In movies, you sometimes see a mirror being held up to the mouth and nose of someone who is unconscious to check whether they are breathing. Explain why this would work.

6 Construct a flowchart like the one on the previous page to show how a gas changes state to become a liquid and then a solid. Include the names and descriptions of the two changes of state that take place.

7 For each of the following changes of state of a substance, identify whether it involves adding energy to the particles or transferring energy away from the particles.
(a) Melting
(b) Condensation
(c) Boiling
(d) Freezing
(e) Sublimation
(f) Evaporation

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8 Simulate heating matter over a Bunsen burner by using the **Changes of state** interactivity in your eBookPLUS. **int-0222**

work sheet 6.5 Changes of state

STUDY CHECKLIST

STATES OF MATTER

- [ ] describe the properties and physical behaviour of solids, liquids and gases
- [ ] define fluid as a substance that flows
- [ ] measure the volume of solids and liquids
- [ ] explain how mass is measured

CHANGES OF STATE

- [ ] describe the changes in the physical properties of substances during melting, freezing, evaporation, boiling, condensation and sublimation
- [ ] relate changes of state to heating and cooling
- [ ] define melting point and boiling point

THE PARTICLE MODEL OF MATTER

- [ ] list the four major assumptions of the particle model of matter
- [ ] describe the arrangement and movement of particles in solids, liquids and gases
- [ ] describe the diffusion of gases and why it occurs in terms of the particle model
- [ ] use the particle model to explain why solids, liquids and gases expand when they are heated
- [ ] describe the behaviour of gases under pressure in terms of the particle model
- [ ] link the energy of particles to heating and cooling
- [ ] link changes in state to the flow of energy into or out of a substance and the subsequent changes in the behaviour of the particles of the substance

SCIENCE AS A HUMAN ENDEAVOUR

- [ ] describe the role of meteorologists in observing, explaining and predicting the weather
- [ ] relate weather events such as rain, hail and snow to changes of state
- [ ] outline the implications of expansion and contraction of materials for engineers and architects

ONLINE PAGE PROOFS

eBookplus DIGITAL RESOURCES

ANSWERS for this chapter can be found online in your eBookPLUS.

Online section

This section of the chapter can be found online in your eBookPLUS.

6.6 Thinking tools Concept maps and mind maps

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Individual pathways

Activity 6.1 Investigating particles doc-6066	**Activity 6.2** Analysing particles doc-6067	**Activity 6.3** Investigating particles further doc-6068

FOCUS activity eBookplus

Access more details about focus activities for this chapter in your eBookPLUS.

doc-10536

eLessons

Under pressure

In this video lesson, you will see animations that reflect the behaviour of gas particles and learn about the factors that affect the pressure of a gas. You will also learn how compressed gases are used to make fire extinguishers and aerosol cans. A worksheet is attached to further your understanding.

Searchlight ID: eles-0058

Understanding a weather forecast

You might watch the weather report every day on the evening news, but do you really understand what all the information means? Just what is a high or low pressure system, and what are those swirly lines and colours all over Australia? This eLesson will help you interpret weather maps for yourself and provide you with an insight into how the experts predict future weather conditions.

Searchlight ID: eles-0161

Interactivity

Changes of state

This interactivity allows you to simulate heating an ice cube over a Bunsen burner. As you add more heat, you will see the effect on the particles as the ice changes state to become boiling water. A worksheet is attached to further your understanding.

Searchlight ID: int-0222

LOOKING BACK

Link to assessON for questions to test your readiness **FOR** learning, your progress **AS** you learn and your levels **OF** achievement. **www.assesson.com.au**

1 Use the particle model to explain why steam takes up more space than liquid water.

2 In which state are the forces of attraction between the particles likely to be greatest?

3 List all of the changes of state that take place in the water cycle.

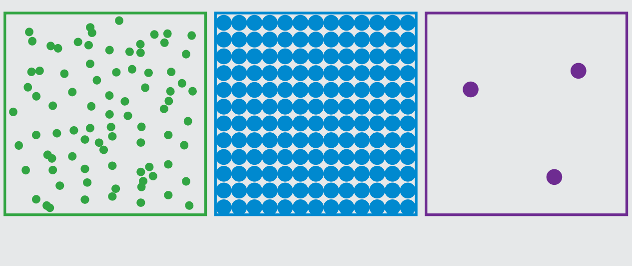
4 In which state — solid, liquid or gas — do the particles have:
(a) the most energy?
(b) the least energy?

5 Explain why perfume or aftershave lotion evaporates more quickly than water.

6 Copy and complete the table below to summarise the properties of solids, liquids and gases. Use a tick to indicate which properties each state *usually* has.

Property	Solid	Liquid	Gas
Has a definite shape that is difficult to change			
Takes up a fixed amount of space			
Can be poured			
Takes up all of the space available			
Can be compressed			
Is made of particles that are strongly attracted to each other and can't move past each other			
Is made of particles that are not held together by attraction			

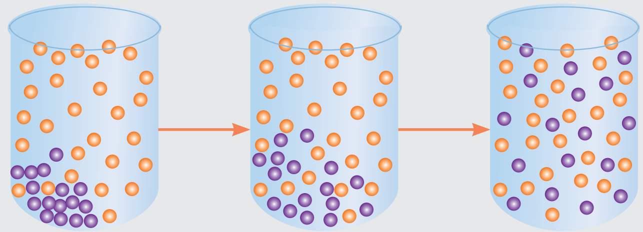
7 Copy and label the three diagrams below to show which represents solids, liquids and gases. Make an improvement to each diagram so that it describes the particle model more fully.



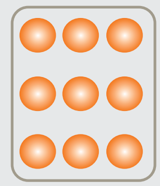
Which states are represented by these diagrams?

8 Snow and hail are water in a solid state. Describe the difference between snow and hail, and explain how each of them is formed.

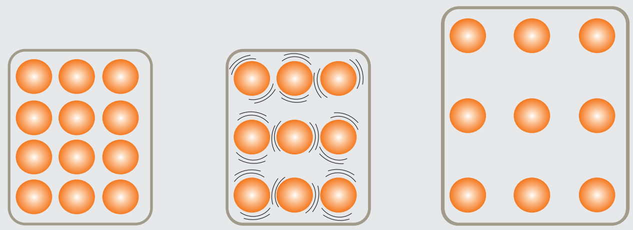
9 Name the process that is taking place in the following diagrams and explain why it occurs only in liquids and gases.



10 Which of the diagrams below (A, B or C) best represents the particles of a solid after expanding?

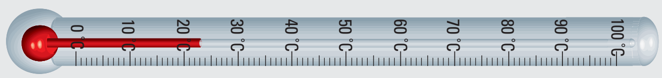


Original solid

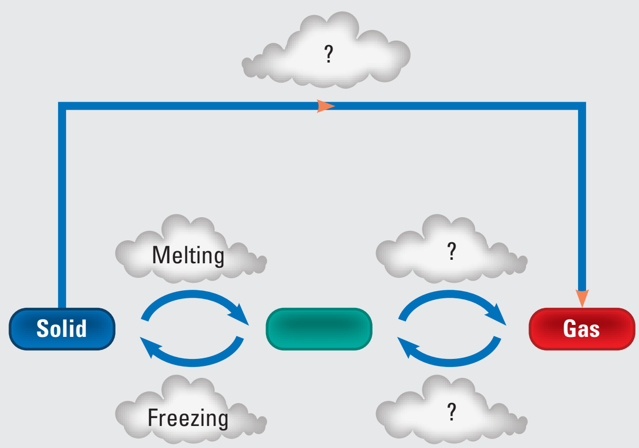


A B C

11 Explain how mercury and alcohol thermometers are able to provide a measure of temperature.



12 Copy and complete the diagram below, labelling the missing state and changes of state.



eBook*plus* work sheet 6.6 Summing up