2.1 Physical and chemical properties

There are millions of different substances in the world. Each can be identified by its properties. Properties describe a substance and how it acts. They include its appearance, what it does when heated or cooled, and how it reacts with other substances.

INQUIRY
science 4 fun

What is foam?

Is shaving foam a solid, a liquid or a gas?

Collect this ...

- can of shaving foam
- plate (not paper)
- small mass (such as a 50c coin or a pebble)

Do this ...

1. Squirt a blob of shaving foam onto the plate. What does it look like? Does the foam flow or change shape without being pushed around?
2. Place the small mass on the top of the foam. Does it stay there or does it sink?
3. Squirt another blob of foam onto the plate. Put the plate into a cupboard so that it won't be touched. Leave it there overnight. What does the foam look like the next day?

Record this ...

Describe what happened.

Explain why you think it happened.

Physical properties

You can probably tell which objects and substances around you are solid, liquid or gas by the way they look and act. What you see are **physical properties**. Testing a substance for its physical properties doesn't destroy the substance, or change it into anything new.

Some of the most useful physical properties of a substance are:

- whether it's a solid, liquid or gas at room temperature (normally taken as 25°C)
- the temperatures at which the substance freezes or boils (known as its freezing point and boiling point)
- its appearance (such as its colour and texture, the shape of any crystals within it and whether it is shiny or dull)
- its density (how heavy it is compared to other substances of the same size)
- how hard or brittle the substance is (whether it is easily scratched or whether it crumbles)
- whether the substance dissolves in different liquids (known as solubility)
- its ability to let heat or electricity pass through it (known as its thermal and electrical conductivity).

Solids, liquids and gases

Substances exist in either solid, liquid or gaseous form. These forms are known as the **states** (or phases) of matter.

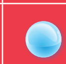
Solids, liquids and gases have very different physical properties. Think of the van in Figure 2.1.1. The bodies of cars and vans only change shape when they are in an accident or when they are broken up to be recycled. Also solids cannot be **compressed** (squashed to make them smaller). Try to compress a sugar cube and it might crumble, but the volume of sugar is exactly the same as it was before. The fact that solids do not change shape or size allows them to be used to build structures.

Liquids are similar to solids in that they don't change their size and are **incompressible** (unable to be compressed or squashed). They differ from solids in that they can flow and change shape. Think of orange juice: it splashes about and can be poured from one container into another, taking on a new shape as shown in Figure 2.1.2. The ability of liquids to squeeze along pipes and hoses without changing volume allows them to be used in hydraulic (powered by liquid) systems such as car brakes.

SciFile

No teardrops!

The shapes of raindrops change as they change size. None of them looks like the teardrops shown in the weather report!

Diameter (mm)	Less than 1	1 to 2	2 to 4.5	Bigger than 4.5
Shape				

Solids:

- have a fixed shape
- have fixed size and volume
- cannot be compressed (pushed in to make it smaller)
- will usually sink when placed in liquids of the same material.

Figure 2.1.1 The bodies of cars and vans are solid. They don't change shape or size unless they are in an accident or they are crushed to be recycled.

Liquids:

- have fixed size and volume
- are able to flow
- take the shape of the bottom of the container they are in
- are incompressible (not able to be compressed).

Figure 2.1.2 Liquids always flow to take up the shape of their container.

Gases are often invisible and many have no **odour** (smell). Water vapour is a gas that is invisible because it is colourless and its particles are spread too far apart for the gas to be seen. However, you can feel water vapour since it gives air its humidity. There is a lot of water vapour in the air on a humid day, making you feel sweaty and sticky. Figure 2.1.3 shows a mixture of gases that does have a smell.

Gases differ from solids and liquids in that they can be compressed. This property allows gases to be squeezed into small volumes such as barbecue gas cylinders. It also makes them useful in the gas struts or shock absorbers found in the suspension of bikes and cars. A bump compresses the gas in the struts, softening the impact of the bump. The gas then expands once more, pushing the strut back to its original shape.

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Prac 2 p. 51

Gases:
- are often colourless and invisible (you may be able to detect their smell)
- will spread out to take the shape of the container
- have no fixed shape or volume
- can be compressed (pushed in to make them take up a smaller amount of space).

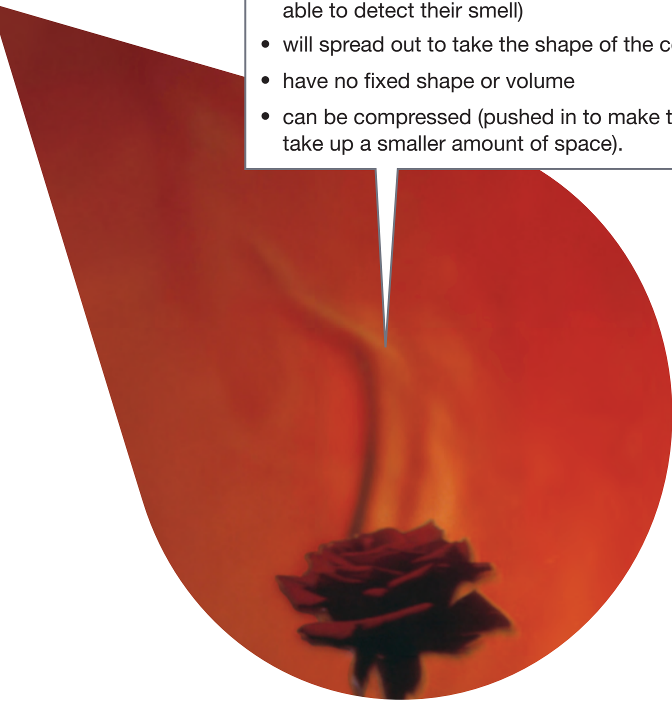


Figure 2.1.3 Perfume, smells, vapours and fumes are all gases. This image shows the gaseous perfume rising from a rose.

SciFile

The fourth state

There is a fourth state of matter but it is very rare on Earth. **Plasma** is a gas-like state that only exists at temperatures above 6000°C, making it common on stars but not here.

Figure 2.1.4 On Earth, plasma is found wherever high-voltage sparks are generated such as lightning bolts or in this plasma sphere.

2.1

Chemical properties

Chemical properties describe how a substance reacts with other substances. A new substance is formed in the process, often with very different properties. For example, iron rusts because it combines with oxygen and water. Iron is grey, hard and often shiny, while the rust it forms is red-orange, flaky and brittle. Likewise, paper burns and dynamite explodes, leaving behind ash and smoke.

Chemical properties that are worthwhile knowing about are whether a substance:

- burns or explodes in oxygen (this is known as combustion)
- rusts or corrodes (known as corrosion) or is corrosion-resistant
- is an acid like vinegar or a base like bicarbonate of soda or neither (this is measured by its pH)
- reacts quickly or slowly with other chemicals (this is known as the rate of reaction). Explosions like the one in Figure 2.1.5 have a very fast rate of reaction.

Figure 2.1.5 The chemical properties of LPG and petrol cause them to explode when there is plenty of oxygen and a flame or spark to start it off.

Choosing the right substance

The different properties of substances affect how they are used. For example, the frame of a skyscraper needs to be solid and strong and so is commonly made out of steel. Shopping bags are made of plastic, paper or fabric because they need to be cheap, light, strong and flexible. Likewise, takeaway food containers are often made of polystyrene because it's light and keeps the heat in.

Sometimes liquids or gases will be a better choice than solids. For example, car brakes only work because liquid is pumped through tubes to activate them, while a gas (air) is used to keep a jumping castle in shape. Imagine if the jumping castle shown in Figure 2.1.6 was filled with lead!

Figure 2.1.6 The walls and floor of a jumping castle need to be solid and strong but also smooth and flexible. Inside is a gas (air) that can compress when you jump on it but which will expand as soon as you jump to another spot.

INQUIRY **science 4 fun**

The mass of a gas

Does gas have mass?

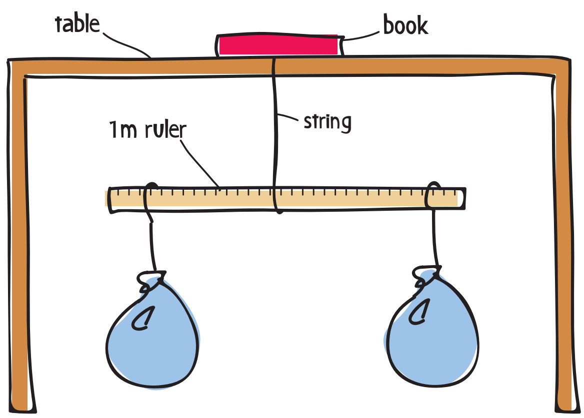
YES

Collect this …

- 2 balloons
- 3 lengths of string (each about 30 cm long)
- 1 m ruler
- needle (sharp enough to burst a balloon)

Do this …

1. Inflate both balloons until they are roughly the same size.
2. Tie their ends and tie a piece of string to the top of each balloon.
3. Tie one balloon to one end of the ruler and the other balloon to the other end as shown in the diagram. Use the ruler markings to make sure that the strings are the same distance from the ends of the ruler.
4. Tie the third string to the middle of the ruler and hang the ruler from the edge of a table.
5. Balance the ruler so that it hangs parallel to the floor. Do this by sliding the middle string along the ruler until you find the balance point.
6. Puncture *one* of the balloons with the needle and observe what happens.



Record this …

Describe what happened.

Explain why you think this happened.

LEARNING ACROSS THE CURRICULUM

SUSTAINABILITY

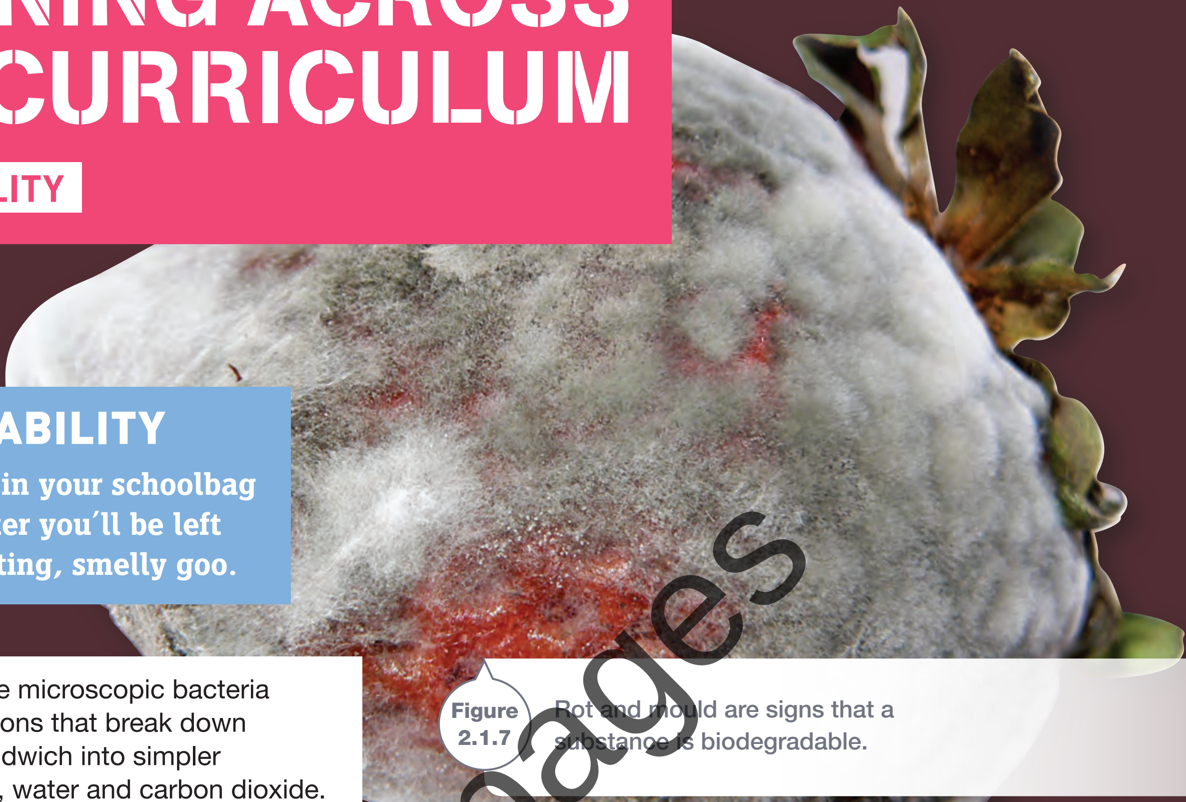


Figure 2.1.7 Rot and mould are signs that a substance is biodegradable.

BIODEGRADABILITY

Leave a sandwich in your schoolbag and a few days later you'll be left with a mess of rotting, smelly goo.

This happens because microscopic bacteria cause chemical reactions that break down substances in the sandwich into simpler substances like sugar, water and carbon dioxide. However, the cling wrap or plastic container holding the sandwich is unlikely to have changed. The chemical properties of the bread, lettuce and tomato caused them to rot, while the chemical properties of the cling wrap or plastic gave them rot-resistance.

BIODEGRADABLE

Substances are classified as being **biodegradable** if bacteria or fungi break them down. Fruit, vegetables, flowers, wood, twigs and leaves are biodegradable since they all break down quickly. This is why they are put into composts: they break down, forming simple substances that can then be used to fertilise other plants. The mould on the strawberry in Figure 2.1.7 shows that it is biodegradable. Animals are biodegradable because bacteria quickly break them down into simpler substances once they die.

Anything made of natural, living substances (or from substances that once lived) is usually biodegradable too:

- paper and cardboard (made from wood)
- cotton, hessian, linen fabrics (made from plants)
- woollen fabrics (the 'hair' of animals like sheep and goats)
- soaps (made from natural fats and oils).

NON-BIODEGRADABLE

Non-biodegradable substances eventually break down but often take hundreds of years to do so. Non-biodegradable substances have structures that bacteria and fungi cannot pull apart. Even though most plastics are made from a long-dead natural substance (crude oil), their structures are too different from the structures of living substances for them to be biodegradable. Other non-biodegradable substances are:

- polyethylene cling wrap (used to wrap sandwiches)
- most plastic shopping bags
- wrappers (used for lollies, chocolate bars and ice-creams)
- polystyrene (used for takeaway food)
- house paints
- glass (used for soft-drink and sauce bottles)
- metal cans (used for soft-drinks and canned spaghetti).

Anything made from these substances remains in the environment as rubbish and pollution for many, many years. They might crush, break or rip into smaller pieces, but their chemicals are still there polluting the environment for a long time.

Figure 2.1.8 Most plastics are non-biodegradable but many can now be recycled. This reduces waste and stops their chemicals from polluting the environment.

WHAT CAN WE DO?

Most non-biodegradable substances can be burnt but they release toxic (poisonous) fumes and smoke unless the fire happens in special incinerators at extremely high temperatures. Some (like glass bottles and plastics like PET) are able to be recycled (Figure 2.1.8). However, most non-biodegradable substances are simply thrown out. To minimise the impact of non-biodegradable substances on the environment, we all need to:

- use biodegradable packaging whenever possible, and buy food with no packaging or wrapped in paper or cardboard
- recycle or dispose of non-biodegradable packaging in bins, so that it will not end up on the street, rivers and oceans where it may catch and tangle fish, dolphins and birds like the one in Figure 2.1.9
- recycle glass, PET bottles and other plastics wherever possible
- re-use plastic shopping bags or use paper or re-useable cloth bags instead.

Scientists have developed biodegradable plastics from plant-based substances but these plastics are more expensive than similar oil-based plastics. They can't be recycled and cannot be used for long-term packaging. For these reasons, their use is not yet widespread.

Figure 2.1.9 Most plastic bags are non-biodegradable and so they don't rot away. If they get washed into rivers and the ocean, wildlife like this bird can get caught up in them and can die.

REVIEW

1 **List** four biodegradable and four non-biodegradable substances.

2 **Describe** the evidence that shows that fruit and cardboard are biodegradable.

3 A log in the forest grows mushroom-like fungi on it.

  a **Use** this information to **classify** the log as biodegradable or non-biodegradable.

  b **Predict** what will be left of the log after 10 years.

4 **Classify** faeces (poo) as biodegradable or non-biodegradable.

2.2

2.1 Unit review

Remembering

1 **State** an alternative term for *states of matter*. L

2 **List** the three states of matter commonly found on Earth.

3 **State** whether the following are solids, liquids or gases.
  a a sugar cube
  b ink
  c air

4 **List** the different states in which different substances exist in the following mixtures.
  a soft drink
  b chicken curry
  c mud

5 **List** two physical properties and one chemical property of a sheet of paper.

6 Shaving foam cannot be classified as a solid or a liquid because it has some of the physical properties of both. **List** the physical properties of shaving foam that could be used to classify it as:
  a a solid
  b a liquid.

Understanding

7 a **Explain** why plasma is usually found in stars but rarely on Earth.
  b **Describe** the conditions on Earth that are required for plasma to form.

8 **Define** the terms: L
  a compressed
  b incompressible
  c odour.

9 **Explain** how the compressibility of gases makes them ideal for using in shock absorbers in the suspension of cars and bikes.

10 a **State** what causes humidity.
  b **Describe** what a humid day feels like.

Applying

11 It is easier to list the physical properties of a substance than its chemical properties. **Use** an example to **explain** why.

Analysing

12 Each of the following substances displays some properties of both liquids and solids. **Analyse** the properties of each substance and **use** them to **classify** it as solid or liquid.
  a sand
  b toothpaste
  c hair gel

Evaluating CCT

13 Inspect the apparatus shown in the science4fun activity on page 46. Two balloons full of air are balancing on a metre ruler.
  a **Predict** what will happen when one of the balloons is punctured.
  b **Justify** your prediction.

14 Liquids flow to take up the shape of their container but on a surface they sometimes form small droplets instead. **Propose** a reason why the liquid doesn't spread across the surface.

Inquiring

ADDITIONAL

Aboriginal and Torres Strait Islander peoples have long used the physical properties of the natural materials around them to create items used in their everyday life. Research some of these materials. Some you might look at are: AHC

- waxes and resins used as glues
- saps, barks, oils, leaves and fruit used for bush medicine
- bark, timber, leaves and fronds used for utensils, shelter and housing
- plant fibres and animal sinews used for string and rope
- stones, bones, shells, teeth, branches and roots used for tools, weapons and utensils
- stalks and leaves used for weaving baskets.

Whatever materials you research, find:

- an image or video of the material being used
- how their physical properties makes them ideal for their particular uses
- whether the use of the material was restricted to a particular region or is/was used Australia-wide.

Present your research as a PowerPoint presentation. ICT

ADDITIONAL

2.1 Practical investigations

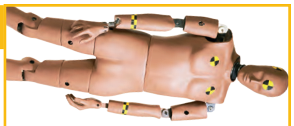
1 Slime

Purpose

To make slime and observe its properties.

Materials

Note: PVA tends to change consistency depending on the brand chosen and its age. The quantities of PVA and borax shown below may need to be altered slightly depending on the brand of PVA used.



SAFETY

Borax may irritate if it is inhaled or it gets into the eyes or on the skin. Wear safety glasses and rubber gloves at all times.

- 10 mL 4–6% borax solution
- 25 mL PVA glue
- a few drops of food dye

- eye dropper/Pasteur pipette
- disposable medicine measuring cup
- 10 mL measuring cylinder
- 2 disposable plastic cups
- icy-pole stick
- disposable rubber gloves

Procedure

1. Use the measuring cylinder to measure out 10 mL of borax solution.
2. Use the disposable medicine measuring cup to measure out 25 mL of PVA glue.
3. Pour the PVA into a disposable plastic cup, using the icy-pole stick to scrape out the last bits.
4. Add a few drops of food dye to the PVA.
5. Pour the borax solution, all at once, into the cup containing the PVA and food dye. Stir thoroughly with the icy-pole stick.
6. Empty out the slime and rinse it gently under a slow-running tap.
7. Test your slime to find:
   - if it can be rolled into a ball
   - what happens when it is stretched
   - whether it flows to take the shape of a container
   - what happens when it is dropped.

Results

Record your results in a table like that shown below.

Practical review

1. **List** the physical properties of your slime.
2. **Use** the physical properties of solids and liquids to **classify** your slime as solid or liquid.
3. **Justify** your classification.

Investigation	Observation	Is this property more like that of a solid or a liquid?
Can slime be rolled into a ball?		
What happens when slime is stretched?		
Does slime flow to take the shape of its container?		
What happens when a ball of slime is dropped?		

STUDENT DESIGN

2 Oobleck

Oobleck is an easy-to-make slimy goo.

Purpose

To find a recipe for oobleck and then to make some.

Materials

To be selected by students.

SAFETY

A Risk Assessment is required for this investigation.

Procedure

1 Search the internet to find recipes or videos that show how to make oobleck. Print or save the recipe and save any video you find.

2 Summarise the main points of the recipe or video and write them in your workbook as your procedure.

3 Before you start making your oobleck, assess your procedure. List any risks that your procedure might involve and what you might do to minimise those risks. Show your teacher your procedure and your assessment of its risks. If they approve, then collect all the required materials and start work.

4 Once you have made your oobleck, test it by:
- hitting it with your fist (or prodding it with your finger if you have only a small amount)
- slowly lower your hand (or a finger) into it
- quickly remove your hand (or finger) from it.
- running the tests that were performed on slime in Prac 1.

Results

Record your results in a table like that used in Prac 1.

Practical review

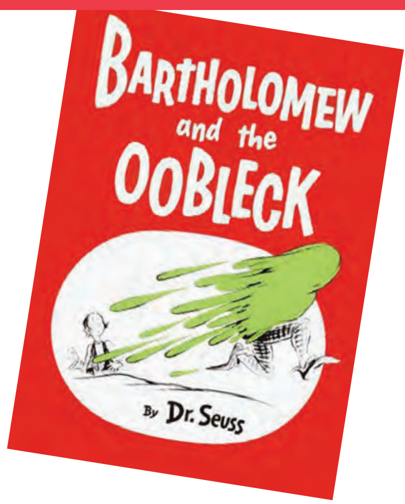
1 **List** the properties of your oobleck that belong to:
   a liquids
   b solids.

2 Oobleck is classified as a 'non-Newtonian' fluid. **Use** the properties found in this investigation to **describe** a non-Newtonian fluid.

The Oobleck of Dr Seuss

SciFile

In the book *Bartholomew and the Oobleck* by Dr Seuss, a king is so bored with ordinary weather that he instructs his wizard to create something new. A green goo called oobleck soon falls from the sky, gumming up the whole kingdom!



Running on wet sand

SciFile

The wet sand at the edge of the sea has many of the physical properties of a solid and a liquid. Run across the sand and it firms up and becomes more solid under your feet. However, walk across and it liquefies and you sink into it. For this reason, wet sand is given a special classification as a non-Newtonian fluid.

2.2 Solids, liquids and gases

Each of the states of matter has its own characteristic properties that can be explained using a simple model called the particle model.

INQUIRY

science 4 fun

Get packing

YES

Collect this ...

- 1 cup uncooked rice
- plastic or glass container (with lid)
- small ball that will fit in jar (such as a squash ball or ping-pong ball)

Do this ...

1. Pour uncooked rice into your container until it is half to three-quarters full.
2. Push the ball under the rice.
3. Put the lid on and shake the container jar sideways (not up and down).

Record this ...

Describe what happened.

Explain why you think this happens.

Models in science

Scientists often use models to test or explain something that is difficult to understand. Sometimes, the model will be a physical model like the one shown in Figure 2.2.1. These models are commonly used by scientists and engineers to test how something acts under certain conditions. For example, a model could be used to test how a building withstands an earthquake, how a car crumples in an accident or how a landscape will be changed by a flood.

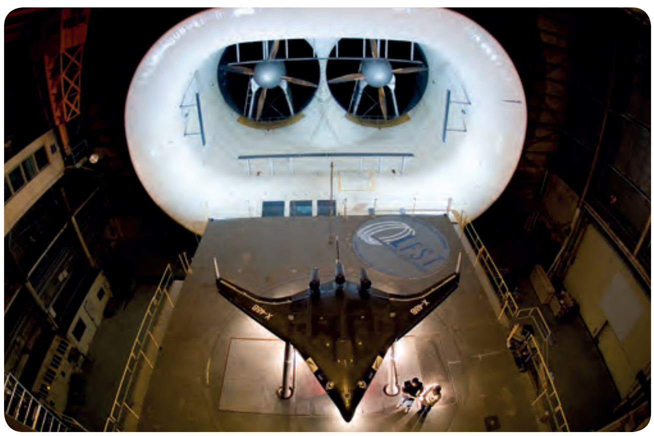


Figure 2.2.1 Engineers use models and wind tunnels to test how new aircraft perform at high speeds. Problems can then be fixed before an expensive full-size aircraft is built.

Analogies

The heart is often compared with a water pump. This simple type of model is known as an 'analogy'. An analogy uses a common, everyday thing to help us understand how something that is complicated works. Likewise, a computer is sometimes used as an analogy for the brain.

Thought models

Models can also be 'thought' models. 'Thought' models help scientists imagine objects and events that are difficult to understand. This might be because the object or event is incredibly large. For example, the universe is so huge that it is difficult to imagine how it is arranged and how it began. For this reason, 'thought' models have been developed for our solar system and the Big Bang, the event which started the whole universe off around 13 billion years ago (Figure 2.2.2).

Thought models are also helpful when you are trying to understand incredibly tiny things and what they do. For example, scientists and doctors use a model to explain how microscopic bacteria or viruses (germs) spread from one person to another during a disease outbreak.

Good scientific thought models are always supported by lots of scientific observations and evidence. Bad thought models are often quickly dismissed because they don't have much real science behind them!

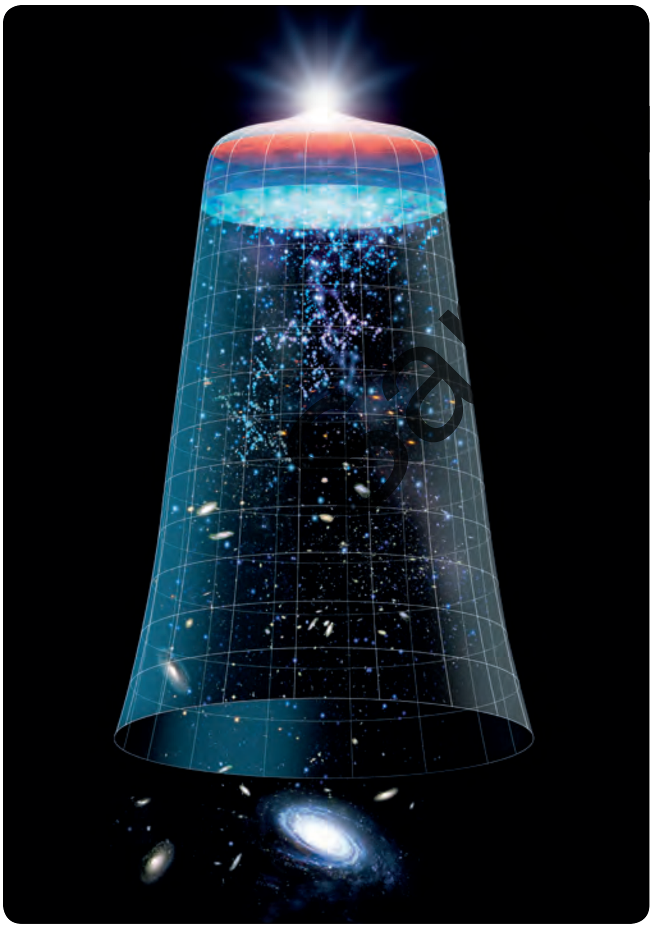


Figure 2.2.2 A computer artwork showing a 'thought' model that describes the evolution of the universe from the Big Bang to now.

The particle model

The **particle model** is a 'thought' model that attempts to explain the properties of substances.

In the particle model, all substances are thought to be made of incredibly small, hard, spherical balls called particles. Each ball has energy and moves according to how much energy it has. If a particle has lots of energy, then it will move about a lot. If the particle has very little energy, then it will be sluggish and move about slowly. You add energy to a substance whenever you heat it. This causes the particles to move about more, and faster. If you cool a substance, then the reverse happens: the particles move about less and move more slowly.

The particle model assumes the following:

- All substances are made up of tiny, hard particles that are too small to see even with a normal microscope.
- The particles always have energy and are moving.
- The particles move about more and move faster as temperature is increased.
- vcloser the particles are to one another, the stronger the attraction between them.

Colder than cold

SciFile

As a substance is cooled, energy is removed from its particles, making them vibrate less and less. Eventually they have no energy at all and all vibrations stop. This happens at a temperature of **absolute zero** (–273°C). The particles can't move any slower and so absolute zero is the lowest temperature that is possible.

Explaining solids

In solids the particles are closely packed in fixed positions. Forces between neighbouring particles form **bonds** that hold all the particles in the solid closely together. The particles in a solid have energy and jiggle about as shown in Figure 2.2.3. The particles don't break out of position but just **vibrate** about on the spot. If you increase the temperature, the particles have more and more energy and so they vibrate about more and more.

Table 2.2.1 shows how the physical properties of solids are explained by the particle model.

Figure 2.2.3 The particles in a solid are closely packed together and just jiggle about on the spot.

Table 2.2.1 How the particle model explains the physical properties of solids

Property of solids	How the particle model explains it
Solids have a defined shape (they do not flow).	The particles in solids are strongly bonded to their neighbours, fixing their positions.
Solids are incompressible.	The particles in a solid cannot be pushed closer to each other because they are so closely packed that there is almost no space between them.
Solids expand when heated and contract when cooled.	Heating causes the particles in a solid to vibrate faster, making them spread further apart and causing the solid to expand. Cooling slows down vibrations and the opposite happens.

SciFile

An exception to the rule

Water is an odd substance in that it expands when it cools to form ice, and contracts when ice melts to form liquid water.

Explaining liquids

In a liquid, the particles are still packed closely together but they are far more loosely bonded (joined) to their neighbours than the particles are in a solid. This is shown in Figure 2.2.4. The loose bonding allows the particles to move about and over each other, allowing the liquid to flow, drip and fill the bottom of whatever container it is in. As the liquid is heated, this movement gets faster.

Table 2.2.2 shows how the particle model explains the properties of liquids.

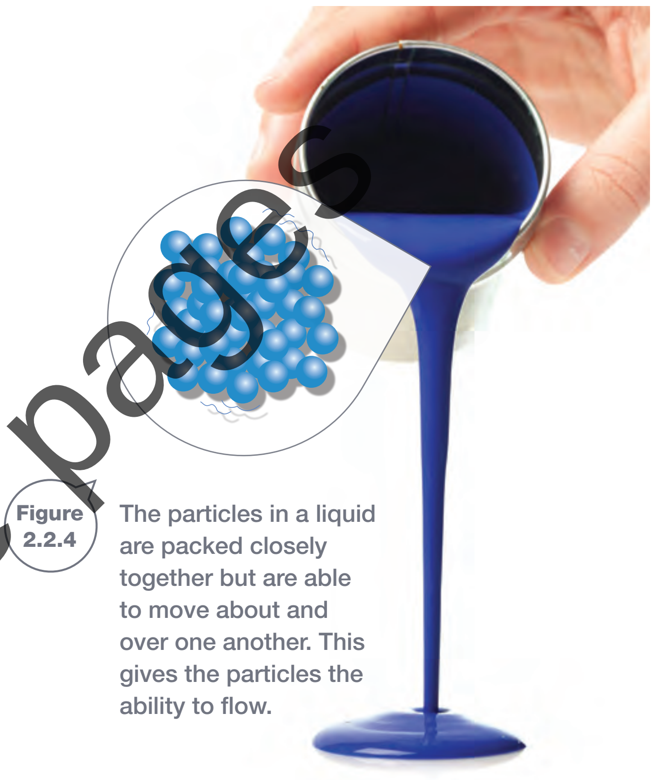


Figure 2.2.4 The particles in a liquid are packed closely together but are able to move about and over one another. This gives the particles the ability to flow.

Table 2.2.2 How the particle model explains the physical properties of liquids

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Property of liquids	How the particle model explains it
Liquids flow to take the shape of the bottom of their container.	Bonds are strong but loose enough to allow the particles in liquids to slip over one another.
Liquids are incompressible.	The particles in a liquid cannot be pushed closer to each other because they are so closely packed that there is almost no space between them.
Liquids expand when heated and contract when cooled.	Heating causes the particles in a liquid to move over each other faster, making them spread further apart and causing the liquid to expand. Cooling slows down this movement and the opposite happens.

Explaining gases

Gases have nothing holding their particles together. This lack of bonds allows the gas particles to travel randomly in straight lines until they hit something. The particles could hit other gas particles or the walls of the container they are in (as shown in Figure 2.2.5).

Table 2.2.3 shows how the particle model explains the properties of gases.

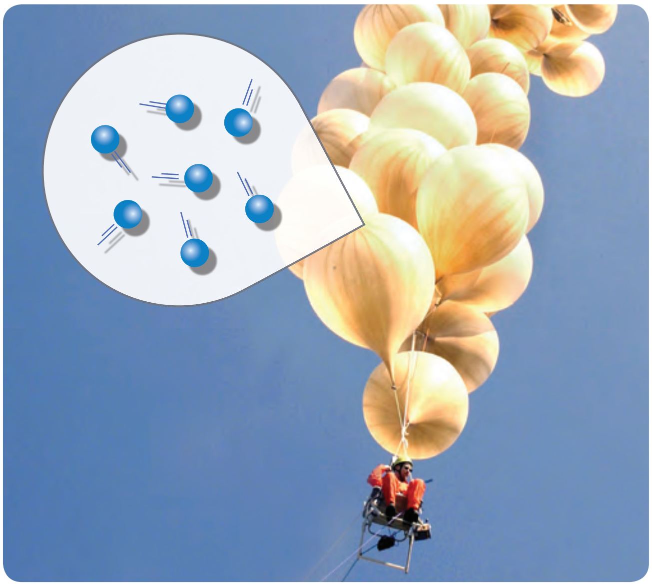


Figure 2.2.5 The particles in a gas are a long way apart and move fast and in straight lines. The particles only change direction when they hit the walls of their container or each other. In this case the gas is contained in balloons.

Prac 2 p. 61
2.3

Table 2.2.3 How the particle model explains the physical properties of gases

Property of gases	How the particle model explains it
Gases are often invisible.	Particles in a gas are spread so far apart that you cannot see the gas.
Gases can be compressed.	Particles in a gas are spread so far that there is plenty of vacant space between them. This space allows them to be pushed closer together.
Gases spread to fill their container.	There are no bonds between gas particles and so they are able to move unrestricted by other particles. They travel until they hit the walls of the container.
Gases expand when heated and contract when cooled.	Heating causes the particles in a gas to move faster, making them spread further apart and causing the gas to expand. Cooling slows down this movement and the opposite happens.

INQUIRY
science 4 fun

Pop the lid

Can pressure pop the lid of a soft-drink bottle?

YES

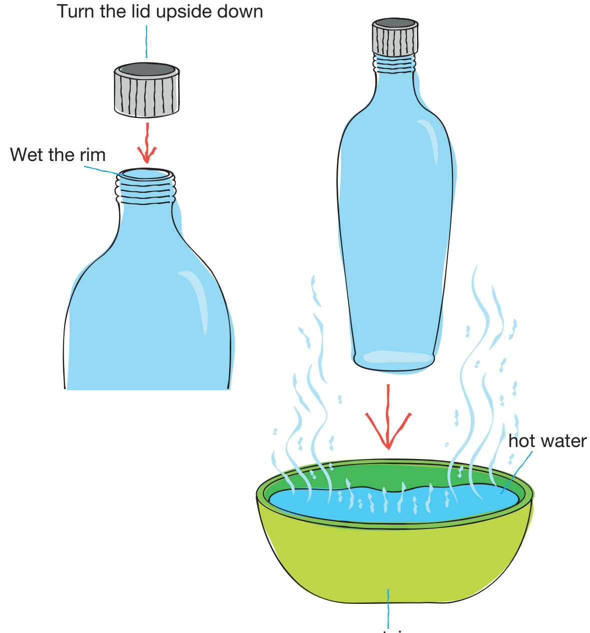
Collect this ...

- hot tap water
- any size plastic soft-drink bottle with its lid
- any container a little bigger than the base of the soft-drink bottle

SAFETY
Be careful handling hot water.

Do this ...

1. Remove the lid from the soft-drink bottle.
2. Run hot water from a tap into the container until it is about 5 cm deep.
3. Lightly wet the top of the lid and then place it UPSIDE DOWN on the bottle. It should stick slightly to it.
4. Carefully lower the soft-drink bottle into the container until the hot water reaches a few centimetres up the side of the bottle.



Record this ...

Describe what happened.

Explain why you think it happened.

Pressure

Any gas particle that hits a wall will bounce off, giving the wall a little push as it does so. The combined push of all the gas particles bouncing off the walls of their container is known as the **pressure** of the gas.

Increasing pressure

The pressure of a gas can be increased by:

- forcing more gas into a particular space
- squashing the gas into a smaller space
- heating the gas up.

Forcing air into a balloon increases the pressure inside it by increasing the number of gas particles and the number of collisions with the walls of the balloon. This forces the balloon to expand (get bigger). The balloon keeps expanding until the pressure inside and outside the balloon becomes the same. This occurs when the gas inside the balloon is pushing the walls out with the same force as that of the outside air pushing the walls in. Forcing more air into the balloon causes the pressure to increase again and so the balloon expands once more. With each breath, the balloon will keep expanding until the rubber it is made of becomes so thin that it breaks.

A balloon has very flexible walls but the walls of the gas bottles shown in Figure 2.2.6 are not flexible. Forcing more gas into a gas bottle increases the pressure inside it. Sometimes, there is so much gas inside the bottle that the gas particles are pushed close enough to attract each other and form a liquid such as LPG (liquefied petroleum gas).

Figure 2.2.6 Gas bottles have rigid walls. Forcing more gas into them increases the pressure inside.

Heating a gas causes its particles to move faster. The particles collide harder with the walls and so pressure increases. A car engine uses the pressure of a hot gas to force its pistons downwards. As Figure 2.2.7 shows, petrol vapour is let into the cylinder and then an electrical spark causes it to explode. The gas formed by the explosion is now extremely hot and its pressure rams the piston downwards. This power is then transmitted to the car's driving wheels. The hot gas is then allowed to escape and the procedure repeats once more.

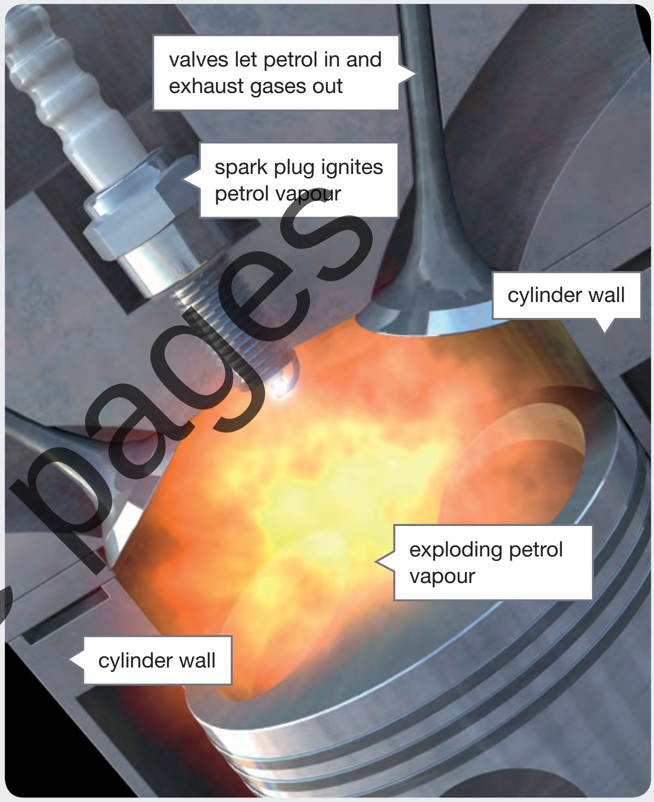


Figure 2.2.7 Heat from explosions increases the pressure of gases inside the cylinders of a car engine. This pressure forces the piston downwards and the power generated is used to get the car moving.

Decreasing pressure

Gas pressure can be reduced by reducing the amount of gas in a container, increasing the size of the container or by cooling the gas. For example, balloons, and car and bike tyres go 'flat' because the pressure inside has dropped so much that they cannot keep their shape. The reason is usually that a hole or leaky valve has allowed air to escape.

Prac 3 p. 61

LEARNING ACROSS THE CURRICULUM

CRITICAL AND CREATIVE THINKING

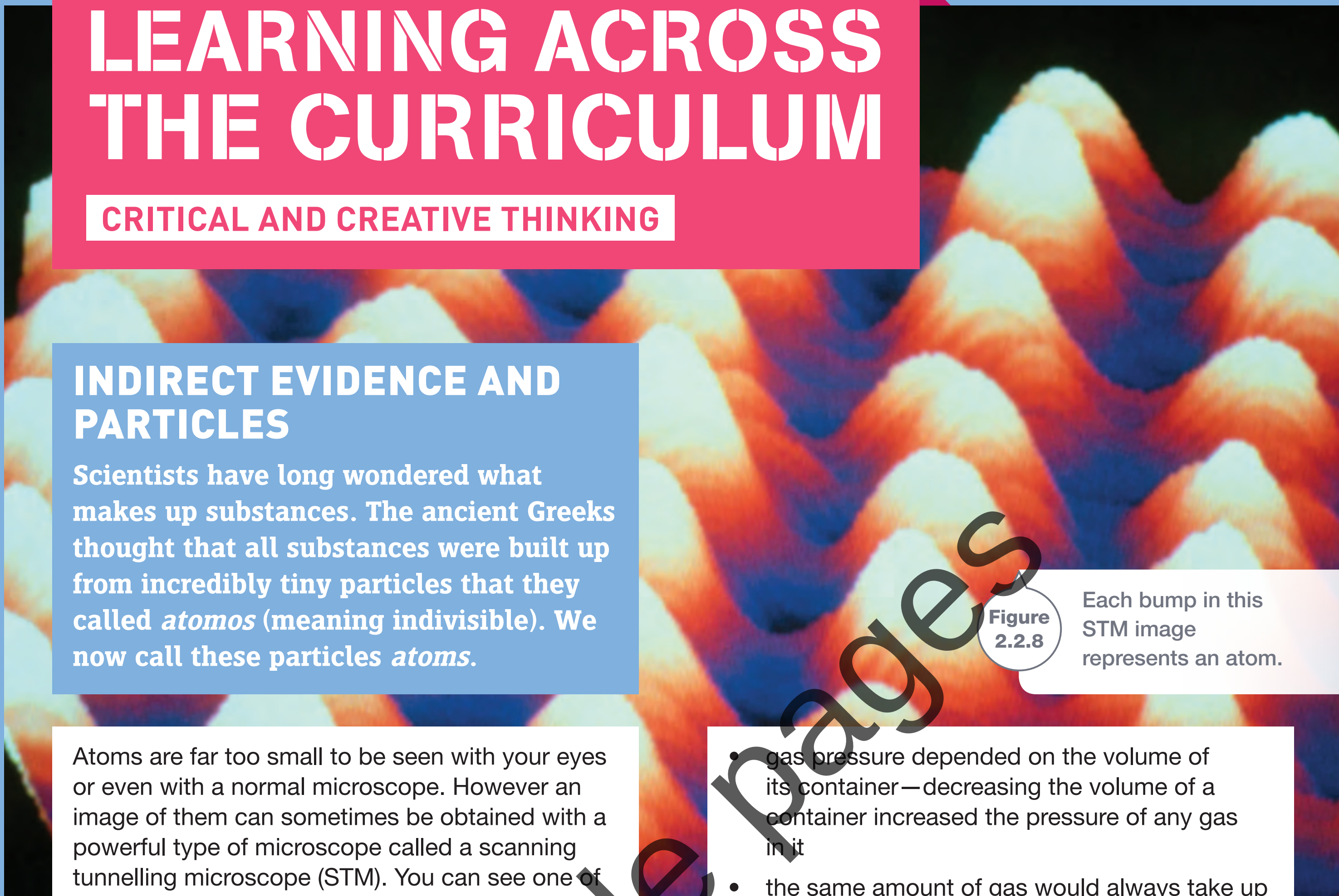


Figure 2.2.8 Each bump in this STM image represents an atom.

INDIRECT EVIDENCE AND PARTICLES

Scientists have long wondered what makes up substances. The ancient Greeks thought that all substances were built up from incredibly tiny particles that they called *atomos* (meaning indivisible). We now call these particles *atoms*.

Atoms are far too small to be seen with your eyes or even with a normal microscope. However an image of them can sometimes be obtained with a powerful type of microscope called a scanning tunnelling microscope (STM). You can see one of these images in Figure 2.2.8.

Even before the invention of the STM, scientists had an extremely good idea that substances were made from tiny atom-like particles.

This is because you don't always need to see something to know that it exists. Observations indicated that, although they are 'invisible', atoms do exist. These types of observations are known as **indirect evidence**. You use indirect evidence every day: you know what you are having for dinner from smells coming from the kitchen, and you can often guess what's in a package by its weight and shape and the sounds it makes when shaken.

BEHAVIOUR OF GASES

During the 17th and 18th centuries, scientists including Robert Boyle, Amedeo Avogadro and Joseph Louis Gay-Lussac investigated how the pressure and volume of a gas were linked to the amount of gas and the temperature. They found that:

- gas pressure depended on temperature: an increase in temperature led to an increase in pressure
- gas pressure depended on the volume of its container—decreasing the volume of a container increased the pressure of any gas in it
- the same amount of gas would always take up the same volume under the same conditions regardless of what type of gas it was.

From these observations, the **gas laws** were developed. These laws use mathematics to predict what gases will do under different conditions. Most importantly, the laws were easily explained if it was assumed that gases were made of fast-moving, widely spaced particles with little or no attraction between them.

DIFFUSION

Perfume quickly spreads throughout the air of a room. Its smell gets weaker until eventually you can't smell it. This spreading process is called **diffusion**. In 1833, the Scottish chemist Thomas Graham used the idea of particles to explain how diffusion might work. Perfume particles are constantly moving and over time they will move through the gaps between the air particles. Likewise, the air particles will move through the gaps between the perfume particles. In this way, the two gases diffuse (mix and spread). The process also happens when two liquids are mixed. This is shown in Figure 2.2.9 on page 58.

Figure 2.2.9 This coloured liquid is easily seen as a twisting ribbon of orange when first added to water but soon diffuses throughout it. Cordial diffuses through water in a similar way, spreading its colour and flavour throughout.

BROWNIAN MOTION

Some of the most convincing indirect evidence for particles came from the work of the Scottish botanist Robert Brown. In 1827, Brown was using his microscope to study tiny pollen grains that were floating on some water. He expected the pollen grains to be still but they were moving about, as if being jostled about by something in the water. His sketches of their motion are shown in Figure 2.2.10. Brown could not explain what was happening and it was 1905 before Albert Einstein explained it: 'invisible' particles in the water were constantly moving about, colliding with the pollen grains and pushing them around as they did so.

Brown was not the first to notice this type of motion. In 1785, Jan Ingenhousz had observed similar movement in coal dust suspended in alcohol, and the ancient Roman Lucretius wrote in around 60 BCE of dust particles jiggling about in a beam of sunlight. You may have already noticed something similar. This jiggling eventually became known as **Brownian motion**.

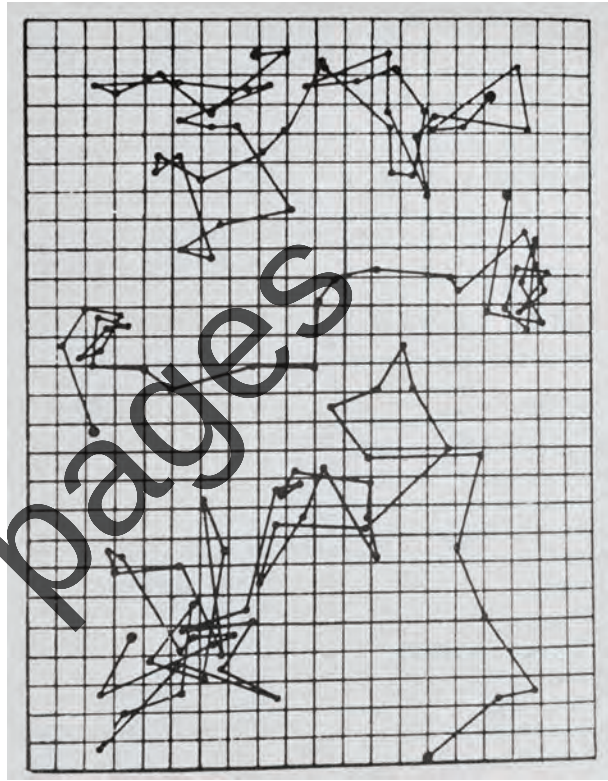


Figure 2.2.10 Robert Brown's original notes marking the positions of pollen grains every 30 seconds.

REVIEW

1 **Outline** three scientific discoveries that advanced our understanding of the particle model.

2 The gas laws predict that the pressure of a gas doubles if the volume of the container it is in is halved. **Use** the particle model to **explain** why.

3 A drop of dye added to a swimming pool spreads and diffuses until eventually you can't see any of its colour. **Use** the particle model to **propose** a way this might happen.

4 a **Outline** what Brownian motion is.

b **Use** the particle model to **explain** Brownian motion.

c **Describe** an example of it in action.

2.2 Unit review

Remembering

1 **State** what causes atoms to move constantly.

2 **State** what temperature is absolute zero.

Understanding

3 Match the state of matter with the movement of its particles that **describes** it best.

Solid	Particles move very fast in straight lines.
Liquid	Particles vibrate on the spot.
Gas	Particles vibrate but can also move over one another.

4 **Explain** what happens to the particles in a substance when it is:
- a heated
- b cooled.

5 **Describe** the arrangement of the particles in a:
- a solid
- b liquid
- c gas.

6 **Define** the following terms:
- a vibrate
- b bonds.

7 **Predict** what would happen in the science4fun activity on page 55 when the bottom of the soft-drink bottle is placed in:
- a hot water
- b ice water.

Applying

8 **Use** the particle model to **explain** why:
- a solids keep their shape
- b a gas can be compressed
- c liquids take the shape of the container into which they are poured
- d a solid cannot be compressed.

Evaluating CCT

9 Barbecue gas cylinders are usually weighed as they are being filled. **Propose** a reason why.

10 The ball in the science4fun activity on page 52 rises when the container of rice is shaken. **Use** packing to **propose** a reason why.

Creating CCT

11 **Construct** a Venn diagram showing which properties are shared between solids, liquids and gases and which properties belong to only one state. Follow these instructions.

- a **Draw** a diagram like that in Figure 2.2.11 in your workbook.

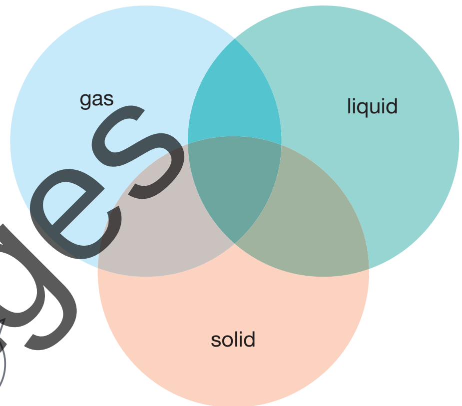


Figure 2.2.11

- b **Identify** which of the following properties is shared by all three states and write it in the overlap of all three circles.

has energy	fixed shape
changing shape	fixed volume
changing volume	can be compressed
incompressible	closely packed
loosely packed	

- c **Identify** the properties shared by two states (for example, solid and gas) and **list** them in the relevant overlaps.
- d **Identify** the properties displayed by only one state and **list** these in the appropriate spaces.

Inquiring

1 Research how LPG is made commercially.

Present your findings as a flow chart showing the main steps in its production.

2 Find the main differences between a petrol car engine and a diesel one.

Present your research as a table or a series of diagrams that compares the two engine types.

2.2 Practical investigations

1 Liquid thermometer

Purpose

To build a model thermometer.

Materials

- water
- 2 drops of food dye
- Plasticine

- 250 mL conical flask
- clear drinking straw
- permanent marker pen

Procedure

1. Set up the apparatus as shown in Figure 2.2.12a.
2. Carefully blow down the drinking straw. Water should rise up it. Stop blowing when the water rises about 1 cm above the Plasticine plug.
3. Use the permanent marker to mark this water level as shown in Figure 2.2.12b. This level represents the 'temperature' of the room today.

Results

1. Hold the conical flask in your hands. Don't squeeze but just let your hands warm it up.
2. Release your hold on the flask and record what happens to the water level.
3. After it reaches the line again, put the flask into a sink of cold water. Record what happens.

Practical review

1. **Explain** what happened in this experiment by copying the following sentences and choosing the correct term.
   a. Adding heat causes liquids to *expand/contract*. This caused the liquid to *rise/drop* in the drinking straw.
   b. Removing heat causes liquids to *expand/contract*. This caused the liquid to *rise/drop* in the drinking straw.
2. Thermometers usually do not use water but instead use alcohol (coloured red) or mercury. **Propose** a reason why.

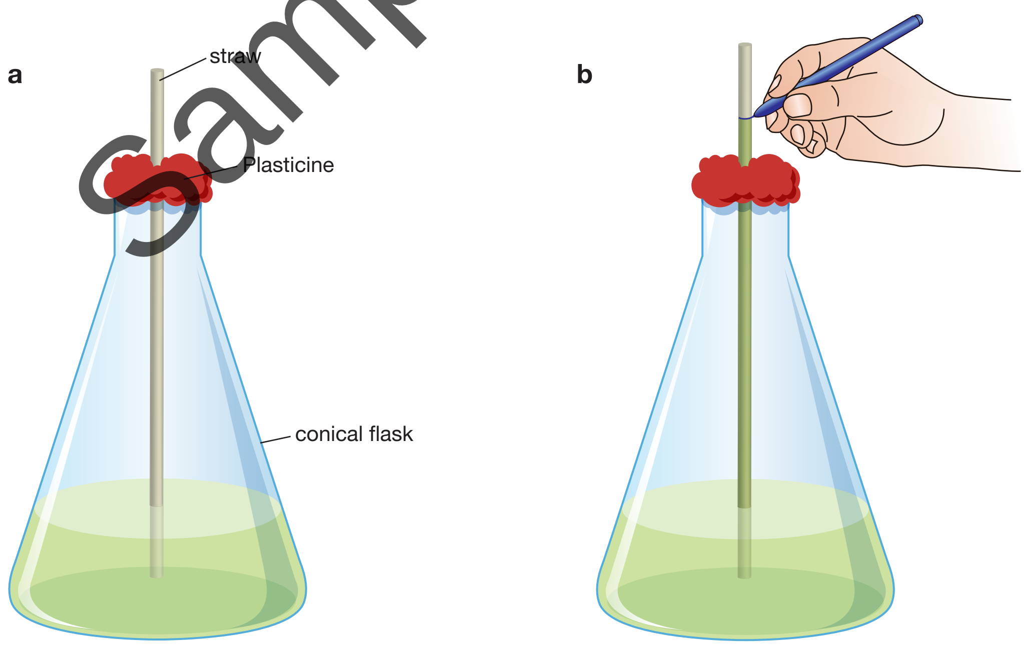


Figure 2.2.12

2 Compressing liquids and gases

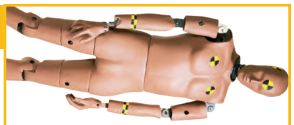
Purpose

To determine whether liquids and gases can be compressed.

Materials

- water

- plastic syringe (without needle)
- 250 mL beaker



SAFETY

Do not use the syringe to squirt water at other people.

Procedure

1. Fill the beaker with water and use the syringe to suck up water until it is full.
2. Push the nozzle of the syringe against your finger as shown in Figure 2.2.13.
3. Push the plunger down and observe what happens. Can you compress the water?
4. Take the syringe apart, empty it of its water and re-assemble it.

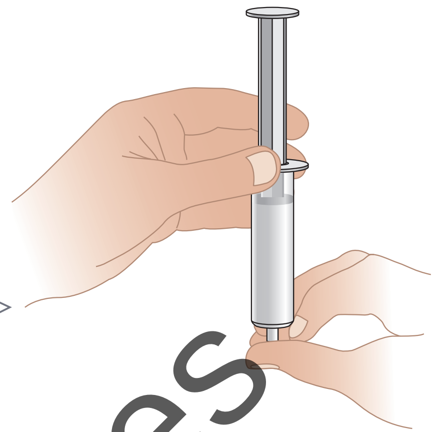


Figure 2.2.13

5. The syringe is now full of air (with a little water that will help seal it). Once again, push the nozzle against your finger and attempt to push the plunger down. Observe what happens. Can you compress the air?

Practical review

1. **Explain** your observations in terms of the spacing of particles in liquids and gases.
2. **Construct** a conclusion for your investigation.

STUDENT DESIGN

3 Pressure can protect

Purpose

To design and test a container that uses pressure to protect an egg.

Materials

- 1 fresh egg (uncooked)

- 2 zip-lock bags
- 1 drinking straw
- sticky-tape

SAFETY

A Risk Assessment is required for this investigation.

Procedure

1. Design:
   a. a container that uses air pressure and the materials listed above to protect a fresh egg when it is dropped onto a hard surface.
   b. an experiment that will test how far your container needs to drop for the egg to break.
2. Before you start constructing your container or start testing, assess your procedure. List any risks that your procedure might involve and what you might do to minimise those risks. Show your teacher your procedure and your assessment of its risks. If they approve, then collect all the required materials and start work.

Results

Construct a table to show the results of your egg drops and the heights they were dropped from.

Practical review

1. **State** the height from which the egg eventually broke (if it ever broke).
2. **Explain** how you used air pressure to protect your egg.

2 Chapter review

Remembering

1 **State** two physical properties each for:
  a solids b liquids c gases.

2 **State** what happens to particles in the following states when they are heated.
  a solid b liquid c gas

3 **Name** the opposite process to:
  a melting b evaporation.

Understanding

4 Gases are less dense than liquids or solids of the same material. **Explain** why.

5 **Describe** the property that makes gases ideal for filling jumping castles.

6 **Predict** which of the following is most likely to be the melting point of butter: N
  A −20°C B 0°C
  C 30°C D 100°C

7 **Predict** what might happen when you place an empty balloon around the rim of a conical flask with some water in it (shown in Figure 2.5.2) and heat the flask.

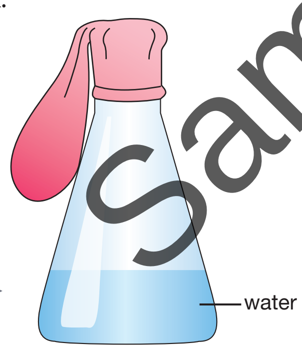


Figure 2.5.2

Applying

8 When you dive into a swimming pool, the water parts around you as you enter it. **Use** the particle model to **explain**:
  a what happens to the water particles as you dive in
  b why the swimming pool water gives you a 'punch' in the stomach when you do a 'belly flop' and not a clean dive.

9 Figure 2.5.1 shows a balloon full of gas. **Identify** which of the following diagrams best shows the gas and balloon after the gas is warmed up.

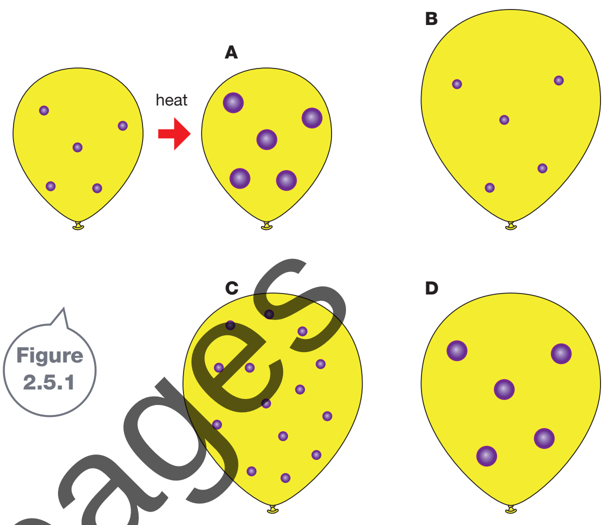


Figure 2.5.1

Analysing

10 **Use** the particle model to **contrast**:
  a melting and freezing
  b evaporation and condensation.

Evaluating CCT

11 a **Propose** what would happen to you if you jumped around in a jumping castle filled with water instead of gas.
  b Refer to the particle model to **justify** your prediction.

12 Aerosol cans should never be thrown in a fire. **Propose** reasons why.

13 a **Determine** whether you can or cannot answer the questions on page 42 at the start of this chapter.
  b **Assess** how well you understand the material presented in this chapter.

Creating CCT

14 **Use** the following ten key words to **construct** a visual summary of the information presented in this chapter.

matter	solid	liquid
gas	melt	freeze
evaporate	condense	
sublime	heat	

2.10

Thinking scientifically

Q1 The properties of a substance never change. Properties describe what a substance looks like, how heavy, dense, hard and brittle it is and how it acts when heated, cooled or mixed with other chemicals. Below are several statements that describe solid gold. Assess which is *not* a property of solid gold. CCT

A Gold is yellow and shiny.

B Gold melts at a temperature of 1064°C.

C One gram cost $49.05 in August 2012.

D Gold reacts with strong acids to form hydrogen gas.

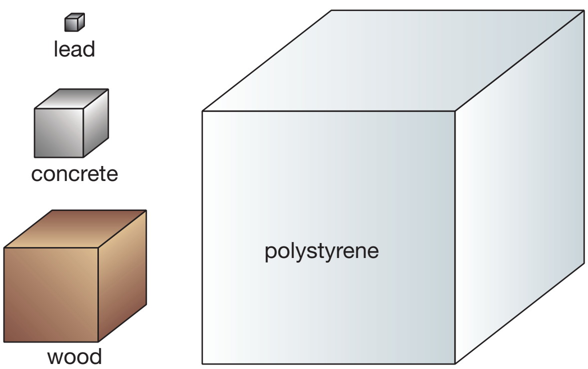
Q2 All the blocks in the diagram below have exactly the same mass. Density measures how much of a substance fits into a volume. Which of the following shows the correct order of densities from highest to lowest density? CCT

A Highest density = concrete
lead
wood
Lowest density = polystyrene

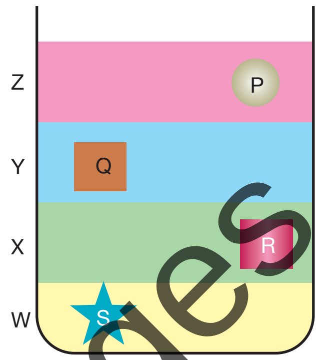
B Highest density = lead
concrete
wood
Lowest density = polystyrene

C Highest density = concrete
wood
lead
Lowest density = polystyrene

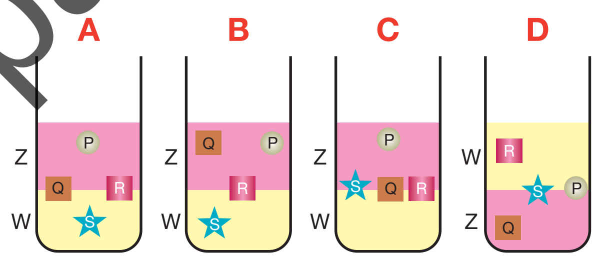
D Highest density = lead
polystyrene
concrete
Lowest density = wood



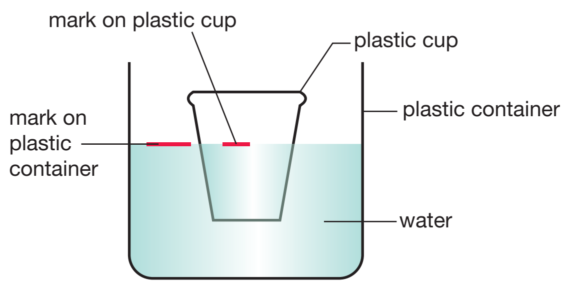
Q3 Liquids do not always mix together. Sometimes one liquid floats on top of another. Alice filled a container with some liquids as shown. P, Q, R and S are different objects floating in the liquids. CCT



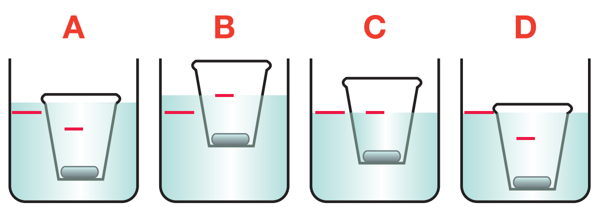
What would happen if liquids X and Y were removed?



Q4 Angus placed a plastic cup in a plastic container filled with water. He marked the level of the water on the cup and the container. CCT



Angus then placed a heavy rock inside the plastic cup. What did he observe?



Glossary

Unit 2.1 L

Biodegradable: bacteria or fungi breaks down the substance into simpler substances

Chemical properties: how substances react with other substances

Compressed: squashed

Incompressible: not able to be compressed or squashed

Non-biodegradable: doesn't rot or break down

Odour: smell

Physical properties: describe things about the substance like its appearance, melting, freezing and boiling points and its hardness

Plasma: the fourth state of matter; found in sparks, lightning bolts and in stars

States (phases): solid, liquid, gas (also plasma at temperatures above 6000˚C)

Chemical properties

Unit 2.2 L

Bonds: forces of attraction that hold particles together (verb: bonds)

Brownian motion: random motion of particles caused by being bumped and jostled by other particles

Diffusion: a process in which two liquids or gases mix

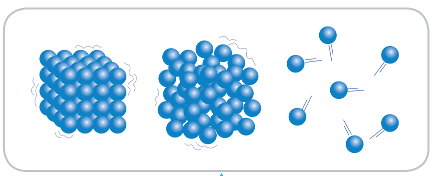
Gas laws: laws that describe how gas particles behave

Indirect evidence: facts and evidence from which something else can be inferred or reasoned

Particle model: the model used to help describe and explain the behaviour of particles in solids, liquids and gases

Pressure: combined push of gas particles bouncing off the walls of their container

Vibration: jiggling about on the spot (verb: vibrates)



Particle model

Unit 2.3 L

Boiling: when vigorous bubbling appears (verb: boils)

Boiling point: the temperature at which a liquid boils; 100°C for water

Condensation: removal of heat, changing a gas into a liquid (verb: condenses)

Evaporation: heat changing a liquid into a gas (verb: evaporates). Also known as vaporisation

Freezing: removal of heat, changing a liquid into a solid (verb: freezes)

Freezing point: the temperature at which a liquid freezes; 0°C for water

Melting: heat changing a solid into a liquid (verb: melts)

Melting point: the temperature at which a solid melts; 0°C for ice

Solidification: removal of heat, changing a liquid into a solid (verb: solidifies). Also known as freezing

Steam: condensation of water vapour, forming a visible fog of water droplets

Vaporisation: heat changing a liquid into a gas (verb: vaporises). Also known as evaporation

Boiling

Melting

Unit 2.4 L

Density: a measure of the mass per unit volume of a substance, $d = \frac{m}{V}$ (unit: g/cm^3)

Displaces: when one object takes the place of another, for example a solid pushes water upwards

Mass: measures how much matter is in a substance (unit: g)

Volume: measures how much space is occupied by a substance (units: mL or cm^3)