●●●○○ Level 3 · Science S3.5

Particles

Everything is made of tiny particles, and how they move explains a great deal.

Picture the particles in a solid, a liquid and a gas. Use them to explain smells, melting, pressure, rails that grow in the heat, dissolving and density.

YOU ARE READY FOR THIS BOOK IF

You can sort ten things at home into solids, liquids and gases.

One step up	S4.6 Atoms, bonding and the periodic table
This book	**S3.5 Particles**
One step down	S2.4 Solids, liquids, gases and the water cycle

Contents

S3.5.1 The particle model

S3.5.2 Evidence for particles

S3.5.3 Changes of state

S3.5.4 Diffusion and temperature

S3.5.5 Gas pressure

S3.5.6 Expanding and shrinking

S3.5.7 Dissolving and solutions

S3.5.8 Density

Key words, A to Z

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S3.5.1 CHAPTER 1

The particle model

> **Water pours and air spreads, but a stone stays put. What is different inside them?**

YOUR GUESS

Pick one before you read on. It is fine to be wrong.

- ☐ **A** The bits inside a stone are hard. The bits inside water are soft and runny.
- ☐ **B** Water and air are smooth all through, with no bits in them at all.
- ☐ **C** Inside a stone the bits are held in place. In water they slide. In air they fly about.

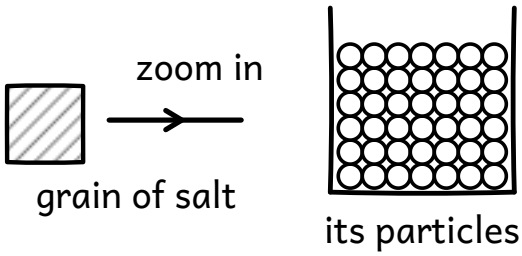
IF THIS FEELS HARD, READ THIS FIRST

- Level 2, Solids, liquids, gases and the water cycle, S2.4.1. You met solids, liquids and gases there. This chapter looks inside them.

BY THE END YOU CAN

- Draw the particles in a solid, a liquid and a gas
- Use the particle model to explain why liquids flow and gases spread

A stone keeps its shape. Water takes the shape of its cup. Air fills a whole room. Now we look inside them, at things far too small to see.



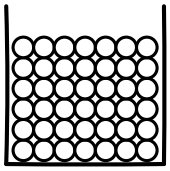
A grain of salt, and the particles inside it. They are far too small to see.

Everything is made of tiny bits called **particles**. A grain of salt holds more of them than there are people on Earth.

The **particle model** is a way of picturing them. We draw each particle as a small circle. The model explains how solids, liquids and gases behave.

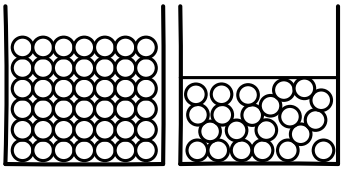
DRAW IT FIRST

Draw the particles in three boxes



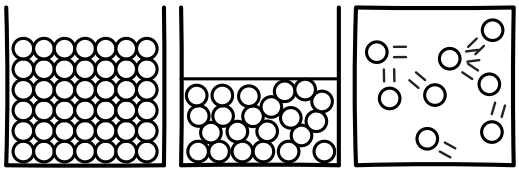
solid

1 Draw a box. Fill it with circles in neat rows, all touching. Label it solid.



solid liquid

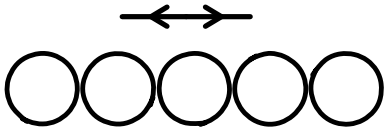
2 Draw a second box with an open top. Fill the bottom with circles that touch but are jumbled. Add a flat top and label it liquid.



solid liquid gas

3 Draw a third box with a lid. Put a few circles in it, far apart. Add short lines behind them. Label it gas.

In a solid, the particles touch and pull on each other. Each one is held in its place. It cannot move around, but it can **vibrate**. To vibrate is to shake to and fro in a tiny space.



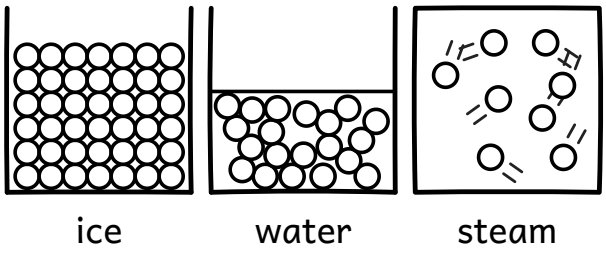
vibrates in place

A particle in a solid shakes to and fro. Its neighbours hold it in place.

In a liquid, the particles still touch and still pull on each other. But they are not held in place. They slide past each other, so a liquid can **flow**.

In a gas, the particles are far apart. They hardly pull on each other. They fly about in every direction. Between them there is nothing at all, only empty space.

The particles are the same in every state. A particle of water is the same in ice, in water and in steam. Only the way the particles are held, and the way they move, is different.



The same particles of water in three states.

Now we can explain what you see. A solid keeps its shape because its particles are held in place. A liquid pours because its particles slide past each other.

A gas spreads out because its particles fly about and nothing holds them. They keep going until they fill the whole container.

SEE IT THREE WAYS

With things

Think of people. In a packed queue, each person keeps a spot and only shuffles. In a busy market, people slide past each other. In a big empty field, a few people walk in any direction.

As a picture

state	shape	volume
solid	keeps	keeps
liquid	changes	keeps
gas	changes	changes

In words

In a solid, the particles touch and vibrate in place. In a liquid, they touch and slide. In a gas, they are far apart and move freely.

TRY IT

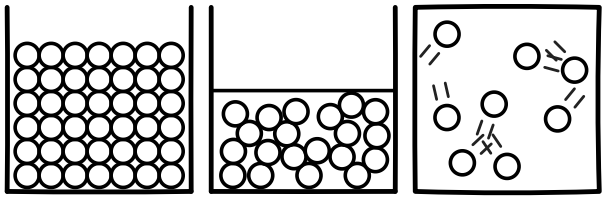
Be the particles with beans

You need: a tray or a shallow box, about 30 dried beans or small stones.

1. Pack the beans into the tray so that they all touch. Shake the tray very gently. The beans only wobble.
2. Tip the beans into a loose heap at one end. Shake the tray a little more. The beans slide past each other.
3. Take out all but 5 beans. Shake the tray hard. The beans scatter and fly about.

What you will see: Packed beans wobble in place, like a solid. Loose beans slide, like a liquid. A few beans fly about and fill the tray, like a gas.

If you cannot try it, this is what happens.



A WRONG IDEA MANY PEOPLE HAVE

~~In a solid, the particles do not move at all.~~

Why it feels right: A stone sits still and keeps its shape.

The test that breaks it: Think of a steel rail in the sun. It gets a little longer as it warms. If its particles stood still, warming could not change its length. The shaking is too small to see or feel, but we feel it as warmth.

What is true: The particles in a solid are held in place, but they vibrate all the time. They never stand still.

KEY WORDS

particles

the tiny bits that everything is made of.

particle model
a picture that shows particles as circles and explains how matter behaves.

vibrate
shake to and fro in a tiny space.

flow
move along because the particles slide past each other.

BACK TO YOUR GUESS

The answer is C: Inside a stone the bits are held in place. In water they slide. In air they fly about.

Every material is made of tiny particles. In a stone they are held in place. In water they slide past each other. In air they fly about.

CHECK YOURSELF

Try each one before you look. A wrong answer tells you where to go next.

1. In which state are the particles far apart and flying about in every direction?

   A Solid

   B Gas

   C Liquid

   Answer at the back of the book.

2. You can pour water but not a stone. Which reason is right?

   A The particles of water are smaller than the particles of a stone.

   B The particles of water do not touch each other.

   C The particles of water slide past each other. The particles of a stone are held in place.

   Answer at the back of the book.

3. Gas fills a closed jar. What is there between its particles?

   A More tiny particles

   B Nothing at all. It is empty space.

   C A thin liquid

   Answer at the back of the book.

4. Tariq says, "The particles in a stone do not move." What should you tell him?

   A They vibrate in place. They cannot move around, but they never stand still.

   B He is right. A stone is too hard for its particles to move.

   C They move faster than the particles of a gas.

   Answer at the back of the book.

5. You draw a box of gas with 6 circles. Which drawing is right?

   A Six circles far apart, spread through the whole box.

   B Six circles in neat rows, all touching.

   C Six circles touching in a jumbled pile at the bottom.

   Answer at the back of the book.

KEEP IT

Copy this into your exercise book.

All things are made of tiny particles. In a solid they touch and vibrate in place. In a liquid they touch and slide past each other. In a gas they are far apart and fly about.

Draw: Draw three boxes. Put neat rows of circles in the first. Put a jumbled pool in the second. Put a few circles far apart in the third.

S3.5.2 CHAPTER 2

Evidence for particles

How can I smell food from across the room when I cannot see anything travel?

YOUR GUESS

Pick one before you read on. It is fine to be wrong.

- ☐ **A** Only wind carries a smell. In still air it could not reach me.
- ☐ **B** A smell is not made of anything. It just appears when you stand near the food.
- ☐ **C** Tiny particles from the food spread out through the air until some reach my nose.

IF THIS FEELS HARD, READ THIS FIRST

- Level 3, Particles, S3.5.1. You need the picture of particles in a gas and a liquid.
- Level 2, Solids, liquids, gases and the water cycle, S2.4.2. Air is a gas that fills the space around us.

BY THE END YOU CAN

- Explain how a smell spreads across a room
- Explain why a spoon of sugar seems to vanish in water

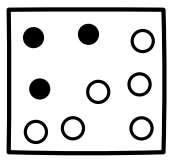
Nobody has ever seen a single particle with their own eyes. So how do we know that particles are there?

We use **evidence**. Evidence is what we see or measure that supports an idea. Scientists use the particle model because it explains a great deal of evidence.

Here is the first piece. Someone peels an orange at one end of a room. Soon people at the other end can smell it. Nothing you can see has crossed the room.

DRAW IT FIRST

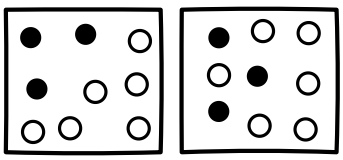
Draw a smell spreading through air



start

○ air ● smell

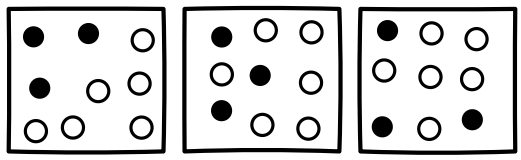
1 Draw a box of air with open circles. Put the smell, dark dots, in one corner.



start soon

○ air ● smell

2 Draw the same box a little later. Some dark dots have moved away from the corner.

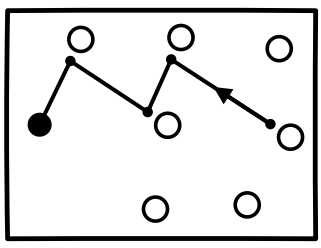


start soon later

○ air ● smell

3 Draw it later still. The dark dots are mixed through the whole box.

The orange gives off particles of a gas. They mix with the air, which is a gas made of particles too. The smell particles fly about and keep bumping into air particles. Each bump sends them a new way, so they zigzag.



one smell particle

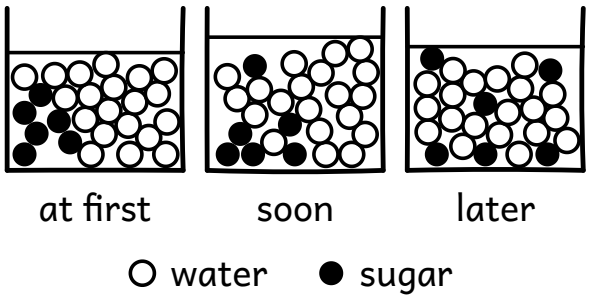
A smell particle flies straight until it hits an air particle. Then it goes a new way.

Slowly, the smell particles spread through the whole room. This is **diffusion**. In diffusion, particles spread out by themselves, from where there are many to where there are few.

In a real room, slow air currents carry most of the smell. Diffusion alone is slower, but it never stops, even in still air. Leave a drop of food colour in a glass of water. With no stirring, the colour still spreads, though it takes an hour or more.

Here is the second piece. Stir a spoon of sugar into water. Soon you cannot see it. Did the sugar vanish?

No. The water particles pull the sugar apart into separate particles. They are far too small to see. They spread out among the water particles, so the water stays clear. We say the sugar **dissolves**.



Sugar in water. The sugar particles are still there. They are spread through the water.

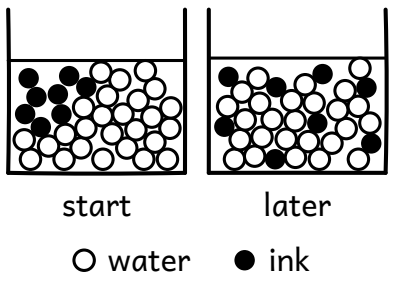
The sugar did not vanish. It is mixed in. Salt does the same. Leave salty water in a dish in the sun. The water goes into the air, and white salt is left on the dish.

SEE IT THREE WAYS

With things

A drop of ink spreads through still water. Perfume spreads through a room. Sugar spreads through tea. In each one, something mixes through something else without a spoon or a wind.

As a picture



In words

Particles of two materials mix by themselves. The particles move about, and they spread from where there are many to where there are few.

TRY IT

Time a smell across a room

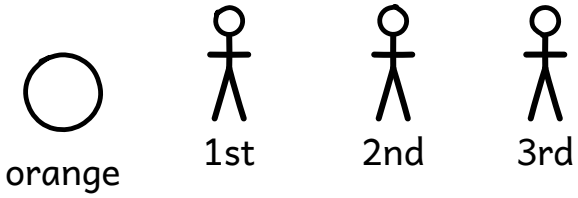
You need: an orange or a lemon, a room with the door and windows shut, 3 friends, a clock, or a way to count seconds.

Be safe: Nobody should sniff the peel close up. Do not try this with anyone who is allergic to oranges or lemons.

1. Ask your friends to stand in the room. One stands near the orange, one halfway, and one at the far end. They must stay still.
2. Peel the orange at one end of the room. Start counting at once.
3. Ask each friend to put a hand up the moment they smell it. Write down each time.

What you will see: The friend nearest the orange smells it first. The friend at the far end smells it last. You saw nothing cross the room, but particles did. Air currents help carry them, so this test cannot show diffusion alone.

If you cannot try it, this is what happens.



A WRONG IDEA MANY PEOPLE HAVE

~~A smell needs wind to travel.~~

Why it feels right: A breeze often brings the smell of cooking from the next house.

The test that breaks it: Leave a drop of food colour in a glass of still water. With no wind and no stirring, the colour still spreads out, though very slowly.

What is true: Wind and air currents carry a smell faster. But the particles also spread out by themselves, even in still air, only slowly. This is diffusion.

KEY WORDS

evidence
what we see or measure that supports an idea.

diffusion
particles spreading out by themselves, from where there are many to where there are few.

dissolves
mixes into a liquid so completely that the particles cannot be seen.

BACK TO YOUR GUESS

The answer is C: Tiny particles from the food spread out through the air until some reach my nose.

Particles from the food mix into the air and spread out by themselves. Air currents carry them faster.

CHECK YOURSELF

Try each one before you look. A wrong answer tells you where to go next.

1. Someone opens a bottle of perfume at one end of a still room. Why can a person at the other end smell it after a while?

   A The bottle pushes the smell across the room in a straight line.

   B It could not. A smell needs wind to travel.

   C Perfume particles fly about, bump into air particles and spread through the room.

   Answer at the back of the book.

2. Why can you not see the sugar after you stir it into water?

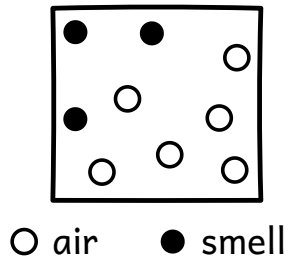
   A The sugar turns into water.

   B The sugar breaks into particles too small to see, and they spread through the water.

   C The sugar is destroyed.

   Answer at the back of the book.

3. The picture shows 6 air particles and 3 smell particles in a box. How many particles are in the box in all?



   A 9 particles in all

   B 6 particles in all

   C 3 particles in all

   Answer at the back of the book.

4. In one orange test, a friend near the orange smelled it after 20 seconds. A friend at the far end smelled it after 90 seconds. How many seconds longer did the far friend wait?

   A 70 seconds longer

   B 90 seconds longer

   C 110 seconds longer

   Answer at the back of the book.

5. You stir salt into water and can no longer see it. How could you show the salt is still there?

   A Weigh the cup. It will weigh less, because the salt has gone.

   B Leave the salty water in a dish in the sun. The water dries away, and white salt is left.

   C Nothing can show it. The salt has turned into water.

   Answer at the back of the book.

6. **From an earlier chapter**

   In which state do the particles touch each other but slide past each other?

   A Solid

   B Liquid

   C Gas

   Answer at the back of the book.

KEEP IT

Copy this into your exercise book.

We cannot see particles, so we use evidence. A smell spreads because its particles fly about and mix with air. This is diffusion. Dissolved sugar is not gone. It is spread out.

Draw: Draw two boxes of open circles. Put dark dots in one corner of the first. Spread them through the second.

S3.5.3 CHAPTER 3

Changes of state

Why does ice melt on a hot day, and steam turn to drops on a cold lid?

YOUR GUESS

Pick one before you read on. It is fine to be wrong.

- ☐ **A** Heat gives the particles energy. They move more and break free of their places.
- ☐ **B** Heat makes the particles melt, so each one turns runny.
- ☐ **C** Heat makes each particle grow bigger until it fills the space.

IF THIS FEELS HARD, READ THIS FIRST

- Level 2, Solids, liquids, gases and the water cycle, S2.4.3. Melting and freezing, and the melting point of ice, are there.
- Level 2, Solids, liquids, gases and the water cycle, S2.4.5. Steam turning back to drops is there.

BY THE END YOU CAN

- Explain melting, boiling and condensing as particles gain or lose energy
- Use melting and boiling points to find the state at room temperature

Ice melts on a hot day. Steam turns back to drops on a cold lid. In both, a material turns from one state to another. This is a **change of state**.

Heat gives particles **energy**. Energy is what makes particles move. The more energy they have, the faster they move.

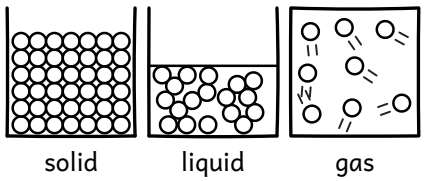
Heat a solid. Its particles vibrate harder and harder. At last they shake free of their places and begin to slide. The solid has melted. The temperature where this happens is the **melting point**.

Keep heating the liquid. Its particles move faster and faster. At the **boiling point** they have enough energy to break free of each other. Bubbles of gas form all through the liquid. It boils.

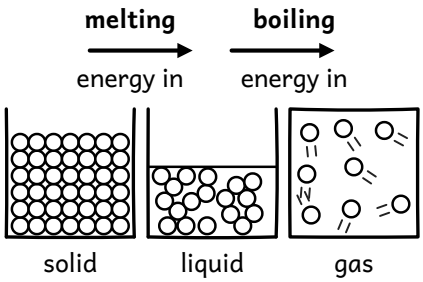
Cooling does the opposite. Energy leaves the material. A gas cools, and its particles slow down. They are pulled together, and the gas condenses into a liquid. Cool the liquid more. The particles slow until they lock in place. It freezes.

DRAW IT FIRST

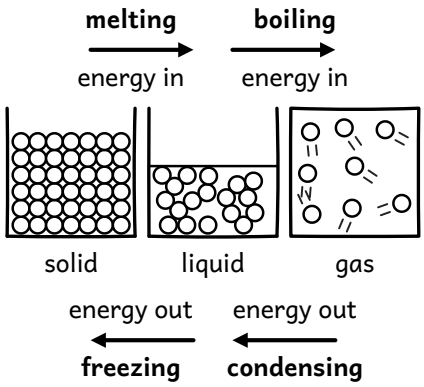
Draw the changes of state



1 Draw three boxes of particles in a row: solid, liquid and gas.

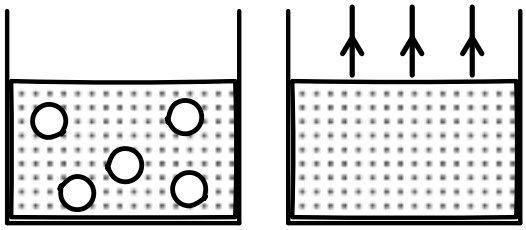


2 Draw arrows above them, pointing right. Heating puts energy in. Write melting and boiling.



3 Draw arrows below them, pointing left. Cooling takes energy out. Write condensing and freezing.

While a pure solid melts, its temperature stays the same. Ice stays at 0 °C until all of it has gone. The energy goes into freeing the particles, not into making them hotter. The same is true while a liquid boils.



boiling 100 °C

evaporating below 100 °C

Boiling makes bubbles all through the liquid. Evaporation happens only at the surface.

Evaporation is different. It happens at the surface of a liquid, at any temperature below the boiling point. A few particles near the surface have more energy than the rest, and they escape as a gas. Boiling happens all through the liquid, and only at the boiling point.

A pure material, such as water or iron, has its own melting point and boiling point. They tell you its state at any temperature. Below the melting point it is a solid. Between the two points it is a liquid. Above the boiling point it is a gas. These points are for normal air pressure, near sea level.

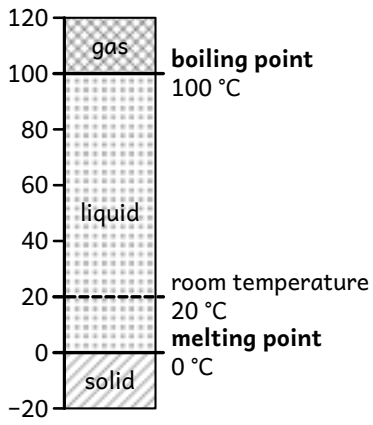
name	melts at	boils at
oxygen	−219	−183
mercury	−39	357
water	0	100
salt	801	1465
iron	1538	2862

Melting points and boiling points in °C, at normal air pressure near sea level. High up, water boils at a lower temperature. Mercury is a poisonous metal. Never touch it.

Room temperature is about 20 °C. Oxygen melts at −219 °C and boils at −183 °C. 20 °C is far above both, so oxygen is a gas in a room. Iron needs 1538 °C to melt, so it is a solid.

SEE IT THREE WAYS

As a picture



In words

Below the melting point, a material is a solid. Between its melting point and its boiling point, it is a liquid. Above its boiling point, it is a gas.

In symbols

At sea level, water is solid below 0 °C. It is liquid from 0 °C to 100 °C. It is gas above 100 °C.

TRY IT

Turn steam back into drops

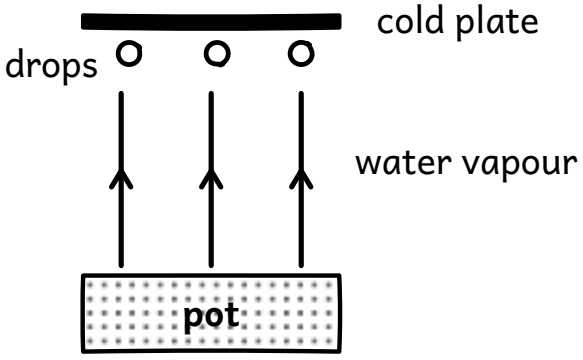
You need: a pot with a little water, a grown up to heat it, a cold metal plate or lid, an oven glove.

Be safe: A grown up must do the heating. Steam and hot water burn badly. Keep your face and hands away from the pot.

1. A grown up heats the water until bubbles rise all through it. Then they turn the heat off.
2. The grown up holds the cold plate, tilted, about 20 cm above the pot, wearing the oven glove.
3. Wait a few seconds. Look at the underside of the plate. Do not touch the pot or the steam.

What you will see: Drops of water form on the underside of the cold plate. The vapour gave energy to the plate and turned back into a liquid. The plate also gets warm.

If you cannot try it, this is what happens.



A WRONG IDEA MANY PEOPLE HAVE

~~When ice melts, the particles themselves turn runny.~~

Why it feels right: The ice turns soft and runny, so it seems each little bit has softened.

The test that breaks it: Freeze the water again and you get ice again, the same as before. If the particles had changed into something else, the ice could not come back.

What is true: The particles do not change. Heat gives them more energy, so they move more and break free of their places.

KEY WORDS

change of state
a material turning from a solid, liquid or gas into another of the three.

energy
what makes particles move. More energy means faster particles.

melting point
the temperature at which a solid melts. It is also where the liquid freezes.

boiling point
the temperature at which a liquid boils, with bubbles of gas all through it.

BACK TO YOUR GUESS

The answer is A: Heat gives the particles energy. They move more and break free of their places.

The particles do not change. Heat gives them energy, so they vibrate harder and slide free. Cooling takes the energy away again.

CHECK YOURSELF

Try each one before you look. A wrong answer tells you where to go next.

1. Ice is heated. What happens to its particles as it melts?

   A They get bigger and softer.

   B They gain energy and break free of their fixed places.

   C They stop moving and sit still.

   Answer at the back of the book.

2. Bubbles of gas form all through a pan of water. What is happening?

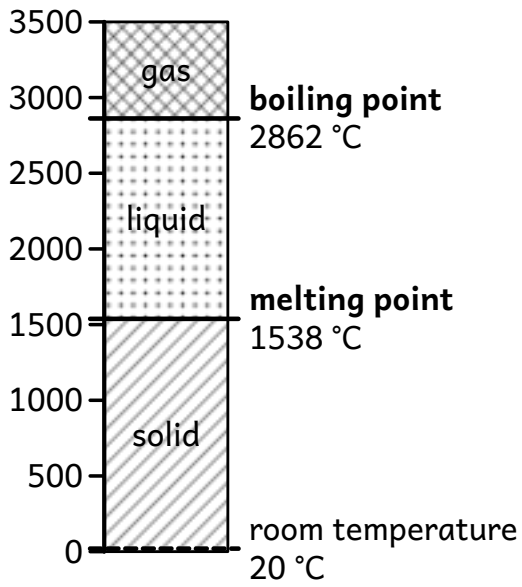
   A The water is boiling.

   B The water is evaporating.

   C The water is melting.

   Answer at the back of the book.

3. The scale is for iron. Is iron a solid, a liquid or a gas at room temperature, about 20 °C?



   A A liquid. 20 °C is above 0 °C, where things melt.

   B A liquid. Metals melt as soon as they get warm.

   C A solid. 20 °C is below the melting point of 1538 °C.

   Answer at the back of the book.

4. Oxygen melts at −219 °C and boils at −183 °C. What state is oxygen at room temperature, about 20 °C?

   A A liquid. 20 °C is above the melting point of −219 °C, so it has melted.

   B A gas. 20 °C is above the boiling point of −183 °C.

   C A solid. A melting point below zero means it is always solid.

   Answer at the back of the book.

5. Steam touches a cold window and turns into drops of water. What happens to the particles?

   A They gain energy and break free of each other.

   B They change into particles of glass.

   C They lose energy, slow down and are pulled together.

   Answer at the back of the book.

6. **From an earlier chapter**

   What is it called when particles spread out by themselves?

   A Freezing

   B Diffusion

   C Melting

   Answer at the back of the book.

KEEP IT

Copy this into your exercise book.

Heat gives particles energy. At the melting point a solid melts. At the boiling point a liquid boils. Cooling takes energy away: gas condenses, liquid freezes.

Draw: Draw solid, liquid and gas boxes in a row. Add arrows above, pointing right, and arrows below, pointing left. Name each one.

S3.5.4 CHAPTER 4

Diffusion and temperature

Why does a drop of colour spread faster in hot water than in cold water?

YOUR GUESS

Pick one before you read on. It is fine to be wrong.

- ☐ **A** In hot water the particles move faster, so the colour spreads out sooner.
- ☐ **B** Hot water has more room between its particles, so the colour has more space.
- ☐ **C** Heat makes the colour particles lighter, so they float up through the water.

IF THIS FEELS HARD, READ THIS FIRST

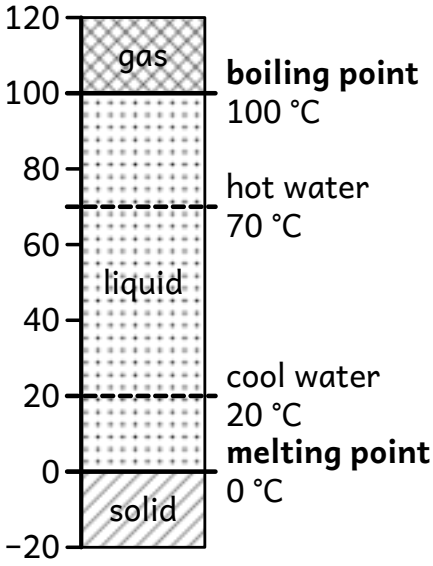
- Level 3, Particles, S3.5.2. Diffusion is how particles spread out by themselves.
- Level 3, Particles, S3.5.3. Heat gives particles energy, so they move faster.

BY THE END YOU CAN

- Compare how fast colour spreads in hot and in cold water
- Explain why particles spread faster when they are warmer

A smell spreads by diffusion. Does it spread faster when it is warm? Think of a drop of food colour in water.

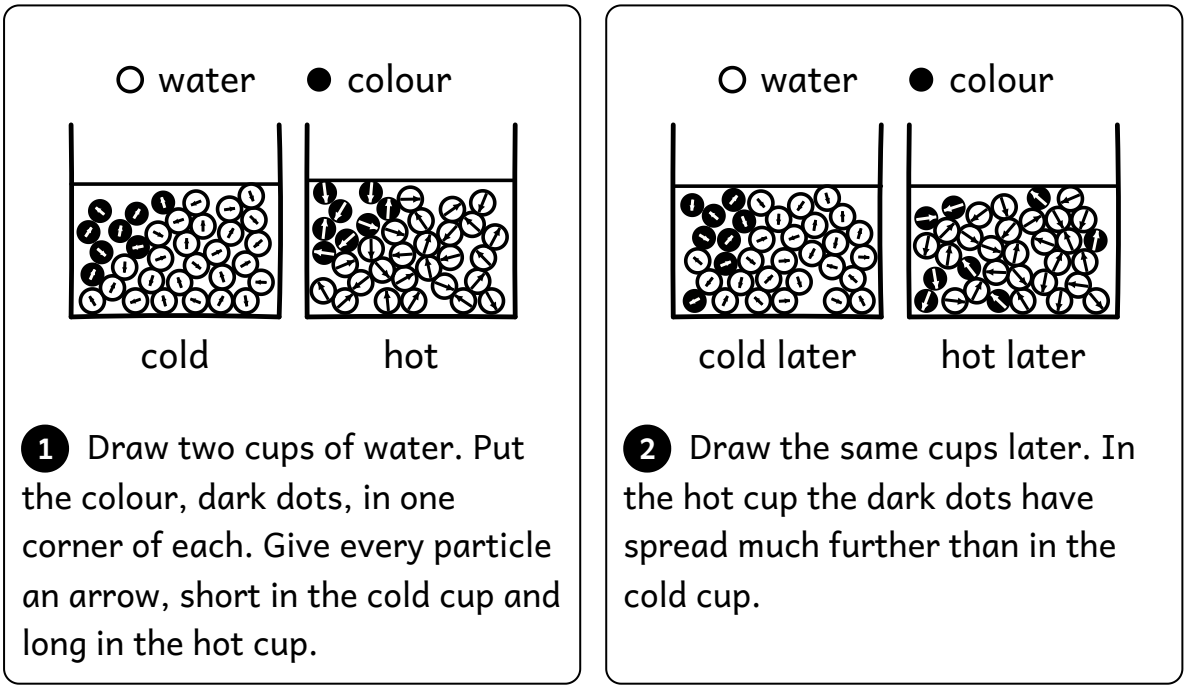
Temperature tells you how hot something is. The hotter it is, the faster its particles move, on average. In hot water the particles move fast. In cold water they move slowly.



Cool water and hot water are both liquid. The hotter water has the faster particles.

DRAW IT FIRST

Draw colour spreading in *a* cold cup *and a* hot cup



1 Draw two cups of water. Put the colour, dark dots, in one corner of each. Give every particle an arrow, short in the cold cup and long in the hot cup.

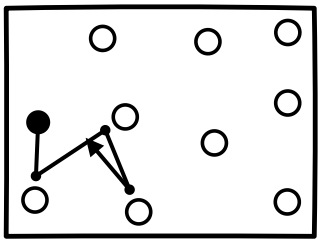
2 Draw the same cups later. In the hot cup the dark dots have spread much further than in the cold cup.

The colour particles are knocked about by the water particles around them. Fast water particles knock them harder and more often. So the colour spreads out sooner in hot water.

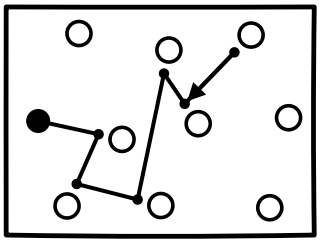
Cold water is not still. Its particles move too, only more slowly. So colour does spread in cold water, just slowly.

In a real cup, small currents help the colour spread too, and hot water makes more of them. So the hot cup is quicker for two reasons. To see diffusion alone, the water would have to be perfectly still.

The same is true of a smell. The smell of food reaches you sooner in a warm kitchen than in a cold one.



cold air

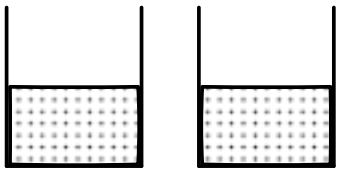


warm air

In air, a faster particle bumps more often in the same time, so it goes farther.

To compare hot and cold fairly, change only one thing. Use the same amount of water and the same colour. Stir neither cup, and do not move them. This is a **fair test**. If you stir one cup, you cannot tell what made the difference.

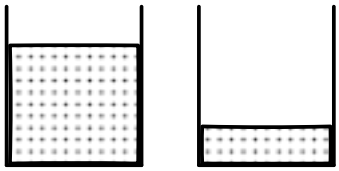
fair test



cold
200 mL

hot
200 mL

not fair



cold
300 mL

hot
100 mL

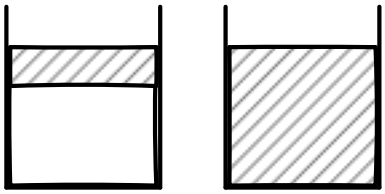
In a fair test only the temperature differs. The amounts of water are the same.

SEE IT THREE WAYS

With things

Add a drop of food colour to a cup of hot water. Add one to a cup of cold water. Leave both alone and watch. The hot cup turns one even colour first.

As a picture



cold hot

In words

In hot water the particles move faster. They bump about and spread out faster. So the colour spreads in less time.

TRY IT

Hot cup, cold cup

You need: 2 clear cups or glasses, food colour or ink, cold water, hot water from a grown up, a clock, or a way to count minutes.

Be safe: A grown up must pour the hot water. Use hot, not boiling, water. Do not drink it. Keep the cups away from the table edge.

1. Pour the same amount of cold water into one cup. A grown up pours the same amount of hot, not boiling, water into the other cup.
2. Wait until both cups are still. Add one drop of colour to each cup, as gently as you can. Do not stir.
3. Look every few minutes. Write down how long each cup takes to become one even colour.

What you will see: The hot cup becomes one even colour sooner. Currents help in the hot cup too, so this test shows the pattern but not diffusion alone.

If you cannot try it, this is what happens.

cup	after a while
cold	still patchy
hot	one even colour

A WRONG IDEA MANY PEOPLE HAVE

~~The particles in cold water stop moving.~~

Why it feels right: Cold water looks perfectly still.

The test that breaks it: Look at the cold cup in the colour test. The colour still spreads, only slowly. If the particles stood still, nothing could spread.

What is true: Particles in cold water move more slowly than in hot water, but they never stand still.

KEY WORDS

temperature
how hot something is. The hotter it is, the faster its particles move.

fair test
a test that changes only one thing and keeps everything else the same.

BACK TO YOUR GUESS

The answer is A: In hot water the particles move faster, so the colour spreads out sooner.

Particles move faster when they are hotter. Fast particles knock the colour particles about harder and more often, so the colour spreads sooner.

CHECK YOURSELF

Try each one before you look. A wrong answer tells you where to go next.

1. Why does a drop of food colour spread faster in hot water?

   A Hot water has more particles, so more colour is pushed out.

   B The colour particles are lighter in hot water.

   C The particles move faster, so they spread out sooner.

   Answer at the back of the book.

2. In Ana's test, food colour took 15 minutes to spread evenly in the hot cup. It took 60 minutes in the cold cup. How many times longer did the cold cup take?

   A 45 times longer

   B 75 times longer

   C 4 times longer

   Answer at the back of the book.

3. Kofi tests hot and cold water. He uses a big cup of cold water and a small cup of hot water. What is wrong with his test?

   A The amounts of water are different, so the test is not fair.

   B Nothing is wrong. The temperatures are different, and that is what he wants.

   C He should stir the cold cup.

   Answer at the back of the book.

4. What does the temperature of a material tell you about its particles?

   A How big they are.

   B How many there are.

   C How fast they move, on average.

   Answer at the back of the book.

5. After five minutes the colour has hardly spread in the cold cup. Sam says, "Cold particles stop moving." What should you tell Sam?

   A Sam is right. Particles in cold water stand still, so nothing spreads.

   B Cold particles still move, only more slowly, so the colour spreads more slowly.

   C Cold water is too thick for particles to move in.

   Answer at the back of the book.

6. **From an earlier chapter**

   Which change happens only at the surface of a liquid, at any temperature below its boiling point?

   A Evaporation

   B Boiling

   C Melting

   Answer at the back of the book.

KEEP IT

Copy this into your exercise book.

The hotter something is, the faster its particles move. Fast particles spread out sooner, so diffusion is quicker when warm. Cold particles still move, only slowly.

Draw: Draw a cold cup and a hot cup of water with dark dots in one corner. Draw the dots later, spread further in the hot cup.

S3.5.5 CHAPTER 5

Gas pressure

Why does a bicycle tyre go hard when I pump air into it?

YOUR GUESS

Pick one before you read on. It is fine to be wrong.

- ☐ **A** Air particles keep hitting the inside of the tyre, which pushes its walls out.
- ☐ **B** The air is heavy, and it pushes down on the bottom of the tyre.
- ☐ **C** The air is squashed until it is stuck, and its particles cannot move at all.

IF THIS FEELS HARD, READ THIS FIRST

- Level 3, Particles, S3.5.1. You need the picture of particles in a gas.
- Level 2, Solids, liquids, gases and the water cycle, S2.4.2. Air takes up space and pushes on things.

BY THE END YOU CAN

- Explain gas pressure as particles hitting the walls of a container
- Explain why a ball or a tyre feels harder on a hot day

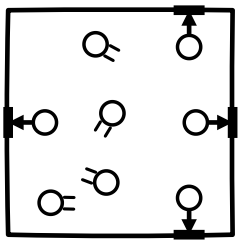
Pump up a bicycle tyre and it goes hard. There is only air inside. Why does air push so hard?

The particles of a gas fly about in every direction. They keep hitting the walls of the container. Each hit gives the wall a tiny push.

A tyre holds an enormous number of particles. They make an enormous number of hits every second. Together they make a steady push. Gas **pressure** is the push of a gas on the walls of its container.

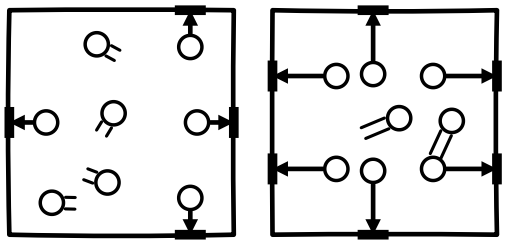
DRAW IT FIRST

Draw a gas pushing on its box



cool

1 Draw a closed box with 8 gas particles. Draw 4 short arrows from particles to the walls. A short arrow is a slow particle. Mark each wall where an arrow lands.

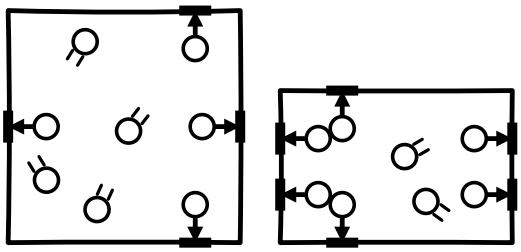


cool hot

2 Draw a second box with 8 particles moving faster. Draw 6 longer arrows. Faster particles hit harder and more often.

A hotter gas has faster particles. They hit the walls harder, and they hit more often. So the pressure goes up.

There are two more ways to raise the pressure. One is to put more particles into the same box. The other is to **compress** the gas. To compress a gas is to squeeze it into a smaller **volume**. Volume is the space a thing takes up.



big squeezed

The same particles in a smaller space hit the walls more often. The pressure goes up.

On a hot day, the air inside a ball or a tyre is warmer. Its particles move faster. They hit the inside harder and more often, so the ball feels harder.

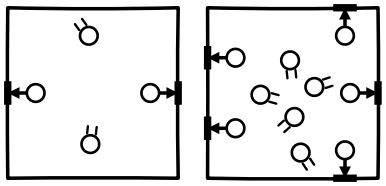
Be safe. Never heat a sealed can or bottle. The pressure inside can rise until it bursts.

SEE IT THREE WAYS

With things

Pump air into a bicycle tyre. The more air you add, the harder the tyre gets.

As a picture



In words

More particles in the same box means more hits on the walls each second. More hits means more pressure.

TRY IT

Feel the push of the air

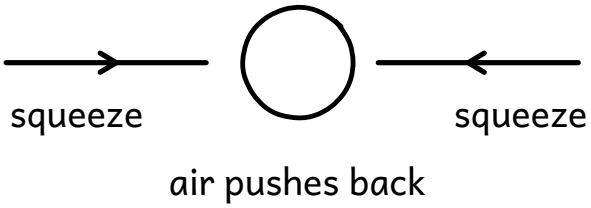
You need: a balloon.

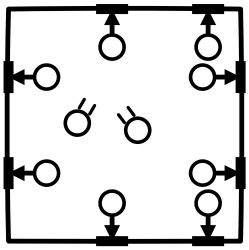
Be safe: Squeeze gently and keep the balloon away from your face. It may burst.

1. Blow up the balloon until it is round and not tight. Tie it.
2. Hold it in both hands and squeeze it gently. Feel it push back.
3. Squeeze a little harder. Let go. The balloon goes back to its round shape.

What you will see: The balloon pushes back on your hands, from every side. The harder you squeeze, the harder it pushes back.

If you cannot try it, this is what happens.





every wall is hit

The hits land on every wall, not only the bottom. The push is the same all round.

A WRONG IDEA MANY PEOPLE HAVE

~~**A gas only pushes down, because air has weight.**~~

Why it feels right: Things you can feel pressing down, such as a heavy lid, push down.

The test that breaks it: Squeeze a balloon from the top, the bottom and both sides. It pushes back on your hands each time. A balloon is round, not flat at the bottom.

What is true: Gas particles fly in every direction. In a small container, a gas pushes equally on every wall: up, down and sideways.

KEY WORDS

pressure
the push of a gas on the walls of its container. It comes from particles hitting the walls.

compress
squeeze into a smaller volume.

volume
the space a thing takes up.

BACK TO YOUR GUESS

The answer is A: Air particles keep hitting the inside of the tyre, which pushes its walls out.

The particles of the air fly about and hit the wall of the tyre again and again. All those hits add up to a push on every part of the wall.

CHECK YOURSELF

Try each one before you look. A wrong answer tells you where to go next.

1. What causes the push of a gas on the walls of its container?

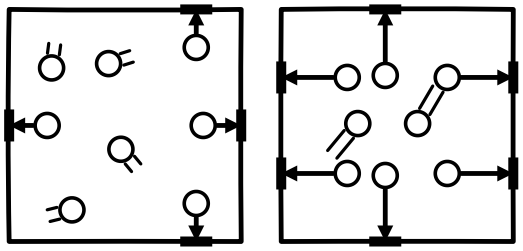
   A The weight of the gas pressing down.

   B Gas particles hitting the walls.

   C Gas particles sticking to the walls.

   Answer at the back of the book.

2. The cool box shows 4 hits. The hot box shows 6 hits. How many more hits does the hot box show?



cool hot

   A 10 more hits

   B 6 more hits

   C 2 more hits

   Answer at the back of the book.

3. Why does a football feel harder on a hot day?

   A The air inside is warmer, so its particles hit the inside harder and more often.

   B The air inside gets heavier, so it pushes down more.

   C More air has come into the ball.

   Answer at the back of the book.

4. The end of a bicycle pump is blocked. You push in the handle, so the air has a smaller volume. What happens to the pressure?

   A It goes down, because the particles are closer together.

   B It goes up, because the particles hit the walls more often.

   C It stays the same, because the same particles are there.

   Answer at the back of the book.

5. **From an earlier chapter**

   In a fair test, how many things do you change?

   A As many as you like.

   B One.

   C None.

   Answer at the back of the book.

6. Why can a sealed can burst if it gets very hot?

   A The gas inside gets hot. Its particles hit the walls harder and more often, and the pressure rises until the can bursts.

   B The gas inside gets heavier, so it pushes down on the bottom of the can until it bursts.

   C The particles inside get bigger and burst the can.

   Answer at the back of the book.

KEEP IT

Copy this into your exercise book.

Gas pressure is the push of particles hitting the walls. Faster particles, more particles, or a smaller volume give more hits, so more pressure.

Draw: Draw a closed box with 8 particles. Add arrows from some of them to the walls, and mark where they land.

S3.5.6 CHAPTER 6

Expanding and shrinking

Why do railway lines have small gaps between them?

YOUR GUESS

Pick one before you read on. It is fine to be wrong.

- ☐ **A** The gaps let rain water drain away so the rails do not rust.
- ☐ **B** Rails get shorter when they are hot, so the gaps stop them pulling apart.
- ☐ **C** Rails get longer when they are hot, so they need room to grow.

IF THIS FEELS HARD, READ THIS FIRST

- Level 3, Particles, S3.5.1. Particles in a solid vibrate in their places.
- Level 3, Particles, S3.5.4. Hotter particles have more energy and move more.

BY THE END YOU CAN

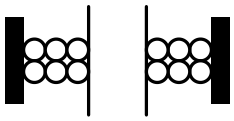
- Explain why things expand when heated, using particles
- Explain why bridges and railway lines have small gaps

Some railway lines have small gaps between the rails. Many bridges have gaps in their road. Why leave a gap in something that should be joined?

Most solids, liquids and gases get bigger when they are heated. They **expand**. When they cool, they get smaller. They **contract**.

DRAW IT FIRST

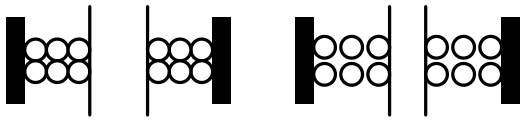
Draw two rails, cold and hot



gap

cold

1 Draw two rails end to end, fixed at the outer ends. Make each rail two rows of touching circles. Leave a gap between them.



gap

cold

gap

hot

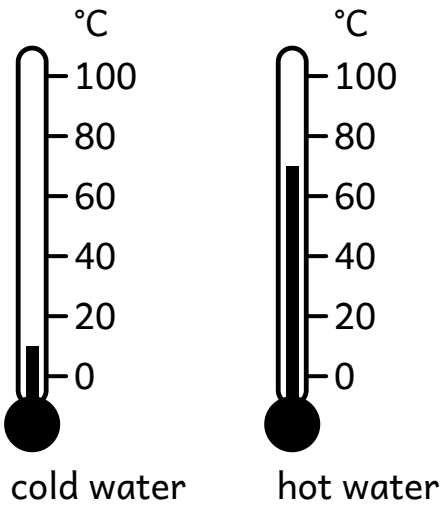
2 Draw them again, hot. Use the same number of circles, but set them a little further apart. Each rail is longer, so the gap is smaller.

The picture is drawn much bigger than real life, so that you can see it. In a real hot rail the particles are still almost touching. They vibrate harder and sit a tiny bit further apart.

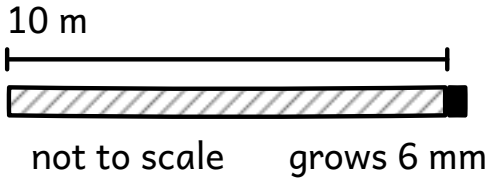
Heat gives the particles energy. In a solid, each particle vibrates harder. It shakes a little further from its place and pushes on its neighbours. So the average space between particles grows, and the whole rail gets longer.

The particles do not get bigger. The same particles are just a little further apart. Cool the rail and they come back together.

Liquids expand too. Gases expand much more than solids, because their particles are free to fly further apart.



The liquid in a thermometer expands as it warms, so it climbs the tube.

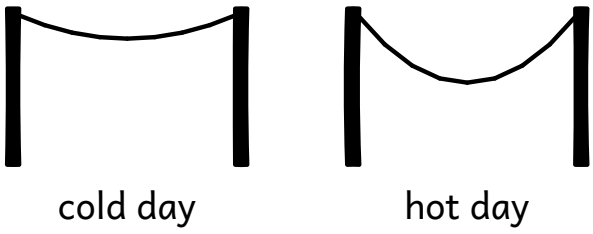


The growth is small. It is drawn much too big, so that you can see it.

The change is small. A steel rail 10 m long grows about 6 mm when it warms by 50 °C. That is about the width of a pencil.

A longer rail has more particles in a row, so it grows more. Double the length and the growth doubles.

Long cables between poles expand too. In the heat a cable is longer, so it hangs lower.



A longer cable between two fixed poles must hang lower. The sag is drawn bigger than in real life.

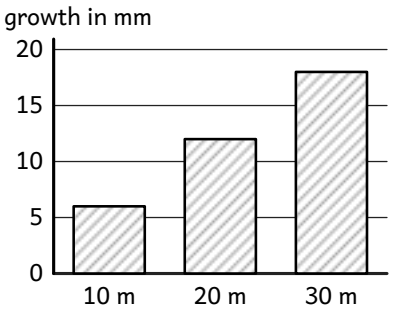
Engineers leave gaps so that hot rails do not push on each other and bend. The gaps in a bridge do the same job. Some modern lines have no gaps. Their rails are welded and held firmly in place.

SEE IT THREE WAYS

With things

A metal lid is stuck on a jar. Hot water poured over the lid makes it a little bigger, and it comes loose.

As a picture



In words

A longer rail has more particles in a row. Each pair moves a little further apart, so the rail grows by more.

In symbols

10 m grows 6 mm.
20 m grows 12 mm. 30 m grows 18 mm.

TRY IT

Warm the air in a bottle

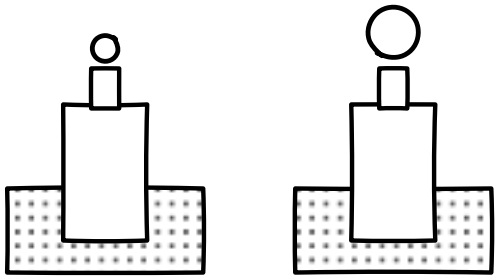
You need: a plastic bottle, a balloon, two bowls, cold water, hot water from a grown up.

Be safe: A grown up must pour the hot water. Use hot, not boiling, water, because it can soften the bottle. Use a plastic bottle, never glass.

1. Stretch the balloon over the neck of the empty bottle. The bottle holds air.
2. Stand the bottle in a bowl of cold water. Wait a minute. Look at the balloon.
3. Move the bottle into a bowl of hot, not boiling, water that a grown up pours. Wait a minute. Look at the balloon.

What you will see: In the hot water, the balloon stands up and swells a little. The air in the bottle got warmer and expanded. Put the bottle back in cold water and the balloon goes limp again.

If you cannot try it, this is what happens.



A WRONG IDEA MANY PEOPLE HAVE

~~Things expand because their particles get bigger.~~

Why it feels right: The object gets bigger, so it seems each part of it must have grown.

The test that breaks it: If growing particles made things expand, a solid would grow most, because its particles touch. In fact the air in the bottle grows far more than a steel rail does. So it is the space between the particles that grows.

What is true: The particles stay the same size. They move or vibrate more, so the average space between them grows. A gas has much more empty space to gain, so it expands far more.

KEY WORDS

expand
get bigger when heated, because the particles move further apart.

contract
get smaller when cooled, because the particles move closer together.

BACK TO YOUR GUESS

The answer is C: Rails get longer when they are hot, so they need room to grow.

Heat makes the particles vibrate harder and sit further apart, so the rail gets longer. The gap gives it room to grow.

CHECK YOURSELF

Try each one before you look. A wrong answer tells you where to go next.

1. Why do railway lines have small gaps between them?

   A The rails grow longer when hot, and the gaps give them room.

   B The gaps let rain water run away.

   C The rails get shorter when hot, so the gaps stop them pulling apart.

   Answer at the back of the book.

2. A metal lid is stuck on a glass jar. A grown up pours hot water over the lid. Why does the lid come loose?

   A The hot lid contracts and grips the jar.

   B The water dissolves the lid.

   C The hot lid expands, so it fits more loosely.

   Answer at the back of the book.

3. A steel rail 10 m long grows 6 mm when it warms by 50 °C. How much does a rail 50 m long grow in the same warming?

   A 6 mm

   B 300 mm

   C 30 mm

   Answer at the back of the book.

4. Two steel rails, each 10 m long, meet at a gap. Their far ends are fixed. On a hot day each rail grows 6 mm toward the gap. How wide must the gap be, at the least, so that the rails do not touch?

   A 12 mm

   B 6 mm

   C 12 m

   Answer at the back of the book.

5. Why do power cables hang lower on a hot day?

   A The cables get heavier in the heat.

   B The cables expand, so they are longer and sag more.

   C The poles lean over in the heat.

   Answer at the back of the book.

6. **From an earlier chapter**

   Sealed air in a box is heated. What happens to its pressure?

   A It goes down, because the particles are further apart.

   B It stays the same.

   C It goes up, because faster particles hit the walls harder and more often.

   Answer at the back of the book.

KEEP IT

Copy this into your exercise book.

Heating gives particles energy. They move further apart, so the material expands. The particles stay the same size. Cooling makes it contract. Gaps give rails room to grow.

Draw: Draw two rails with a wide gap and cold circles touching. Draw them hot, with circles further apart and a smaller gap.

S3.5.7 CHAPTER 7

Dissolving and solutions

Where does the salt go when I stir it into water, and does the cup weigh less?

YOUR GUESS

Pick one before you read on. It is fine to be wrong.

- ☐ **A** The salt is still there, spread through the water, so the total weighs the same.
- ☐ **B** The salt is destroyed, so the cup weighs less.
- ☐ **C** The salt melts into the water, because stirring warms it up.

IF THIS FEELS HARD, READ THIS FIRST

- Level 3, Particles, S3.5.2. Sugar spreading through water is there.
- Level 3, Particles, S3.5.4. Warmer particles move faster, and a fair test changes one thing.

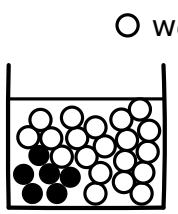
BY THE END YOU CAN

- Use the words solute, solvent and solution correctly
- Test how warm water and stirring change how fast sugar dissolves
- Explain why mass stays the same when salt dissolves

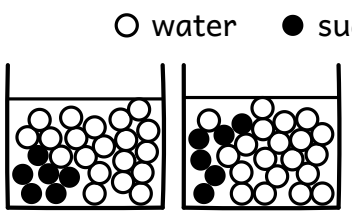
Sugar disappears when you stir it into tea. Salt disappears in soup. Where do they go? Does the cup weigh less afterwards?

DRAW IT FIRST

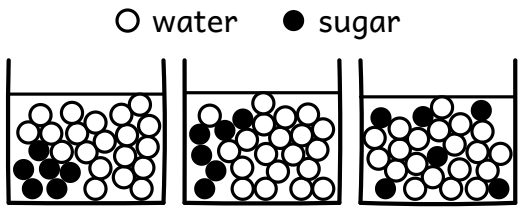
Draw sugar mixing into water



1 Draw a cup of water with open circles. Put the sugar, dark dots, in a lump at the bottom.



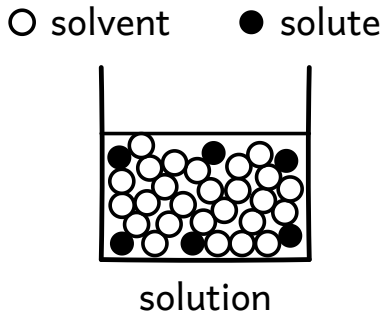
2 Draw it again a little later. The water particles pull some dark dots away from the lump.



3 Draw it later still. The dark dots are mixed through the water.

Water particles pull on the sugar particles and drag them away from the lump. The sugar particles spread out among the water particles. They are too small to see, so the water stays clear.

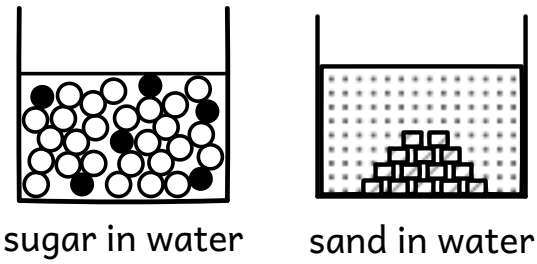
When a solid mixes into a liquid and can no longer be seen, we say it **dissolves**. The solid that dissolves is the **solute**. The liquid that does the dissolving is the **solvent**. Together they make a **solution**.



Salt in water. The water is the solvent. The salt is the solute. The mixture is the solution.

In salty water, the salt is the solute and the water is the solvent. The salty water is the solution. A solution is clear. You can see through it, though it may have a colour.

Not everything dissolves in water. Sand sinks to the bottom and stays as grains you can see, however long you stir. Sugar is **soluble** in water, which means it can dissolve. Sand is insoluble, which means it cannot.



Sugar spreads through the water as particles too small to see. Sand stays as grains at the bottom.

Dissolving is not melting. Melting is a solid turning into a liquid when it is heated. Dissolving is a solid mixing into a liquid, and it needs no heat.

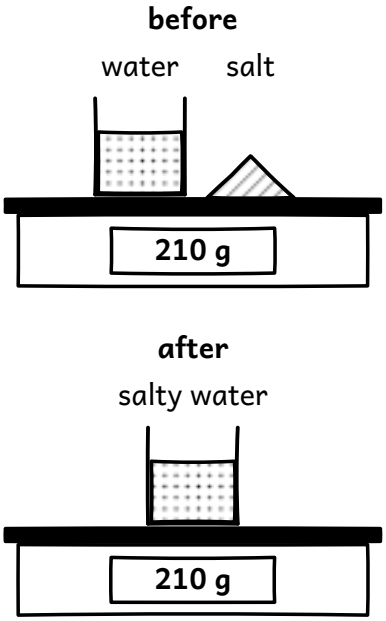
Nothing is lost when a solid dissolves. The sugar particles are still in the cup. So the mass of the solution is the mass of the water plus the mass of the solute. Mass is how much matter something has, and we measure it in grams.

SEE IT THREE WAYS

With things

Put a cup of water and a heap of salt on a kitchen scale. Read the scale. Then stir the salt into the water, and read the scale again.

As a picture



In words

The salt is still in the cup, spread through the water. Nothing has been lost, so the scale shows the same mass.

In symbols

200 g + 10 g = 210 g

Three things make a solid dissolve faster. Warm the water, so the particles move faster. Stir, so fresh water reaches the solid. Use smaller pieces, such as grains instead of a lump, so more of the solid touches the water.

Water can only hold so much. Keep adding salt, and at last some stays on the bottom.

TRY IT

Race the sugar

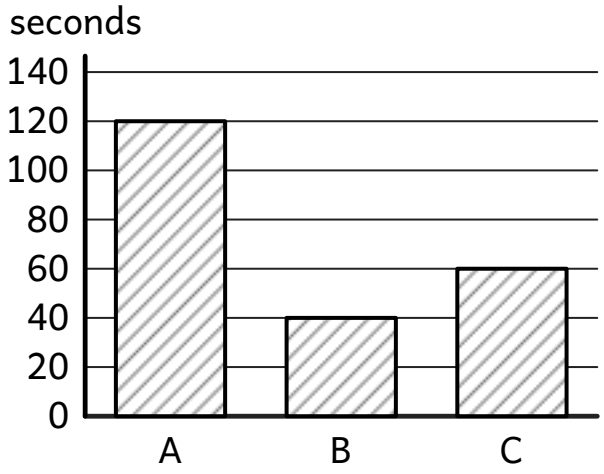
You need: 3 clear cups, sugar, a spoon, cold water, warm water from a grown up, a clock, or a way to count seconds.

Be safe: A grown up must pour the warm water. Use warm water, never boiling. Do not taste anything.

1. Pour the same amount of water into three cups. Cups A and B get cold water. Cup C gets warm water poured by a grown up.
2. Add one level spoon of sugar to each cup at the same moment. Stir cup B only, gently and steadily.
3. Count the seconds until no sugar can be seen in each cup. Cup A can take several minutes. Write the three times down.

What you will see: The sugar in cups B and C disappears much sooner than in cup A. Your times will differ, but the pattern will be the same. Warmth and stirring both speed up dissolving.

If you cannot try it, this is what happens.



A WRONG IDEA MANY PEOPLE HAVE

~~Dissolving is the same as melting.~~

Why it feels right: Both turn a solid into something runny, and warmth helps both.

The test that breaks it: Salt melts at 801 °C, far hotter than any cup of water. Yet salt dissolves in cold water. Leave salty water in the sun. The water goes into the air, and the salt is left behind.

What is true: Melting is a solid turning into a liquid when it is heated. Dissolving is a solid mixing into a liquid, with its particles spread among the liquid particles.

KEY WORDS

dissolves
mixes into a liquid so completely that it cannot be seen.

solute
the solid that dissolves.

solvent
the liquid that does the dissolving.

solution
the clear mixture of a solute dissolved in a solvent.

soluble
able to dissolve in a liquid.

BACK TO YOUR GUESS

The answer is A: The salt is still there, spread through the water, so the total weighs the same.

The salt particles are still in the cup, mixed among the water particles. Nothing is lost, so the mass is the same.

CHECK YOURSELF

Try each one before you look. A wrong answer tells you where to go next.

1. Salt is stirred into water until it has dissolved. Which names are right?

   A The water is the solute, because there is more of it. The salt is the solvent.

   B The salt is the solute. The water is the solvent. The salty water is the solution.

   C The salt is the solute. The water is the solution.

   Answer at the back of the book.

2. A cup of water has a mass of 200 g. You stir in 10 g of salt until it dissolves. What mass does the scale show now?

   A 210 g

   B 200 g

   C 190 g

   Answer at the back of the book.

3. A cup of salty water has a mass of 250 g. It holds 20 g of dissolved salt. What was the mass of the cup of water before the salt went in?

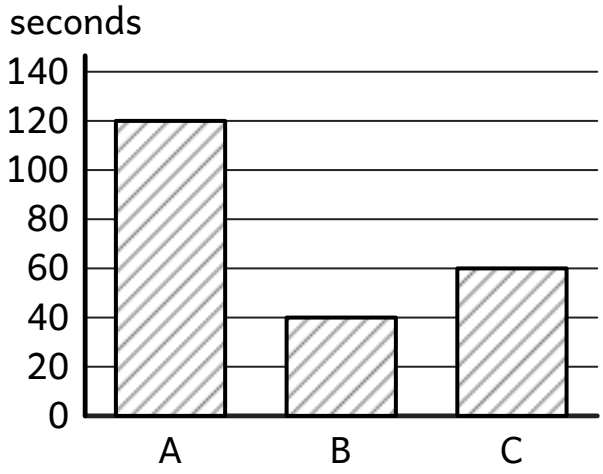
   A 250 g

   B 230 g

   C 270 g

   Answer at the back of the book.

4. The chart shows the seconds the sugar took to disappear. Cup A was cold and not stirred. Cup B was cold and stirred. How many seconds sooner did the sugar disappear in cup B?



A 40 seconds sooner

B 80 seconds sooner

C 120 seconds sooner

Answer at the back of the book.

5. Sand is stirred into water. It sinks to the bottom and stays as grains you can see, however long you stir. Is sand soluble or insoluble in water?

A Soluble. Sand is a solid, and solids dissolve in water.

B Soluble. It mixes into the water when you stir it.

C Insoluble. The grains stay as grains and sink.

Answer at the back of the book.

6. **From an earlier chapter**

Why does sugar dissolve faster in warm water than in cold water?

A Warm particles move faster, so they pull sugar apart and spread it sooner.

B Warm water has more water particles in it.

C The sugar melts in warm water.

Answer at the back of the book.

KEEP IT

Copy this into your exercise book.

A solute dissolves in a solvent to make a solution. Its particles spread among the solvent particles. Nothing is lost, so the mass stays the same. Warm water and stirring dissolve faster.

Draw: Draw a cup of water with sugar in a lump. Draw it again with the dark dots spread through the water.

S3.5.8 CHAPTER 8

Density

Why does oil float on water, and why does a stone sink?

YOUR GUESS

Pick one before you read on. It is fine to be wrong.

- ☐ **A** Heavy things sink and light things float.
- ☐ **B** A thing floats when it packs less mass into each cm^3 than the liquid does.
- ☐ **C** Big things float and small things sink.

IF THIS FEELS HARD, READ THIS FIRST

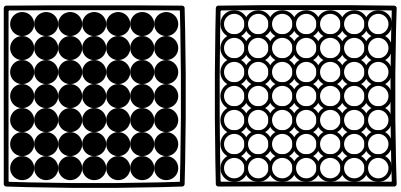
- Level 3, Particles, S3.5.1. Particles in a gas are far apart. In a solid they touch.
- Level 3, Particles, S3.5.7. Mass is how much matter there is, and it stays the same.

BY THE END YOU CAN

- Explain density as how much mass is packed into a space
- Explain why oil floats on water and a stone sinks
- Calculate density from mass and volume

A stone sinks in water, but a big log floats. A little oil floats on water. So heavy things do not always sink. What decides it?

The **mass** of a thing is how much matter it holds. Its **volume** is the space it takes up. We measure mass in grams, and volume in cubic centimetres, written cm^3. A cm^3 is the space of a cube 1 cm wide.



heavy light

The same space and the same number of particles. The box of heavy particles holds more mass.

Both boxes take up the same space. The box of heavy particles holds more mass in that space. We say it is more dense.

The same volume of different materials can have very different masses. 1 cm^3 of water has a mass of 1 g. 1 cm^3 of iron has a mass of about 8 g.

Density tells you the mass in each cm^3. A dense material packs a lot of mass into a small space.

SEE IT THREE WAYS

With things

Fill one cup with dry sand and an identical cup with cotton wool. Lift them. The cup of sand is far heavier. Sand is denser than cotton wool.

As a picture

material	g/cm³
air	0.001
cork	0.2
pine	0.5
cooking oil	0.9
water	1
stone	2.7
iron	7.8
gold	19

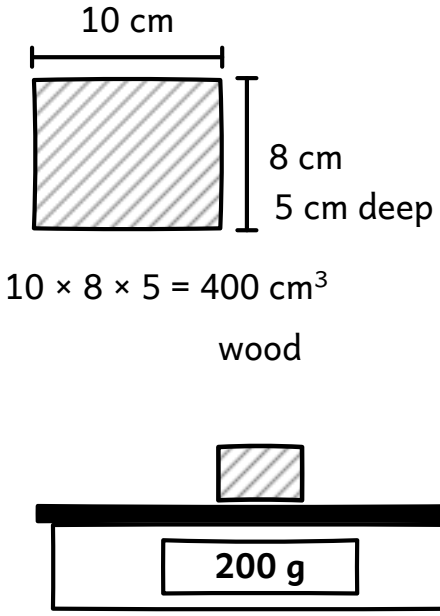
In words

A dense material has a lot of mass in each cm^3. A material with a low density has little. The table shows about how many grams are in 1 cm^3. Real samples differ a little.

In symbols

density = mass ÷ volume. The unit is g/cm^3.

Heavier particles make a material denser. A gas has very few particles in each cm^3, because they are far apart. So a gas has a very low density. Water is hundreds of times denser than air. Cotton wool and cork are light because they hold pockets of air.



A block of wood. Its volume is 10 × 8 × 5 = 400 cm^3, and its mass is 200 g.

To find a density, divide the mass by the volume. Here is a worked example with this block.

WORKED EXAMPLE

A block of wood has a mass of 200 g and a volume of 400 cm^3. What is its density?

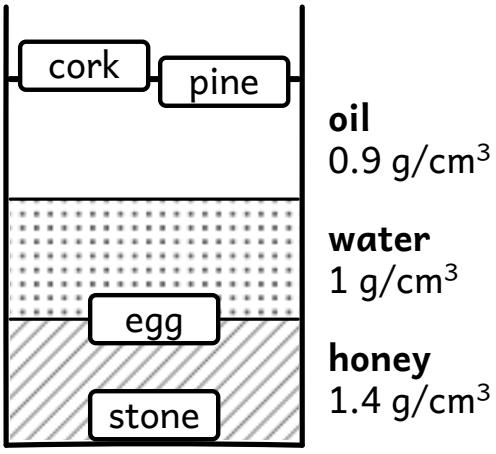
1. Write the rule: density = mass ÷ volume.
2. Put in the numbers: 200 ÷ 400.
3. 200 ÷ 400 = 0.5.

Answer: 0.5 g/cm^3. This is less than the density of water, so the block floats.

Now the rule for floating. A thing floats in a liquid if it is less dense than the liquid. It sinks if it is denser. If the two are equal, it stays wherever you put it, neither rising nor sinking.

Oil floats on water because oil is less dense than water. Oil and water do not mix, so they stay in two layers. A ship is mostly air inside, so the whole ship is less dense than water. That is why it floats.

Most woods float, but a few very dense woods, such as ebony, sink. Most metals are denser than water, so a lump of iron sinks. Always compare the density of the thing with the density of the liquid.

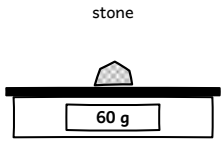


The densest liquid is at the bottom. Each thing rests on the first layer that is denser than it.

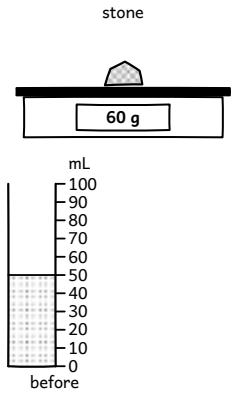
How do you find the volume of a stone? A stone pushes water out of its way. We say it **displaces** water. The water level rises by exactly the volume of the stone. Remember that 1 mL is the same as 1 cm^3.

DRAW IT FIRST

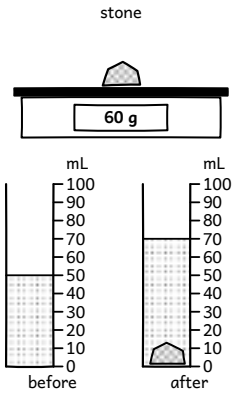
Find the density of *a* stone



1 Put the stone on *a* scale. Read its mass in grams.



2 Pour water into *a* measuring cylinder. Read the level in mL.



3 Lower the stone in. Read the new level. The rise in the level is the volume of the stone.

Take the first level from the second to get the volume. Then divide the mass by the volume to get the density.

TRY IT

Sink or float

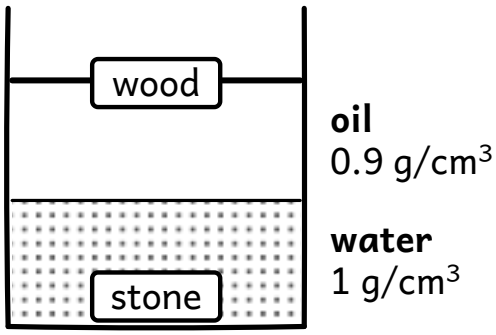
You need: *a* bowl of water, *a* stone, *a* piece of wood or cork, *a* spoon of cooking oil.

Be safe: Wipe up spilled oil, because it is slippery. Do not drink the water.

1. Write down which of the stone and the wood you think will float.
2. Put each into the water, one at *a* time. See which float and which sink.
3. Pour the spoon of oil onto the water. Watch where the oil goes.

What you will see: The stone sinks. The wood floats. The oil spreads in *a* thin layer on top of the water and stays there. The picture draws the oil layer thicker so that you can see it.

If you cannot try it, this is what happens.



A WRONG IDEA MANY PEOPLE HAVE

~~Heavy things sink and light things float.~~

Why it feels right: A stone is heavy and sinks. A feather is light and floats.

The test that breaks it: A big log floats on *a* river. A tiny steel pin sinks in *a* cup. The log has far more mass than the pin.

What is true: Mass alone does not decide it. What counts is density, the mass in each cm^3. A thing less dense than the liquid floats. A denser thing sinks.

KEY WORDS

mass
how much matter a thing holds. We measure it in grams.

volume
the space a thing takes up. We measure it in cm^3 or mL.

density
the mass in each cm^3: mass ÷ volume.

displaces
pushes water out of its way, so the level rises by the volume of the thing.

BACK TO YOUR GUESS

The answer is B: A thing floats when it packs less mass into each cm^3 than the liquid does.

What counts is how much mass is packed into each cm^3. That is density. A thing less dense than the liquid floats. A denser thing sinks.

CHECK YOURSELF

Try each one before you look. A wrong answer tells you where to go next.

1. A lump of metal has a mass of 800 g and a volume of 100 cm^3. What is its density?

   A 0.125 g/cm^3

   B 80000 g/cm^3

   C 8 g/cm^3

   Answer at the back of the book.

2. A block has a mass of 90 g and a volume of 100 cm^3. Water has a density of 1 g/cm^3. Does the block float on water?

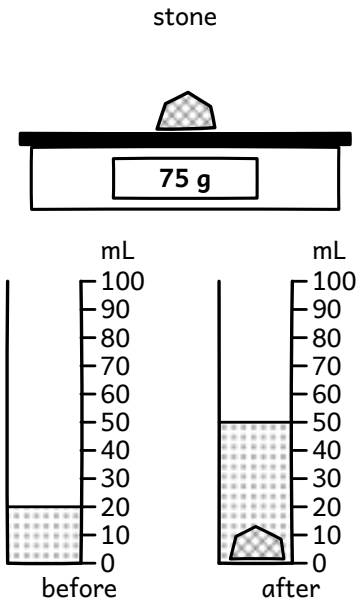
   A No. A mass of 90 g is heavy, so the block sinks.

   B No. The block is bigger than a drop of water, so it sinks.

   C Yes. Its density is 0.9 g/cm^3, which is less than 1 g/cm^3.

   Answer at the back of the book.

3. A stone is put on a scale. Then it goes into a measuring cylinder of water. Use the pictures to find the density of the stone.



A 2.5 g/cm^3

B 1.5 g/cm^3

C 3.75 g/cm^3

Answer at the back of the book.

4. Why does oil float on water?

A Oil is lighter than water, whatever the amount.

B Oil particles are smaller than water particles.

C Oil is less dense than water.

Answer at the back of the book.

5. Why does a big log float while a tiny steel pin sinks?

A Big things float and small things sink.

B The log has less mass than the pin.

C The wood is less dense than water, but the steel is denser than water.

Answer at the back of the book.

6. **From an earlier chapter**

A cup of water has a mass of 300 g. You stir in 20 g of sugar until it dissolves. What mass does a scale show now?

A 300 g

B 320 g

C 280 g

Answer at the back of the book.

KEEP IT

Copy this into your exercise book.

Density is mass divided by volume, in g/cm³. A thing floats if it is less dense than the liquid and sinks if it is denser. Water is about 1 g/cm³.

Draw: Draw a jar with oil on top, water in the middle and honey below. Put a cork at the top and a stone at the bottom.

Key words, A to Z

Every key word in this book, what it means, and the chapter that teaches it.

boiling point
the temperature at which a liquid boils, with bubbles of gas all through it. S3.5.3

change of state
a material turning from a solid, liquid or gas into another of the three. S3.5.3

compress
squeeze into a smaller volume. S3.5.5

contract
get smaller when cooled, because the particles move closer together. S3.5.6

density
the mass in each cm^3: mass ÷ volume. S3.5.8

diffusion
particles spreading out by themselves, from where there are many to where there are few. S3.5.2

displaces
pushes water out of its way, so the level rises by the volume of the thing. S3.5.8

dissolves
mixes into a liquid so completely that the particles cannot be seen. S3.5.2, S3.5.7

energy
what makes particles move. More energy means faster particles. S3.5.3

evidence
what we see or measure that supports an idea. S3.5.2

expand
get bigger when heated, because the particles move further apart. S3.5.6

fair test
a test that changes only one thing and keeps everything else the same. S3.5.4

flow
move along because the particles slide past each other. S3.5.1

mass
how much matter a thing holds. We measure it in grams. S3.5.8

melting point

the temperature at which a solid melts. It is also where the liquid freezes. S3.5.3

particle model
a picture that shows particles as circles and explains how matter behaves. S3.5.1

particles
the tiny bits that everything is made of. S3.5.1

pressure
the push of a gas on the walls of its container. It comes from particles hitting the walls. S3.5.5

soluble
able to dissolve in a liquid. S3.5.7

solute
the solid that dissolves. S3.5.7

solution
the clear mixture of a solute dissolved in a solvent. S3.5.7

solvent
the liquid that does the dissolving. S3.5.7

temperature
how hot something is. The hotter it is, the faster its particles move. S3.5.4

vibrate
shake to and fro in a tiny space. S3.5.1

volume
the space a thing takes up. S3.5.5, S3.5.8

Answers

S3.5.1. The particle model

1. **Gas**

   The particles of a gas are far apart. Almost nothing holds them, so they fly about and fill the container.

   - **If you chose A:** In a solid the particles touch and are held in place. Go to S3.5.1.
   - **If you chose C:** In a liquid the particles touch. They slide past each other, but they stay close. Go to S3.5.1.

2. **The particles of water slide past each other. The particles of a stone are held in place.**

   Sliding particles let a liquid flow. Particles held in place keep a solid in its shape.

   - **If you chose A:** The particles are the same in every state. Their size does not explain pouring. How they are held does. Go to S3.5.1.
   - **If you chose B:** In a liquid the particles do touch. They are free to slide, and that lets it pour. Go to S3.5.1.

3. **Nothing at all. It is empty space.**

   The particles of a gas are far apart. The space between them has nothing in it.

   - **If you chose A:** The particles are the gas itself. Between them there is empty space. Go to S3.5.1.
   - **If you chose C:** A gas is not a liquid. Its particles are far apart with nothing between them. Go to S3.5.1.

4. **They vibrate in place. They cannot move around, but they never stand still.**

   Held in place does not mean still. Each particle shakes to and fro where it is.

   - **If you chose B:** The particles of a solid vibrate. You feel this as warmth, and it grows when the solid is heated. Go to S3.5.1.
   - **If you chose C:** Gas particles fly about freely. Solid particles only vibrate in place. Go to S3.5.1.

5. **Six circles far apart, spread through the whole box.**

   The particles of a gas are far apart and fill the box. The empty space between them stays empty.

   - **If you chose B:** That is how a solid is drawn. The particles of a gas are far apart. Go to S3.5.1.
   - **If you chose C:** That is how a liquid is drawn. A gas spreads out to fill the whole box. Go to S3.5.1.

S3.5.2. Evidence for particles

1. **Perfume particles fly about, bump into air particles and spread through the room.**

   The particles spread out. Air currents help, and diffusion alone is slower, but it needs no wind.

   - **If you chose A:** The particles zigzag as they bump into air particles. They spread out, and nothing pushes them in a line. Go to S3.5.2.
   - **If you chose B:** Wind helps, but particles spread by themselves, even in still air. Go to S3.5.2.

2. **The sugar breaks into particles too small to see, and they spread through the water.**

   The sugar dissolves. Its particles are mixed among the water particles, so the water stays clear.

   - **If you chose A:** The sugar does not change into water. Its particles are still sugar, spread through the water. Go to S3.5.2.
   - **If you chose C:** Nothing is destroyed. Leave the water to dry and the sugar is still there. Go to S3.5.2.

3. **9 particles in all**

   Add the air particles and the smell particles. 6 + 3 = 9.

   - **If you chose B:** A smell is made of particles too. Count the dark dots as well as the open circles. Go to S3.5.2.
   - **If you chose C:** The air is made of particles too. Count the open circles as well as the dark dots. Go to S3.5.2.

4. **70 seconds longer**

   The smell took longer to reach the far end. 90 − 20 = 70.

   - **If you chose B:** That is the far friend's whole time. The question asks how much longer than the near friend. Go to S3.5.2.
   - **If you chose C:** To find how much longer, take the shorter time away. Do not add the times. Go to S3.5.2.

5. **Leave the salty water in a dish in the sun. The water dries away, and white salt is left.**

   The water goes into the air as a gas, and the salt particles stay behind. That shows the salt was dissolved, not destroyed.

   - **If you chose A:** The salt has not gone. Its particles are still in the water, so nothing has been lost. Go to S3.5.2.
   - **If you chose C:** Salt does not turn into water. It dissolves, and its particles are spread among the water particles. Go to S3.5.2.

6. **Liquid**

   In a liquid the particles touch, but they are free to slide. That is why a liquid flows.

   - **If you chose A:** In a solid the particles touch but are held in place. Go to S3.5.1.
   - **If you chose C:** In a gas the particles are far apart. Go to S3.5.1.

S3.5.3. Changes of state

1. **They gain energy and break free of their fixed places.**

   Heat gives the particles energy. They vibrate harder until they slide free, and the solid is a liquid.

   - **If you chose A:** The particles stay the same size. Only their energy and the way they are held change. Go to S3.5.3.
   - **If you chose C:** Heating makes particles move more, not less. Go to S3.5.3.

2. **The water is boiling.**

   Boiling makes bubbles all through the liquid, at the boiling point. Evaporation happens at the surface, at any lower temperature.

   - **If you chose B:** Evaporation happens only at the surface. Bubbles all through the water mean it is boiling. Go to S2.4.4.
   - **If you chose C:** Melting turns a solid into a liquid. This water is already a liquid. Go to S3.5.3.

3. **A solid. 20 °C is below the melting point of 1538 °C.**

   Room temperature is far below the melting point, so the iron is a solid. It would need 1538 °C to melt.

   - **If you chose A:** Zero degrees is the melting point of water. Iron has its own melting point, and it is much higher. Go to S3.5.3.
   - **If you chose B:** Metals do not melt easily. Iron needs 1538 °C to melt, and a room is far cooler than that. Go to S3.5.3.

4. **A gas. 20 °C is above the boiling point of −183 °C.**

   20 °C is above the boiling point, so the particles have broken free of each other. Oxygen is a gas.

   - **If you chose A:** It has melted, but it is also far above its boiling point of −183 °C. So it has boiled and is a gas. Go to S3.5.3.
   - **If you chose C:** A solid melts when it gets warmer than its melting point. At 20 °C oxygen is far warmer than −219 °C. Go to S3.5.3.

5. **They lose energy, slow down and are pulled together.**

   The cold glass takes energy from the vapour. The particles slow down until they are held close together. That is a liquid, so the vapour condenses.

   - **If you chose A:** That is what happens when a liquid boils. Steam turning into drops is the opposite. Go to S3.5.3.
   - **If you chose B:** The particles stay water particles. Only their energy and the way they are held change. Go to S3.5.3.

6. **Diffusion**

   Diffusion is the spreading of particles by their own movement, such as a smell crossing a room.

   - **If you chose A:** Freezing is a liquid turning into a solid. Spreading out by themselves has another name. Go to S3.5.2.
   - **If you chose C:** Melting is a solid turning into a liquid. Spreading out by themselves has another name. Go to S3.5.2.

S3.5.4. Diffusion and temperature

1. **The particles move faster, so they spread out sooner.**

   Heat gives particles energy and they move faster. They knock the colour about harder and more often.

   - **If you chose A:** A cup of hot water and a cup of cold water hold about the same number of particles. What differs is how fast they move. Go to S3.5.4.
   - **If you chose B:** The colour particles do not change. It is the movement of the water particles that is different. Go to S3.5.4.

2. **4 times longer**

   Divide the longer time by the shorter time. 60 ÷ 15 = 4.

   - **If you chose A:** You took the shorter time away. That gives how many minutes longer. To find how many times longer, divide. Go to S3.5.4.
   - **If you chose B:** Adding the two times does not compare them. Divide the longer time by the shorter time. Go to S3.5.4.

3. **The amounts of water are different, so the test is not fair.**

   A fair test changes only the temperature. The amount of water, and the colour, must be the same in both cups.

   - **If you chose B:** The temperature should be the only thing that changes. The amount of water must stay the same. Go to S3.5.4.
   - **If you chose C:** Stirring would add another change. In a fair test only one thing changes. Go to S3.5.4.

4. **How fast they move, on average.**

   The hotter a material is, the faster its particles move, on average.

   - **If you chose A:** The size of particles does not change with temperature. Go to S3.5.4.
   - **If you chose B:** Heating a material does not add particles. It makes them move faster. Go to S3.5.4.

5. **Cold particles still move, only more slowly, so the colour spreads more slowly.**

   Temperature tells how fast the particles move, on average. Cold particles move slowly but never stand still.

   - **If you chose A:** If the particles stood still, the colour could not spread at all. It does spread, only slowly. Go to S3.5.4.
   - **If you chose C:** Cold water is not thicker in a way that stops the particles. They move, but more slowly than in hot water. Go to S3.5.4.

6. **Evaporation**

   A few particles at the surface have more energy than the rest, and they escape as a gas. This can happen at any temperature.

   - **If you chose B:** Boiling makes bubbles all through the liquid, and only at the boiling point. Go to S3.5.3.
   - **If you chose C:** Melting turns a solid into a liquid. Here the liquid is turning into a gas. Go to S3.5.3.

S3.5.5. Gas pressure

1. **Gas particles hitting the walls.**

   Each hit is a tiny push. More hits every second than anyone could count make a steady pressure.

   - **If you chose A:** A gas pushes on every wall, not only the bottom. It is not the weight. It is the hits. Go to S3.5.5.
   - **If you chose C:** The particles do not stick. They hit the wall and bounce away. Go to S3.5.5.

2. **2 more hits**

   Subtract the hits in the cool box from the hits in the hot box. 6 − 4 = 2. The hot gas also hits harder.

   - **If you chose A:** You added the two numbers. To find how many more, take the smaller number from the larger. Go to S3.5.5.
   - **If you chose B:** That is the number of hits in the hot box on its own. Compare it with the cool box. Go to S3.5.5.

3. **The air inside is warmer, so its particles hit the inside harder and more often.**

   Warm particles move faster. Faster particles hit the wall harder and more often, so the pressure rises.

   - **If you chose B:** The air does not get heavier. Its particles move faster, so they hit the walls harder and more often. Go to S3.5.5.
   - **If you chose C:** The ball is sealed. The same air is inside. It is the particles that move faster. Go to S3.5.5.

4. **It goes up, because the particles hit the walls more often.**

   The same particles now have less room. They reach a wall sooner and hit it more often.

   - **If you chose A:** Closer together means more hits on the walls, not fewer. The pressure goes up. Go to S3.5.5.
   - **If you chose C:** The same particles in a smaller space hit the walls more often. The pressure changes. Go to S3.5.5.

5. **One.**

   A fair test changes one thing and keeps everything else the same.

   - **If you chose A:** Then you could not tell which change made the difference. Go to S3.5.4.
   - **If you chose C:** You change one thing, so you can see what it does. Go to S3.5.4.

6. **The gas inside gets hot. Its particles hit the walls harder and more often, and the pressure rises until the can bursts.**

   Heat gives the particles energy. More energy means harder hits. A sealed can has no way to let the gas out.

   - **If you chose B:** Heating does not make the gas heavier. It makes the particles move faster, and a gas pushes on every wall. Go to S3.5.5.
   - **If you chose C:** The particles stay the same size. They move faster, so they hit the walls harder and more often. Go to S3.5.5.

S3.5.6. Expanding and shrinking

1. **The rails grow longer when hot, and the gaps give them room.**

   Heat makes the particles vibrate harder and sit further apart. The rails expand and need room.

   - **If you chose B:** Rain is not the reason. The gaps are for the rails to grow into when they are hot. Go to S3.5.6.
   - **If you chose C:** Heat makes things expand, not shrink. The gaps give the rails room to grow. Go to S3.5.6.

2. **The hot lid expands, so it fits more loosely.**

   The metal warms first. Its particles move further apart, so the lid is a little wider.

   - **If you chose A:** Heat makes a lid expand, not contract. Cooling makes it contract. Go to S3.5.6.
   - **If you chose B:** Metal does not dissolve in water. The lid only gets a little bigger. Go to S3.5.6.

3. **30 mm**

   The rail is 5 times as long, so it grows 5 times as much. 6 × 5 = 30.

   - **If you chose A:** That is the growth of the 10 m rail. A longer rail has more particles in a row, so it grows more. Go to S3.5.6.
   - **If you chose B:** You multiplied by the length. The rail is 5 times as long, so it grows 5 times as much. Go to S3.5.6.

4. **12 mm**

   Each rail grows 6 mm, and there are two rails. 6 + 6 = 12. The gap must be at least that wide.

   - **If you chose B:** You counted only one rail. There are two, and each one grows toward the gap. Go to S3.5.6.
   - **If you chose C:** The growth is in millimetres, not metres. The rails grow by a few millimetres only. Go to S3.5.6.

5. **The cables expand, so they are longer and sag more.**

   A longer cable between two fixed poles has to hang lower. Bridges have gaps for the same reason: they give the road room to grow.

   - **If you chose A:** The cables do not gain any matter. They expand, so they get longer. Go to S3.5.6.
   - **If you chose C:** The poles stay put. It is the cables that get longer when they are hot. Go to S3.5.6.

6. **It goes up, because faster particles hit the walls harder and more often.**

   Heat gives the particles energy, so they move faster. Each hit is harder, and there are more hits.

   - **If you chose A:** The box is sealed, so the particles are no further apart. They move faster, so the pressure rises. Go to S3.5.5.
   - **If you chose B:** Faster particles hit harder and more often. The pressure changes. Go to S3.5.5.

S3.5.7. Dissolving and solutions

1. **The salt is the solute. The water is the solvent. The salty water is the solution.**

   The solute is the solid that dissolves. The solvent is the liquid that does the dissolving. Together they make the solution.

   - **If you chose A:** The solute is the solid that dissolves, however little of it there is. The liquid that does the dissolving is the solvent. Go to S3.5.7.
   - **If you chose C:** The water alone is the solvent. The solution is the whole mixture of salt and water together. Go to S3.5.7.

2. **210 g**

   Nothing is lost when salt dissolves. Add the two masses. 200 + 10 = 210.

   - **If you chose B:** The salt is not gone. Its particles are still in the cup, so their mass counts. Go to S3.5.7.
   - **If you chose C:** Dissolving does not take mass away. The salt is still there, spread through the water. Go to S3.5.7.

3. **230 g**

   The mass of the solution is the water plus the salt. So take the salt away from the whole mass. 250 − 20 = 230.

   - **If you chose A:** The 20 g of salt is part of the total. Take it away to find the water alone. Go to S3.5.7.
   - **If you chose C:** You added the salt. The total already holds the salt, so take it away. Go to S3.5.7.

4. **80 seconds sooner**

   Stirring brings fresh water to the sugar. Take the shorter time from the longer time. 120 − 40 = 80.

   - **If you chose A:** That is the time for cup B on its own. The question asks how much sooner than cup A, so take it away from the time for A. Go to S3.5.7.
   - **If you chose C:** That is the time for cup A on its own. Compare the two cups: take the shorter time from the longer. Go to S3.5.7.

5. **Insoluble. The grains stay as grains and sink.**

   The water particles cannot pull sand apart. The grains stay as they are, and sink.

   - **If you chose A:** Not every solid dissolves. A soluble solid disappears and leaves a clear solution. Sand does not. Go to S3.5.7.
   - **If you chose B:** Stirring only moves the grains about. They settle again, so they have not dissolved. Go to S3.5.7.

6. **Warm particles move faster, so they pull sugar apart and spread it sooner.**

   Faster particles hit the sugar harder and more often, and they carry it away sooner.

   - **If you chose B:** Warm and cold water in a cup hold about the same number of particles. Warm particles move faster. Go to S3.5.4.
   - **If you chose C:** Sugar is not melting. It is dissolving, and warmth only makes the particles move faster. Go to S3.5.2.

S3.5.8. Density

1. **8 g/cm^3**

   Divide the mass by the volume. 800 ÷ 100 = 8.

   - **If you chose A:** You divided the volume by the mass. Density is the mass for each cm^3, so divide the mass by the volume. Go to S3.5.8.
   - **If you chose B:** You multiplied. Density is how much mass is in each cm^3, so you divide the mass by the volume. Go to S3.5.8.

2. **Yes. Its density is 0.9 g/cm^3, which is less than 1 g/cm^3.**

   90 ÷ 100 = 0.9. A thing less dense than the water floats.

   - **If you chose A:** Mass alone does not decide it. A big log has a lot of mass and floats. Work out the density and compare. Go to S3.5.8.
   - **If you chose B:** Size does not decide it. Compare the density of the block with the density of the water. Go to S3.5.8.

3. **2.5 g/cm^3**

   The water rose from 20 to 50, so the volume is 30 cm^3. The mass is 75 g. 75 ÷ 30 = 2.5. This is more than the density of water, so the stone sinks.

   - **If you chose B:** You used the water level after the stone went in as the volume. The volume of the stone is how far the level rose. Go to S3.5.8.
   - **If you chose C:** You used the water level before the stone went in as the volume. The volume of the stone is how far the level rose. Go to S3.5.8.

4. **Oil is less dense than water.**

   Each cm^3 of oil has less mass than each cm^3 of water. So the water stays under the oil.

   - **If you chose A:** A big bottle of oil has more mass than a spoon of water, yet it still floats. Compare equal volumes. That is density. Go to S3.5.8.
   - **If you chose B:** The size of the particles is not the rule. What counts is the mass in each cm^3. Go to S3.5.8.

5. **The wood is less dense than water, but the steel is denser than water.**

   Mass alone does not decide it. Each cm^3 of wood has less mass than a cm^3 of water. Each cm^3 of steel has more.

   - **If you chose A:** A big stone sinks in water. Size does not decide it. Density does. Go to S3.5.8.
   - **If you chose B:** The log has far more mass than the pin. It floats because it is less dense than water. Go to S3.5.8.

6. **320 g**

   Nothing is lost when sugar dissolves. Add the masses. 300 + 20 = 320.

   - **If you chose A:** The sugar is not gone. Its particles are still in the cup, so their mass counts. Go to S3.5.7.
   - **If you chose C:** Dissolving does not take mass away. The sugar is still there, spread through the water. Go to S3.5.7.

About this book

For learners who can read a page alone and use the four operations. In many schools this fits children of about 11 to 13, and older learners can use it too. Activities use water, cups, jars, stones, salt and sugar. Any heating, and any hot water, needs a grown up. A learner can work alone: every exercise has its answer and the reason for it.

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