6 States of matter

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 to that same question.

Water exists as a liquid in oceans, lakes and rivers, as solid icebergs in the oceans, and as water vapour in the air. Without it plants and animals could not exist. Each of the forms of water has its own different properties and uses.

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?

OVERARCHING IDEAS

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

SCIENCE UNDERSTANDING

The properties of the different states of matter can be explained in terms of the motion and arrangement of particles.

Elaborations

Modelling the arrangement of particles in solids, liquids and gases

Linking the energy of particles to temperature changes

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 in the shower 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.

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

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?

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

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

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

6.1 SCIENCE UNDERSTANDING

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

INQUIRY: INVESTIGATION 6.1

Comparing solids, liquids and gases

KEY INQUIRY SKILLS:

- questioning and predicting
- processing and analysing data and information

Equipment:

ice cube *plastic syringe* *spatula*
balloon *beaker of water*

- 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.

DISCUSS AND EXPLAIN

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			

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 poured.

Liquids

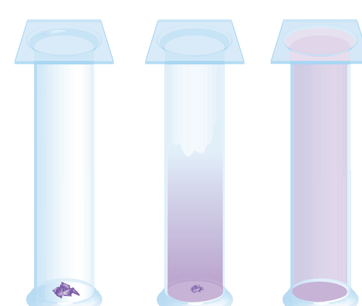
Water is a liquid and its shape changes to that of the container in which it is kept. Like solids, liquids take up a fixed amount of space.

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.

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



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

WHAT DOES IT MEAN?

The word *diffusion* comes from the Latin word ***diffusio***, meaning 'spreading out'.

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 100 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.

INQUIRY: INVESTIGATION 6.2

Measuring the volume of an irregular-shaped solid

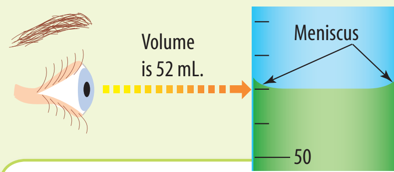
KEY INQUIRY SKILLS:

- processing and analysing data and information
- evaluating

Equipment:

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

- Half-fill (approximately) a 100 mL beaker with water.
- Carefully pour the water into the measuring cylinder.
- Read and record the volume of water in the measuring cylinder using the technique shown in the diagram above right.
- Carefully place the pebble into the measuring cylinder. Take care not to spill any water.
- Read and record the new volume.



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.

DISCUSS AND EXPLAIN

1 What was the volume of the solid in mL?
2 What was the volume of the solid in cm^3?
3 Suggest another way of measuring the volume of the solid object.

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 that of 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?

IMAGINE

10 You are designing a new type of armchair. It needs to be comfortable and capable of fitting in different positions or spaces around the room.
(a) What properties would you want in the chair?
(b) Would you need to develop a new material to match these properties? If so, would it be a solid or a liquid, or perhaps a combination of states?

INVESTIGATE

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

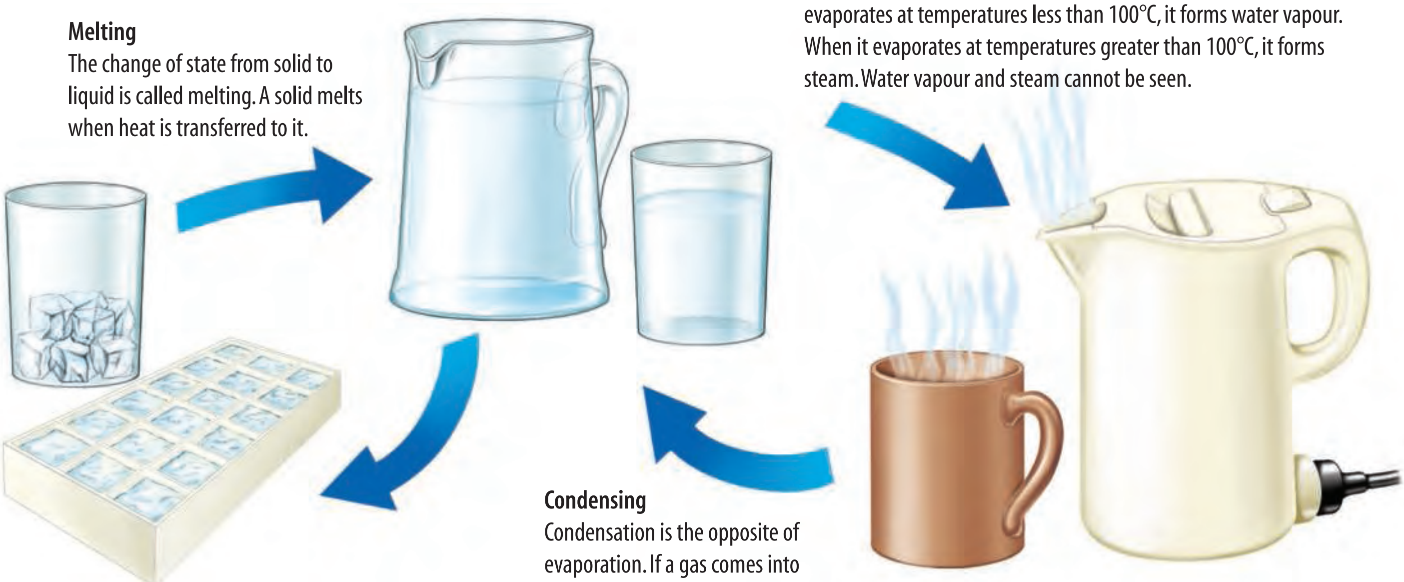
Water is the only substance on Earth that exists naturally in three different states at normal temperatures. It is in the oceans, in the polar ice and in the air as water vapour. Water is constantly moving and changing states. You can also observe water changing states in the kitchen. To change the state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

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.

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

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.

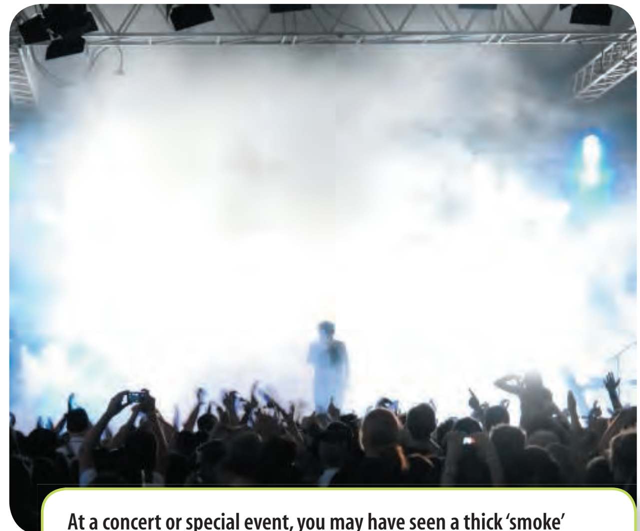
Boiling
During boiling, the change from liquid to gas (evaporation) happens quickly. The change is so fast that bubbles form in the liquid as the gas rises through it and escapes. During boiling, the entire substance is heated. A liquid remains at its boiling point until it has all turned into a gas.

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

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.

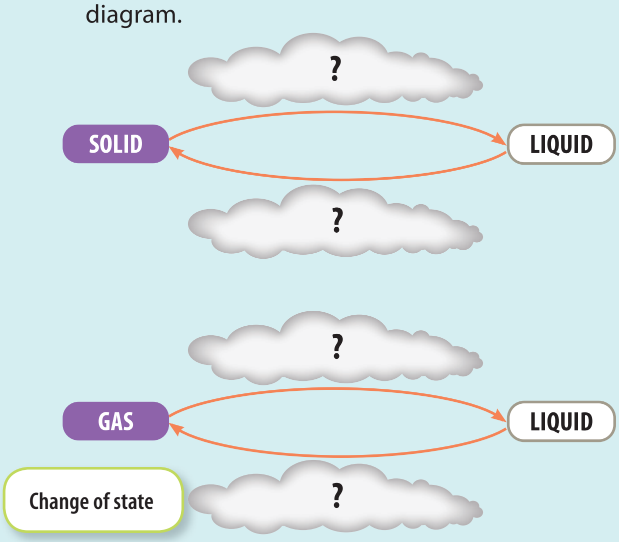


At a concert or special event, you may have seen a thick 'smoke' used for effect. This smoke is produced when solid carbon dioxide, called 'dry ice', changes state from a solid directly to a gas. This very unusual change of state is called **sublimation**. The 'smoke' is actually tiny droplets of water 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.



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 with a towel 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?

work sheet 6.1 Changing the boiling point of water

6.3 SCIENCE AS A HUMAN ENDEAVOUR

The state of the weather

Two-thirds of the Earth's surface is covered with water. But not all of it is in liquid form. About 2 per cent of the Earth's water exists as ice, mostly in Antarctica. A much smaller amount exists as water vapour in the atmosphere. Energy from the sun melts ice and causes liquid water to evaporate. Low temperatures in the atmosphere and on the surface freeze liquid water and cause water vapour in the air to condense.

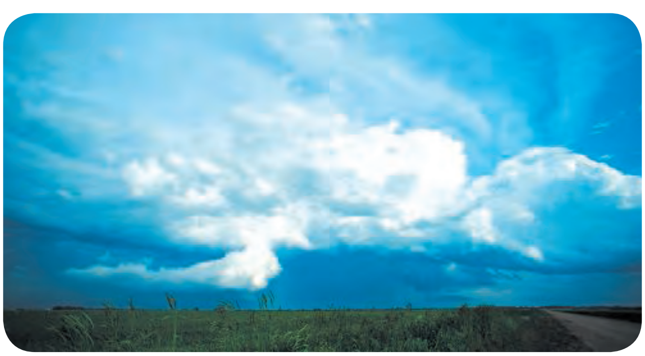
Water and the weather

Rain, hail, snow and sleet are all types of **precipitation**. Precipitation is falling water, whether in solid or liquid form. The type of precipitation depends mostly on the temperature in the clouds and the air around them.

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.

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.



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

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 of the cloud. The rising raindrops freeze very quickly. The frozen raindrops fall back towards the bottom of the cloud. If the air currents are strong enough, the rain drops rise again, adding a new layer of ice around the frozen raindrop. It falls again, then rises 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.

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.

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 in the cloud. Crystals of ice form when clouds have temperatures of less than –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.

eBook*plus* **eLesson**

Understanding a weather forecast
Interpret weather maps for yourself and find out how isobars indicate air pressure.
eles-0161

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 need to be made in order 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 Explain using words or a labelled diagram how hailstones are formed.

3 How can hailstones get as large as those 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 have suffered a shortage of snow in recent years. What conditions would they be looking for to predict coming snowfalls?

INVESTIGATE

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

10 In which occupations does 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 the following day's newspaper. 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 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**.

WHAT DOES IT MEAN?

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

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

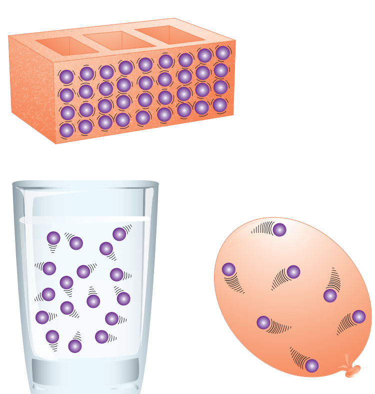
In solids the particles are very close together, so they cannot be compressed. The attraction between neighbouring particles in a solid is usually strong. Because there are such strong bonds between the particles, solids usually have a fixed shape and a constant volume. The particles in solids cannot move freely. 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' from each other. For this reason, liquids have a fixed volume but the rolling motion of the particles allows liquids 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.

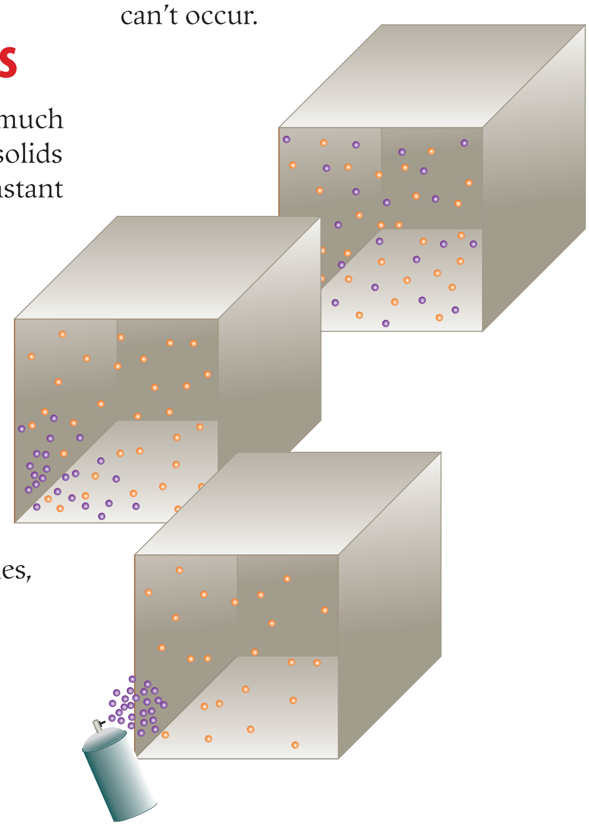
Particles in a gas

The particles in a gas have much more energy than those in solids and liquids. 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 are moving around. You would expect diffusion to happen faster in gases than in liquids because the particles are moving faster. Particles in a solid are vibrating in a fixed position, so diffusion can't occur.



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

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 are constantly moving in all directions. They are colliding with each other and with the 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 are colliding with the inside wall of the balloon. It gets smaller or **contracts**.

INQUIRY: INVESTIGATION 6.3

Investigating diffusion

KEY INQUIRY SKILL:

- processing and analysing data and information

Equipment:

250 mL beaker

water

food colouring

eye-dropper

fragrant spray

- 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.

DISCUSS AND EXPLAIN

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

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 — liquid or gas?
   (b) Why do you think this is so?

Heating solids, liquids and gases

When a substance is heated, the particles gain energy, move faster, become further apart and take up more space. The substance will expand.

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

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 in hot weather. Electrical wires are hung from poles loosely so that, when the weather cools, they will not become too tight and break as they contract. The amount by which each structure will expand or contract depends on the material it is made from; so when choosing a material for a special purpose, it is important to find out how much that material will expand or contract. The table on page 230 shows how much some commonly used materials expand when the temperature increases by 10°C.

Thermometers

Liquids expand more than solids. This property makes them useful in thermometers. Most thermometers consist of thin tubes and a bulb that contains a liquid. As the temperature rises, the liquid expands, moving up the tube. In a thermometer, the tube is sealed at the top.

The two most commonly used liquids for 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 especially designed to measure human body temperature.

INQUIRY: INVESTIGATION 6.4

Explaining gases

KEY INQUIRY SKILLS:

- planning and conducting
- processing and analysing data and information

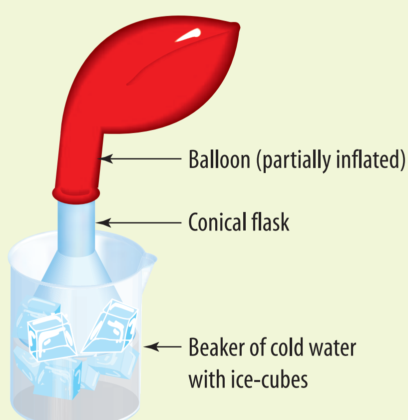
Equipment:

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

- Copy the table below 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.
- 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. 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. Leave for a few minutes, then measure and record the balloon's circumference.

DISCUSS AND EXPLAIN

1. Was any air added to or removed from the balloon after it was placed over the conical flask?
2. After being in ice-water and hot water, were there any changes in the size of the balloon?
3. Using the particle model, try to explain what might have made the balloon contract and expand.
4. What quantity was varied or changed in this experiment? What things were kept the same?

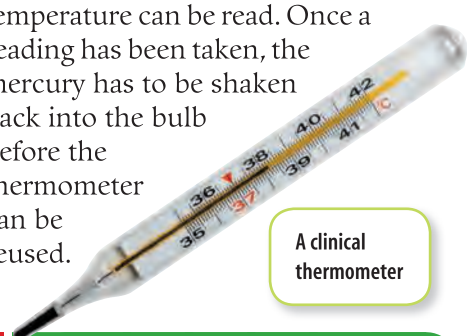


What happens to the air in the balloon when it gets cold?

Effect of temperature on air

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

Look at the photograph below. 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

INQUIRY: INVESTIGATION 6.5

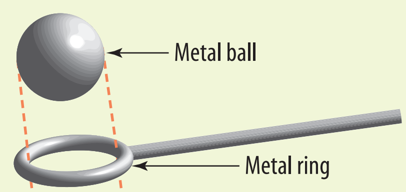
Expansion of solids

KEY INQUIRY SKILL:

- processing and analysing data and information

Equipment:

metal ball and ring set
Bunsen burner and heatproof mat
tongs



A ball and ring set

- 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 has 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.

1. Gases, including carbon dioxide, have lots of space between their particles.
2. The carbon dioxide is compressed into the 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. The particles push outwards on the walls of the cylinder. 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.

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

INQUIRY: INVESTIGATION 6.6

Expansion of liquids

KEY INQUIRY SKILLS:

- planning and conducting
- processing and analysing data and information

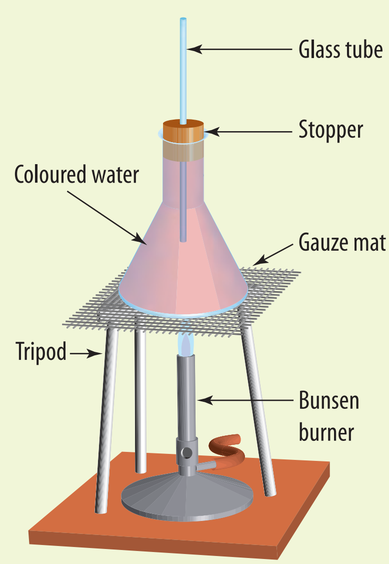
Equipment:

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

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

DISCUSS AND EXPLAIN

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



Investigating the expansion of liquids

UNDERSTANDING AND INQUIRING

REMEMBER

1 List the four main ideas of the particle model.

2 What is diffusion?

3 Explain why solids generally expand when they are heated.

4 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.

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

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

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

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

9 Use a double bubble map to show the similarities and differences between alcohol and mercury thermometers.

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
Iron	12
Platinum	9
Brass	19
Concrete	11
Glass — soda	9
Glass — Pyrex	3
Lead	29
Tin	21
Aluminium	23
Bronze	18

Use the table above to answer the following questions.

11 If a steel rod of 10 metres in length were 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 occurring.

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 happens to the length and width of a solid substance when 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 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

21 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?

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

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

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

25 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 sheets
6.2 Fire! Fire!
6.3 Expansion of liquids
6.4 Particles in our lives

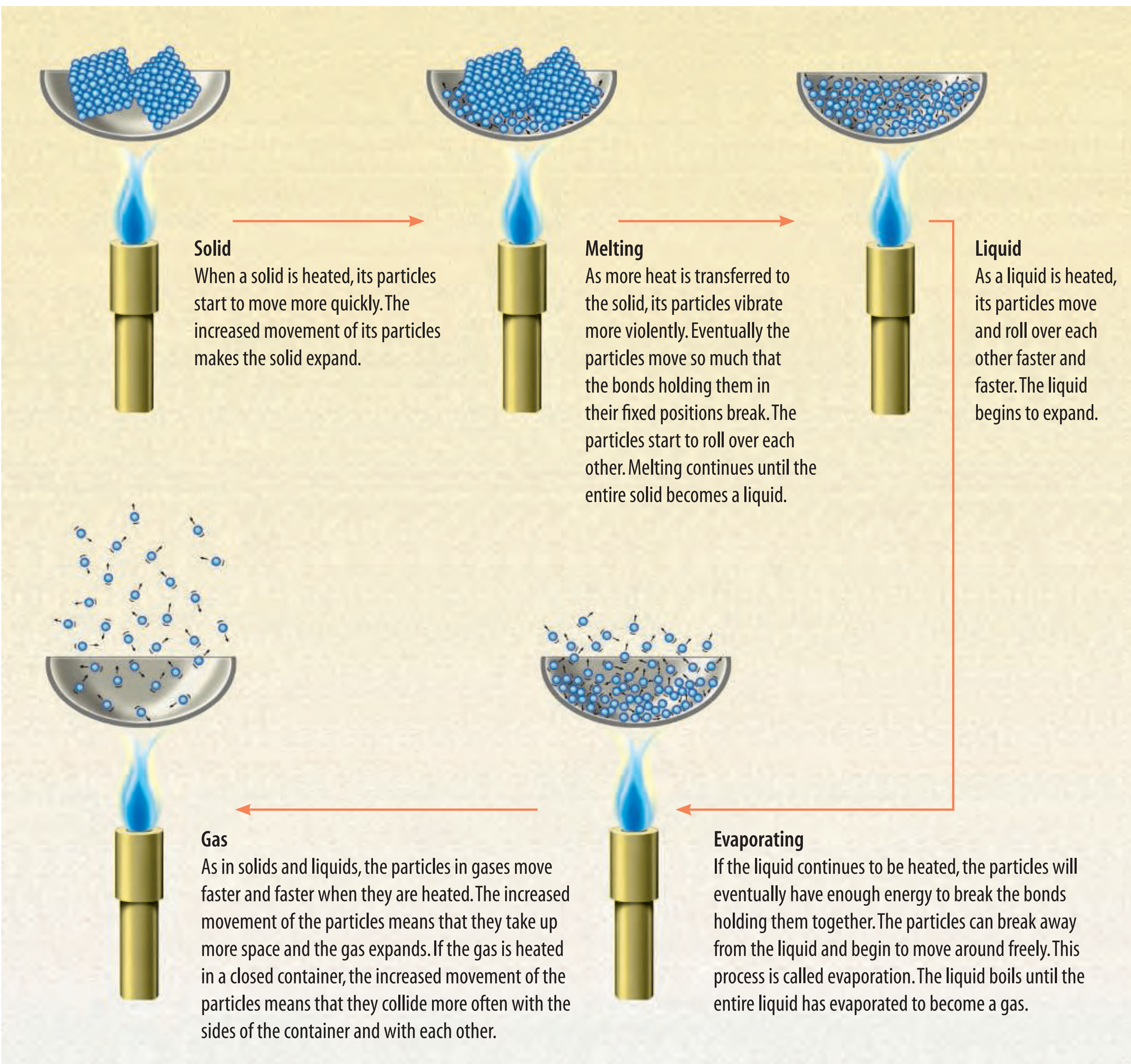
6.5 SCIENCE UNDERSTANDING

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.

The flowchart below shows what happens to the particles that make up a substance when it changes from a solid state into the gas state.

When a gas is cooled, the direction of the flowchart can be reversed as the substance changes from the gas state into a solid state.



Foggy mirrors

Have you noticed how the mirror in the bathroom 'fogs up' after a hot shower? The 'fog' is actually formed when invisible water vapour in the air cools 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 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.

5 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.

6 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

7 Use the particle model to explain why an ice cube changes shape when it melts.

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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

6.6 THINKING TOOLS

Concept maps and mind maps

1. On small pieces of paper, write down all the ideas you can think of about a particular topic.
2. Select the most important ideas and arrange them under your topic. Link these main ideas to your topic and write the relationship along the link.
3. Choose ideas related to your main ideas and arrange them in order of importance under your main ideas, adding links and relationships.
4. When you have placed all of your ideas, try to find links between the branches and write in the relationships.

how to ...?

question

How can I explain this topic to someone else?
What do I understand about this particular topic?

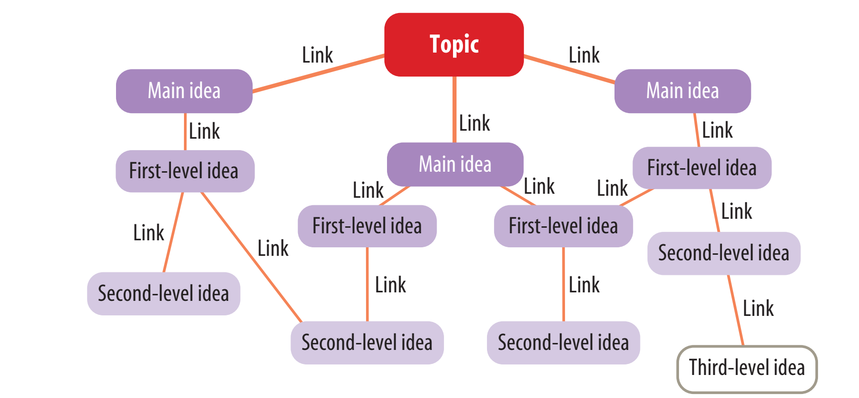
why use?

To show what you understand about a particular topic

also called

Knowledge map; concept web

Concept map



comparison

Similarity

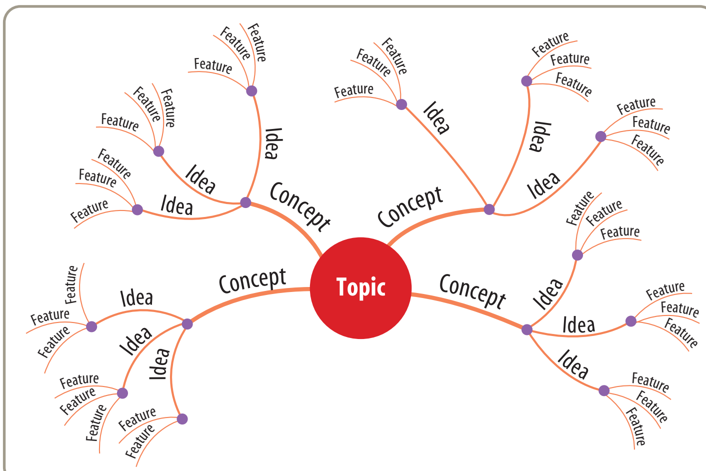
Both show graphically the structure of a topic in a hierarchical way.

Difference

Concept maps explain the relationship between the parts or elements with statements on the links.

example

Mind map



UNDERSTANDING AND INQUIRING

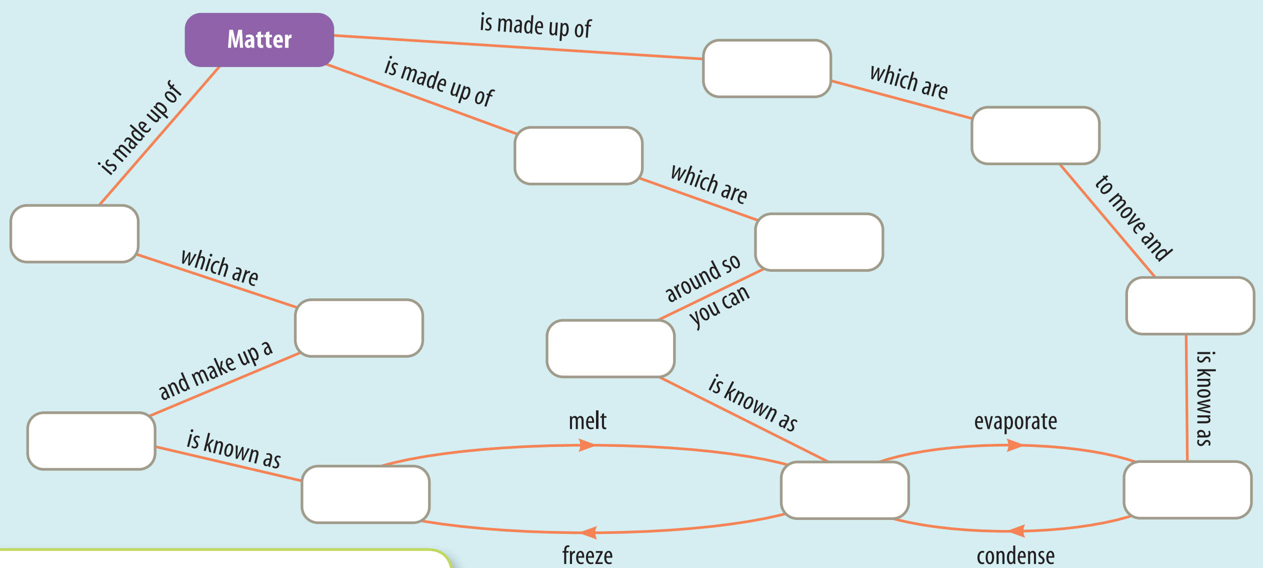
THINK AND CREATE

1 The concept map below represents some of our knowledge about the states of matter. This concept map is just one way of representing ideas about matter and how they are linked. However, all but one of the keywords in the boxes are missing.

Copy the concept map and complete it by writing in suitable keywords in the boxes.

Select the keywords from the list below. One keyword is used three times.

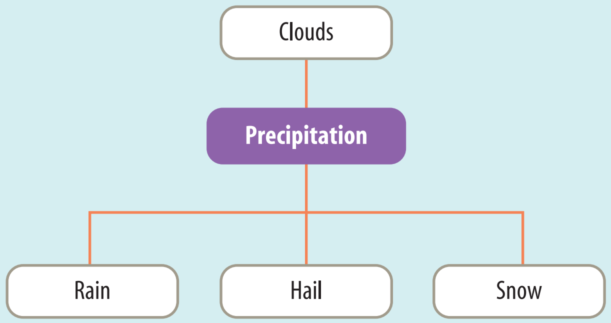
fill space	liquid	sliding
fixed shape	particles	solid
free	pour	vibrating
gas		



A concept map shows links between important ideas.

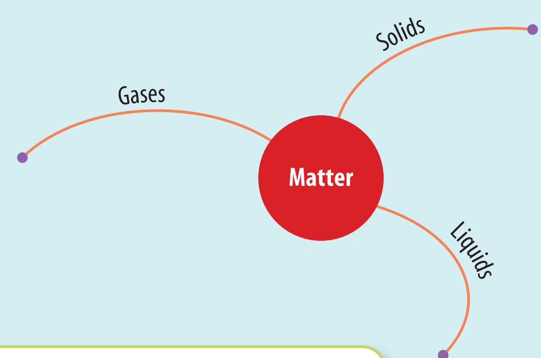
2 Using sticky notes, create a concept map similar to the one above to represent your knowledge about the three states of water. Start with the word 'water' at the top.

3 Create a concept map of your own to represent your knowledge of how water in the atmosphere affects precipitation. The diagram below shows one way of starting your concept map. You'll need to write in suitable link words yourself. (*Hint:* Start by writing down all of the important words or terms related to precipitation that you can think of and use as many of them as you can in your concept map.)



A concept map of precipitation could begin like this.

4 A mind map is similar to a concept map, but the topic is placed in the centre instead of at the top. There are no other boxes — just branches on which the keywords and terms are listed. Complete the mind map below to represent your knowledge of the states of matter.



A mind map begins with the topic in the centre.

5 The states of matter can be represented by a concept map or a mind map. Which map did you find easier to construct? Explain why.

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 substance 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

INDIVIDUAL PATHWAYS

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

ICT

eBook*plus* **Summary**

eLESSON

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

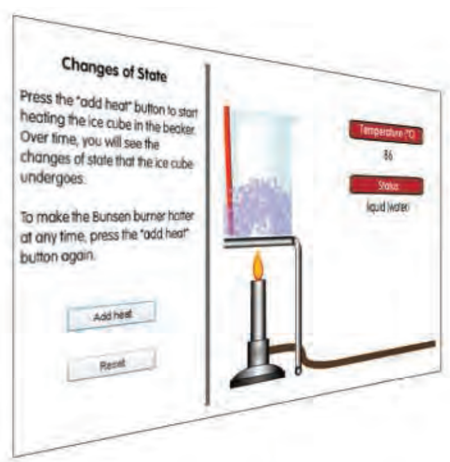
You might watch the weather report every day on the evening news, but do you really understand what all the information means? Just what is a high or low pressure system, and what are all those swirly lines and colours all over Australia? This eLesson will help you interpret weather maps for yourself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

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.

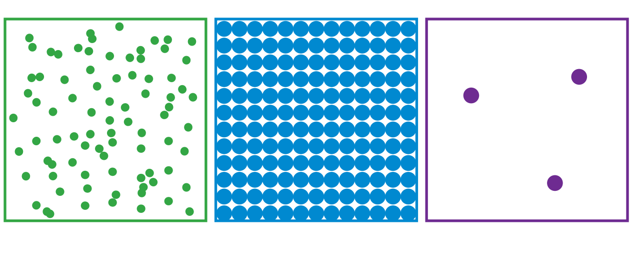
4 In which state — solid, liquid or gas — do the particles have:
(a) the most energy?
(b) the least energy?

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			

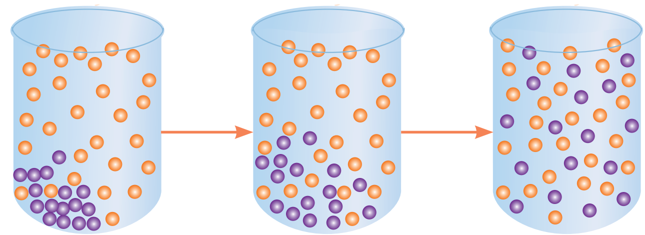
7 Copy and label the three diagrams below to show which represent solids, liquids and gases. Make an improvement to each of the diagrams so that they describe the particle model more fully.



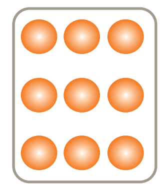
Which states are represented by these diagrams?

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.

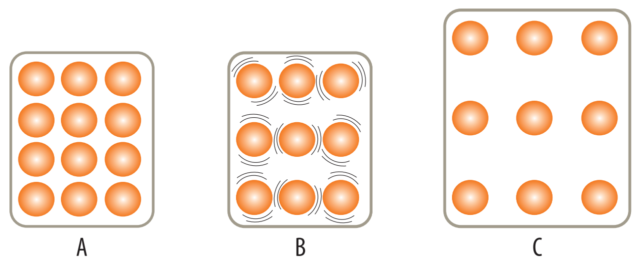
9 Name the process that is taking place in the following diagrams and explain why it occurs only in liquids and gases.



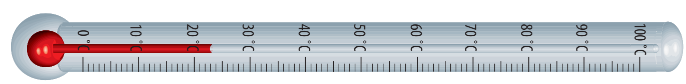
10 Which of the diagrams below (A, B or C) best represents the particles of a solid after expanding?



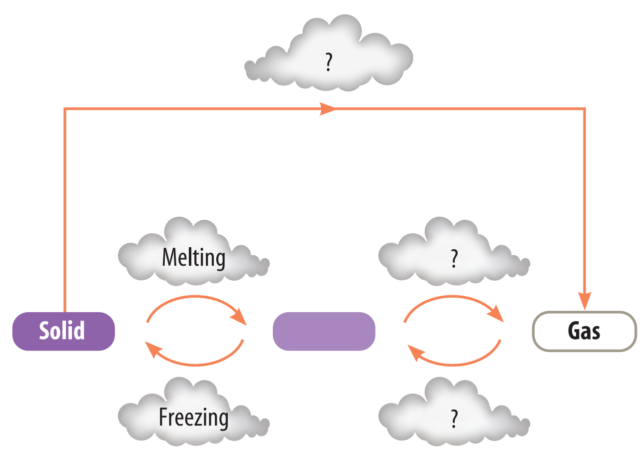
Original solid



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.



work sheet 6.6 Summing up