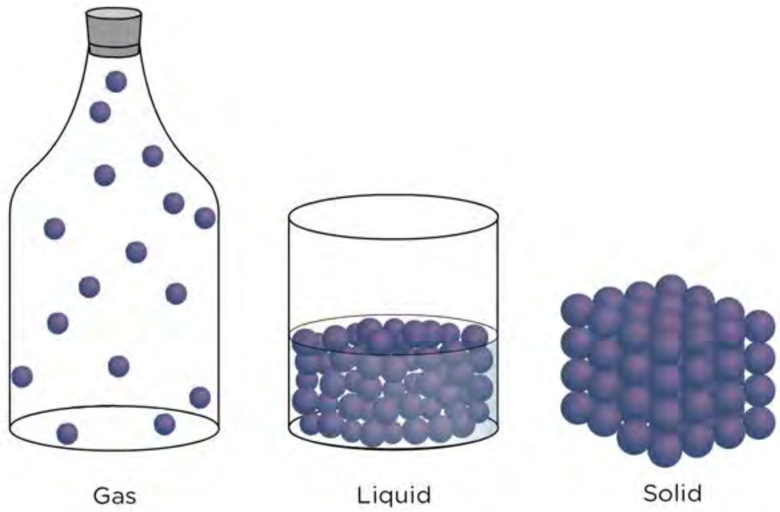
Particle model of matter

KEY QUESTIONS:

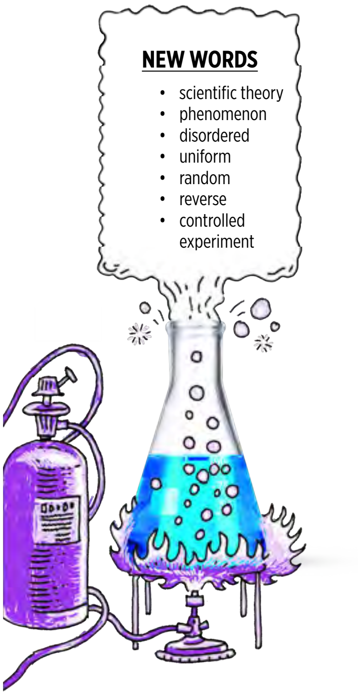
- What is the particle model of matter?
- How small are atoms and molecules?
- How does the particle model of matter describe solids, liquids and gases?
- How does the particle model of matter help us understand the process of diffusion?
- How can materials be made to change their state?
- How does the particle model of matter help us to understand changes of state in materials, such as melting, evaporation, condensation and freezing?
- How are density, mass and volume related to each other?
- How do the densities of solids, liquids and gases compare?
- Which aspects of the particles in a given material influence the density of that material?
- Why does oil float on water? Is this related to density?
- How can the particle model of matter help us to understand expansion and contraction?
- How does a gas exert pressure?
- Is the pressure a gas exerts related to the number of gas particles? If so, how?
- What happens to pressure when we change its volume and temperature?

Can you remember learning that matter can exist in three different states? What are the three states called?

Can you remember the properties of the different states of matter? Discuss this in your class. Look at the following diagram of the states of matter to help you. Remember to take some notes as you discuss in class.



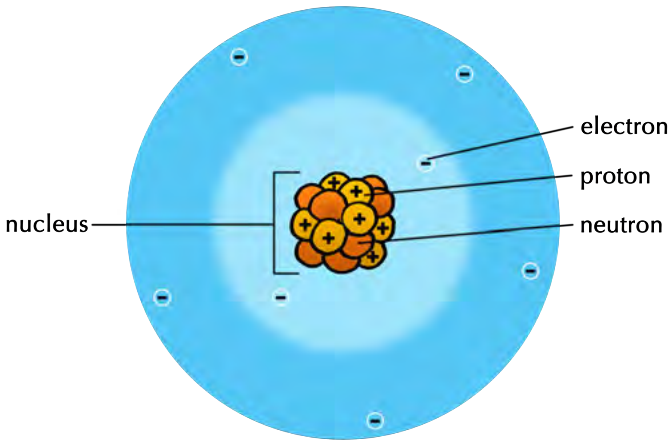
Each state of matter behaves differently and the particles in each state behave differently. This diagram compares the particles in a gas, a liquid and a solid.



In this chapter we are going to review what we know about solids, liquids and gases. We are going to learn about a scientific model that can be used to describe how the particles in all three states behave. This model is called the particle model of matter and it will help us understand much more about the properties of solids, liquids and gases. Let's get started!

2.1 What is the particle model of matter?

In the previous chapter we learnt that scientists use models when they want to describe things that are difficult to understand. We discussed a model of the atom that helped us to imagine what atoms look like.



This model of the atom shows us where the different sub-atomic particles can be found. The sub-atomic particles shown here are the proton, neutron and electron.

Theories are similar to models. They explain scientific **phenomena** (things and events that can be described and explained in scientific terms) using pictures and words.

TAKE NOTE

If you need to, turn back to chapter 1 to revise the terms atom, element, compound and molecule and how they relate.

What does the particle model of matter teach us?

The particle model describes matter in a very specific way. It describes four important aspects of matter:

- All matter is made up of particles that are incredibly small - much too small to see with the naked eye. The particles can be atoms or combinations of atoms that are bonded.
- There are forces between the particles.
- The particles in matter are always moving. The more energy they have, the faster they move.
- The spaces between the particles in matter are empty. You might assume that the spaces between particles are filled with air, but this is not the case. They contain nothing at all.

Why is the particle model of matter so useful?

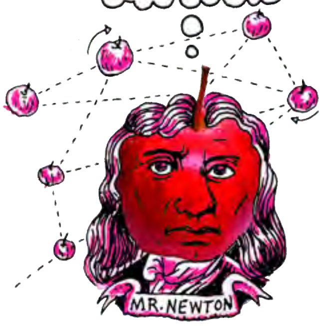
The particle model of matter is one of the most useful scientific models because it describes matter in all three states. Understanding how the particles of matter behave is vital if we hope to understand science!

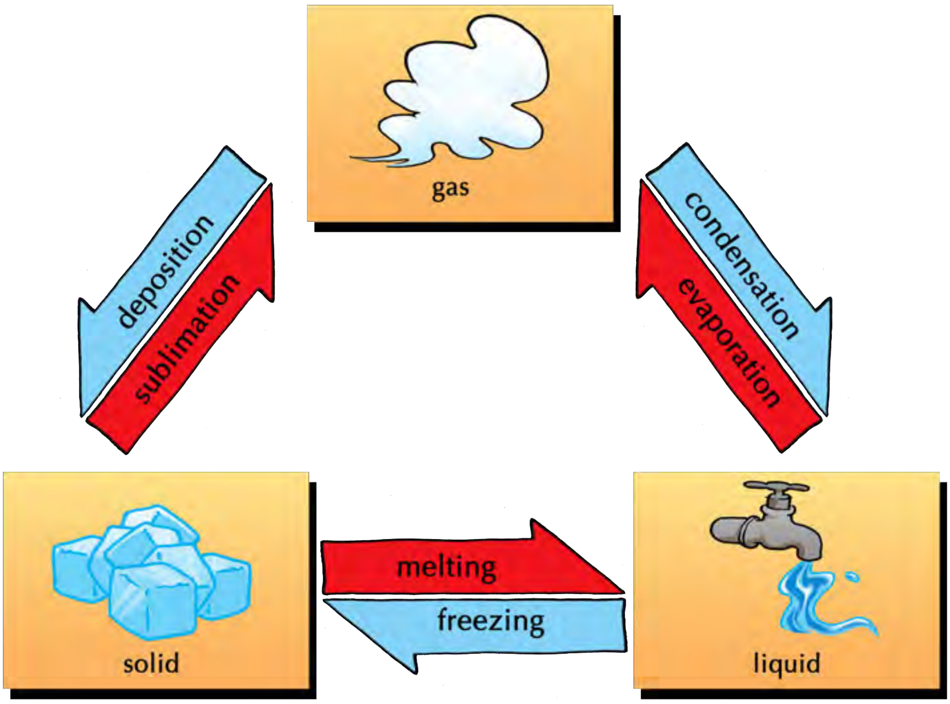
The model also helps us to understand what happens to the particles when matter changes from one state to another.

The following diagram shows different changes of state, as well as which processes are the **reverse** of each other. Melting and freezing are the reverse processes of each other and so are evaporation (boiling) and condensation.

DID YOU KNOW?

Under special circumstances, a solid can change directly into a gas without melting first. This process is known as **sublimation** and its reverse (when a gas changes directly into a solid without condensing first) is called **deposition**.





The change of states

ACTIVITY: Changes of state revision

INSTRUCTIONS:

1. Refer to the previous diagram.
2. Check that you remember some of the concepts you learnt about in previous grades by going through these quick questions.

QUESTIONS:

1. What is the name of the process when a solid turns into a liquid?

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2. What is the reverse process to melting?

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3. What can we do to make ice melt quickly?

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4. Explain the steps that a solid must go through to become a gas.

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5. What is the reverse process of evaporation?

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6. When we heat something, are we adding energy to it, or taking energy away?

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7. How do you think the particles in a substance behave when we give them more energy?

We will use the model to look at each of these changes more closely. But first, we will look at how the model describes each state of matter.

NEW WORDS

- compress
- collide
- diffuse
- rate
- constant motion
- observation
- forces of attraction
- regular arrangement
- vibrate

VISIT

This video shows us the different ways that particles behave in the solid, liquid and gaseous states.

bit.ly/13mAd4o

2.2 Solids, liquids and gases

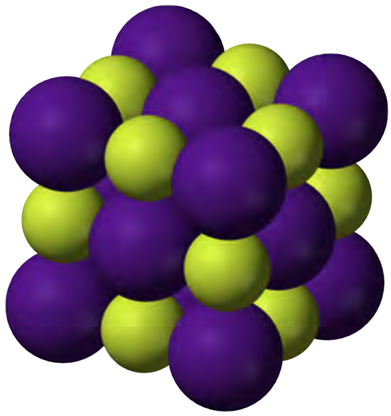
We can use the particle model to help us understand the behaviour of each of the states of matter. We are going to look at each state in turn.

There is one very important thing to remember when we consider the different states of matter. For any matter, the individual particles of that matter are exactly the same in all three states, solid, liquid and gas. It is the *behaviour* of the particles that changes in each state.

The solid state

Solids keep their shape and cannot be **compressed**. Let us see if the particle model can help us understand why solids behave in this way.

In a solid, the particles are packed close to each other in fixed positions. They are locked into place, and this explains why solids have a fixed shape. Look at the following images of sodium chloride (table salt). Do you remember the formula for sodium chloride?

Macroscopic view of sodium chloride	Submicroscopic view of sodium chloride
	
Table salt crystals are hard and have a fixed shape.	Can you see how the chloride atoms (purple) alternate with the sodium atoms (yellow) in a fixed arrangement?

Take a good look at the picture of the particles in a solid (table salt) above. You will see that they are packed in a ***regular* arrangement**. There are very small spaces between the particles in a solid.

Particles are held together by **forces of attraction**. In solids, these forces are strong enough to hold the particles firmly in position.

Does that mean the particles in a solid do not move at all? No. The particles in a solid move a little bit. They **vibrate** in their fixed positions. The more energy the particles have, the faster and more strongly they vibrate.

Do you see how we have used the particle model of matter to explain the properties of solids that we can **observe**? For example, the particles in solids are closely packed and have strong forces between them explains why solids have a fixed shape and you cannot compress them.

The liquid state

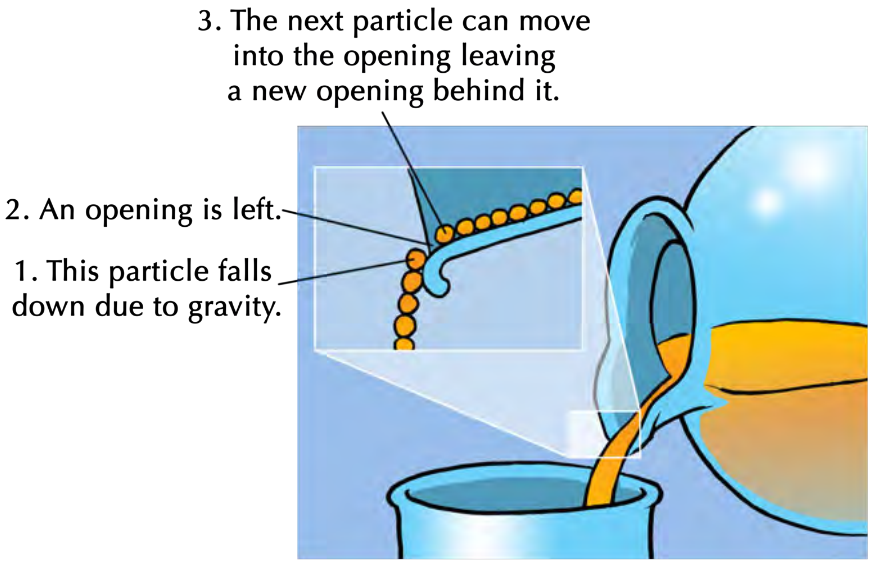
An important characteristic of liquids is that they flow. They fill containers they are poured into. Liquids are also not very compressible. How can these properties be explained?

In the liquid state, particles do not have fixed positions. They move about freely, but they stay close together because the forces of attraction between them are quite strong, but not as strong as in solids.

Have you noticed how a liquid always takes the shape of the container it is in? Within the liquid, the particles slip and slide past each other. This is why liquid flows. Their particles are free to move around, filling the spaces left by other particles. Look at the image of the juice being poured. Let's zoom in and have a look at what the particles are doing as the juice is poured.

Orange juice is a liquid, which can be poured.

The particles in a liquid have small spaces between them, but not as small as in solids. The particles in a liquid are loosely arranged which means they do not have a fixed shape like solids, but they rather take the shape of the container they are in.



The speed at which the particles move around inside the liquid depends on the energy of the particles. When we heat a liquid, we are giving the particles more energy and speeding them up.

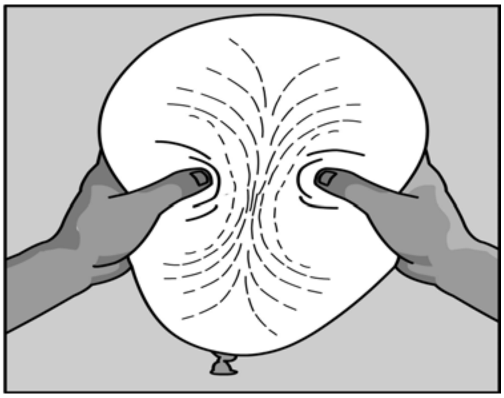
In gases, the particles move at even greater speeds.

The gaseous state

Gases spread out quickly to fill all the space available to them. Think of when you blow up a balloon. The air that you blow into the balloon fills up the whole balloon. A gas will fill the entire space that is available to it. This is because the particles in a gas have no particular arrangement.

Gases do not have a fixed shape. Think about the balloon again: the gas fills the entire space inside the balloon. You can squeeze the balloon, changing the shape.

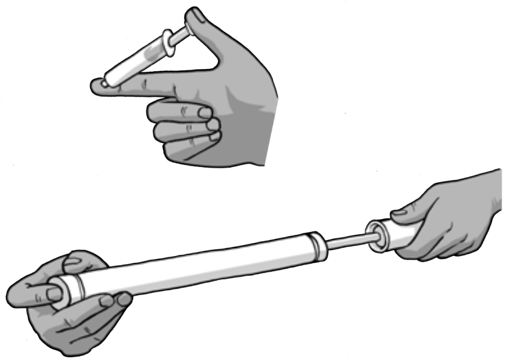
Gases fill the space available to them.



Gases do not have a fixed shape.

Gas particles move very fast, much faster than in solids and liquids. The particles in a gas possess a lot of energy.

Have you ever tried to compress the gas in a syringe or in a bicycle pump? Why do you think you can compress the gas?

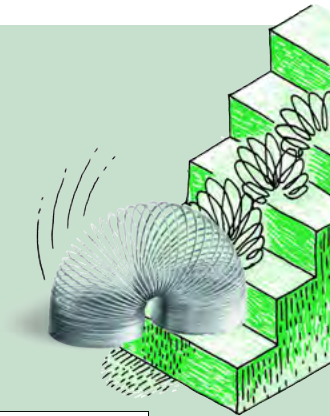


In gases, the forces between particles are very weak. This explains why the particles in gases are not neatly arranged. They are not held together tightly and there are large spaces between them. These spaces are much larger than in the solid and liquid state.

Gases can be compressed, because their particles can be forced closer together. Look at the photo of a scuba diver underwater. Do you see the tank on his back? He uses this tank to breathe underwater. A scuba diver can stay underwater for almost an hour. How do you think he can get enough air to breathe for a whole hour from a small tank like that? Discuss this with your class.

A scuba diver underwater with a tank of air.

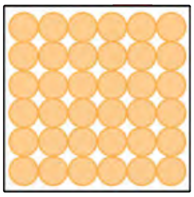
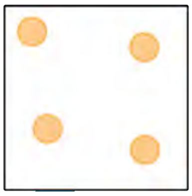
ACTIVITY: Comparing solids, liquids and gases



Let's summarise what we have learnt about what the particle model of matter tells us about solids, liquids and gases.

INSTRUCTIONS:

1. Use the images of the different states to help you, and go back over the text in your workbook.

	Solid 	**Liquid** 	**Gas** 
Arrangement of particles			
Movement of particles			
Forces between particles			
Spaces between particles			

QUESTIONS:

1. Use the particle model of matter to explain why solids have a fixed shape, but gases fill the shape of the container they are in.

VISIT

A video explaining the difference between the solid, liquid and gaseous states of matter.

bit.ly/15frMav

2. Use the particle model of matter to explain why you can compress a gas easily, but you cannot compress a liquid very easily.

3. Think of a bag of cake flour. You can pour the cake flour out of the bag and into a mixing bowl. Does this mean the flour is a liquid? Explain whether you think the cake flour (and all powders) are solids or liquids.

Diffusion

Have you ever noticed how quickly smells travel? Perhaps you have walked past a rubbish bin, and smelled the garbage.

You can often smell garbage bins when you walk past them.

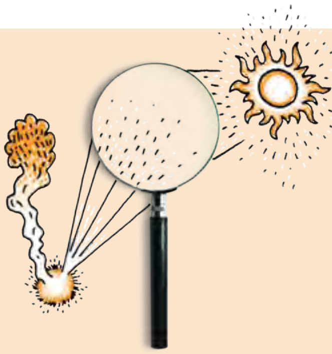
Has anyone ever set off a stink bomb near you?!

Have you ever smelled a stink bomb? When you smell these things, how do the 'stink bomb' or 'garbage' particles reach your nose?

Most smells travel fast, because their particles mix with air and get into our noses when we breathe. We say that the particles **diffuse** through the air.

In Gr. 7 we learnt about different kinds of mixtures. In the next investigation we are going to explore whether particles mix faster when they are in the liquid state or in the gas state. This is called the **rate of diffusion**. What would your prediction be?

INVESTIGATION: Comparing the diffusion of particles in a gas and in a liquid



INVESTIGATIVE QUESTIONS:

1. Do particles diffuse (mix) faster when they are in the liquid state or in the gaseous state? Which particles will mix more quickly: gases or liquids?
2. Do particles diffuse faster with or without mixing?

HYPOTHESIS:

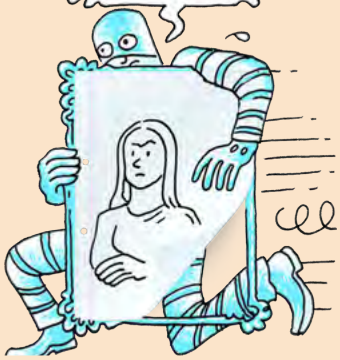
What are your predictions? Do you expect liquids to mix more quickly than gases, or the other way around? Will stirring influence the speed at which gases mix? Write down your hypothesis below.

IDENTIFY VARIABLES:

This is not a **controlled experiment** as we are not measuring the rates of mixing of the liquids and gases under exactly the same conditions. We will make a simple comparison of the mixing rates, by seeing how long it takes each to mix under two different sets of conditions.

TAKE NOTE

When we talk about a **rate**, we are measuring how something changes in relation to another factor, such as time. Another example is speed measured in km/h - this is a rate of how distance in kilometres changes over a period of time (hours).



MATERIALS AND APPARATUS:

- large glass beaker or other large clear glass container
- dropper
- food colouring or ink
- tap water
- vanilla essence
- shallow dish or saucer

METHOD:

Part 1: How fast do liquids mix?

1. Fill a large, clear container with tap water and place it where everyone can see it.
2. Use a dropper to place one or two drops of the food colouring in the water.
3. Record the time at which the colouring is added to the water.
4. Look carefully at the two liquids mixing, and write your observations below. Allow the liquids to mix without any stirring.
5. Record the time when the liquids are fully mixed, in other words, when the colour is uniformly spread throughout the water.

Part 2: How fast do gases mix?

This experiment should be performed with the windows closed.

1. Raise your hand as soon as you can smell vanilla essence.
2. Pour some vanilla essence into the saucer.
3. Record the time when the vanilla essence is poured out.
4. Record the time when the first learner puts up his/her hand to indicate that they can smell the vanilla essence.
5. Record the time when roughly half of the learners in the class have their hands up, to indicate that they can smell the vanilla essence.
6. Record the time when the learners at the back of the class first smell the vanilla essence.
7. If there is enough time during your next Natural Sciences lesson, repeat steps 1-5. You should do everything exactly the same, but this time, you should move your arms and try to 'wave' the air towards the back of the class.

RESULTS AND OBSERVATIONS:

1. What did you observe in the container immediately after the liquids were mixed?

2. How long did it take for the liquids to be fully mixed, until the colour was uniformly spread throughout the water?

3. When you did NOT wave your arms during the experiment:
   a) How long did it take until the first learners smelled the vanilla essence molecules?

   b) How long did it take until the last learners smelled the vanilla essence?

4. When you DID wave your arms during the experiment:
   a) How long did it take until the first learners smelled the vanilla essence molecules?

   b) How long did it take until the last learners smelled the vanilla essence?

5. Draw a table with your results for the vanilla essence experiment. You can choose your own column and row headings. Remember to give your table a heading.

ANALYSIS AND EVALUATION:

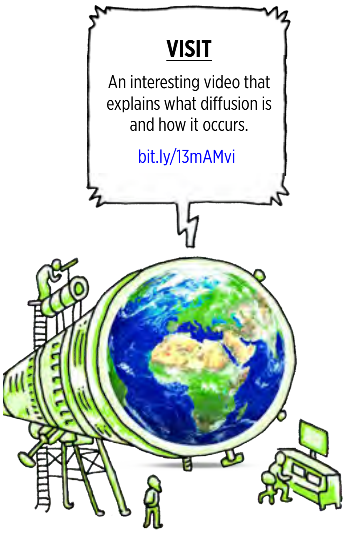
1. Did anything go wrong during the experiment?

2. Can you think of anything that could have improved this experiment?

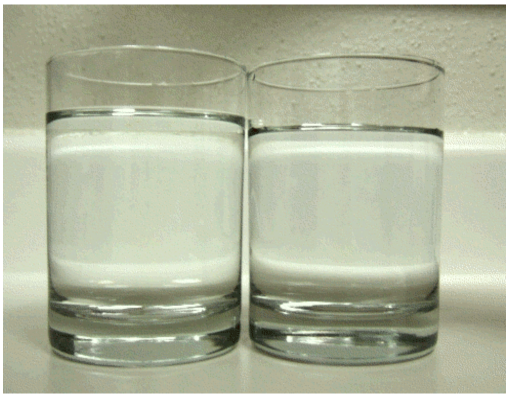
CONCLUSIONS:

What are your conclusions? (What are your answers to the investigative questions?)

In this investigation we explored the rates at which particles diffuse. What do you think happens at the particle level when two substances mix?

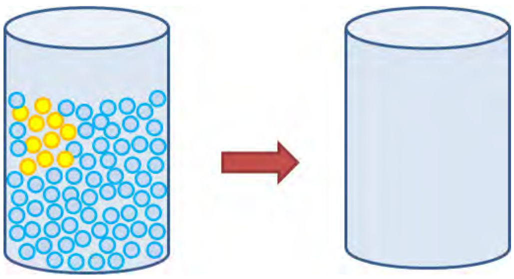


In the photos, we see a yellow liquid being added to a colourless one. Notice how the yellow liquid swirls and spreads out as the yellow particles mix with the colourless particles. Of course we cannot see the particles, but we can make a macroscopic observation (something we can see with the naked eye) of the process.



What will the mixture look like when the coloured particles are uniformly spread out amongst the water molecules?

What will the mixing process look like on particle level? The following diagram represents one of the glasses pictured above, containing a colourless liquid (represented by the blue circles) to which a yellow liquid (represented by the yellow circles) is added. The glass on the left shows the particles in the mixture directly after the yellow liquid was added to the colourless liquid. The glass on the right is empty. You must draw the particles in the mixture after the yellow liquid has spread **uniformly** throughout the colourless liquid.

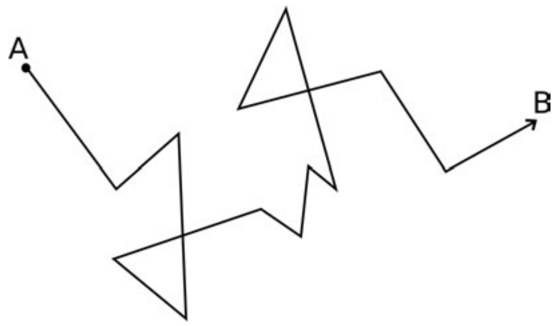


When you were watching the coloured liquid mix with the water in the last investigation, was it possible to predict the direction in which the colour would swirl? What made the two liquids mix?

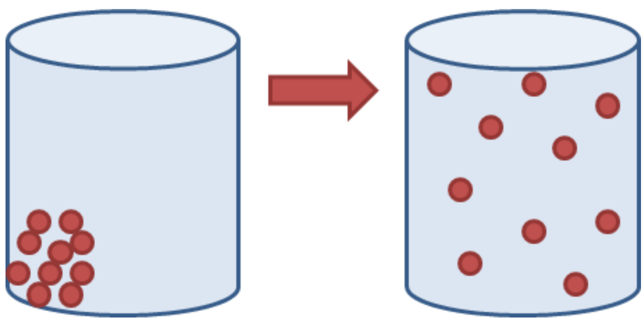
Random movement of particles

The particles in liquids and gases are constantly moving. Their movements are unpredictable: we say the particles move **randomly**. It is the random movement of the particles that allow liquid and gaseous substances to diffuse.

The following zigzag diagram explains what is meant by 'random' movement. When a gas particle travels from point A to point B, it will collide with many other gas particles along the way - up to eight billion collisions every second! Only a few of those collisions are shown in the diagram. Each time the particle collides, it will change direction. This means the actual distance travelled by the particle is much further than the direct distance between points A and B.



The process responsible for the mixing and spread of particles in a gas and liquid is called diffusion. We can define diffusion as the random movement of liquid or gas particles from a high concentration to a low concentration to spread evenly. The following diagram illustrates the idea in a very simple way: it shows the particles in a gas spreading out over time to fill all the space that is available to it.



In the diagram on the left some particles were placed into an empty container. At first they were close together (at high concentration), but over time they spread out to fill the entire container.

Factors that affect the rate at which particles diffuse

The speed at which particles diffuse depends on several factors, namely:

- The mass of the particles: lighter particles will diffuse faster, because on average they move faster.
- The state of the particles: the particles in a gas are always moving fast; we say their average speed is high. The particles in a liquid travel more slowly.
- The temperature of the particles: temperature is a measure of the kinetic energy of the particles. The higher the temperature, the more energy the particles have and the faster they will move and diffuse.
- The size of the spaces between particles: If there are large spaces between the particles of one substance, the particles of another substance can move into those spaces easily.

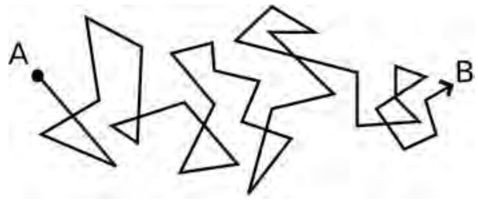
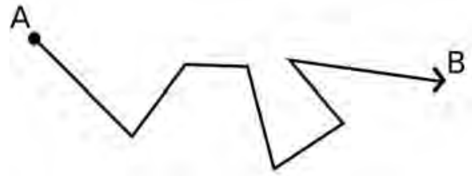
Particles diffuse because they are in **constant motion**. We found that gas particles diffused much more quickly than the liquid particles in the last investigation. Can we explain that result using the factors listed above?

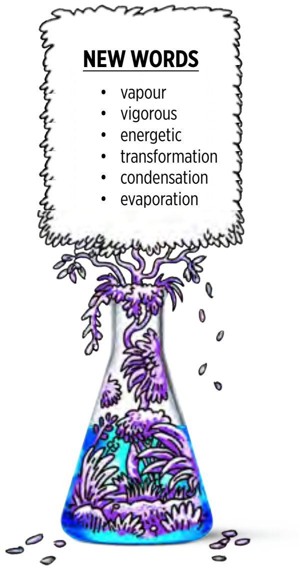
Think of it in this way: imagine you are trying to move through a crowd of people. The closer they are together, the more often you are going to have to change direction to make it through the crowd and the longer it will take to get to your destination.

Imagine walking through this crowd of people. This is similar to diffusion through a liquid.

A particle in a liquid cannot travel very far before colliding with another particle, because the particles are so close together. That means the liquid particles are constantly colliding and are sent into a new direction with each collision. This means the rate of diffusion is much slower in liquids than in gases, because the particles of a gas are further apart and collide much less. Gas particles can travel further without being sent in a different direction by a collision. This is why gases diffuse more quickly.

The following table shows similar zigzag drawings as you saw before, but now you can see the difference between the random movement of a particle through a liquid and through a gas. It will take the particle much longer to travel from A to B in the liquid than in the gas.

Liquid	Gas
	



Now that we have a better idea of the behaviour of particles in the different states of matter, we are ready to look at how particles behave when matter changes its state.

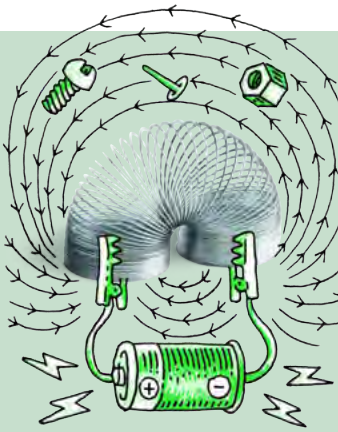
2.3 Changes of state

In science, a change of state refers to a change in physical state (e.g. when a liquid changes to a solid). What is this process is called?

____

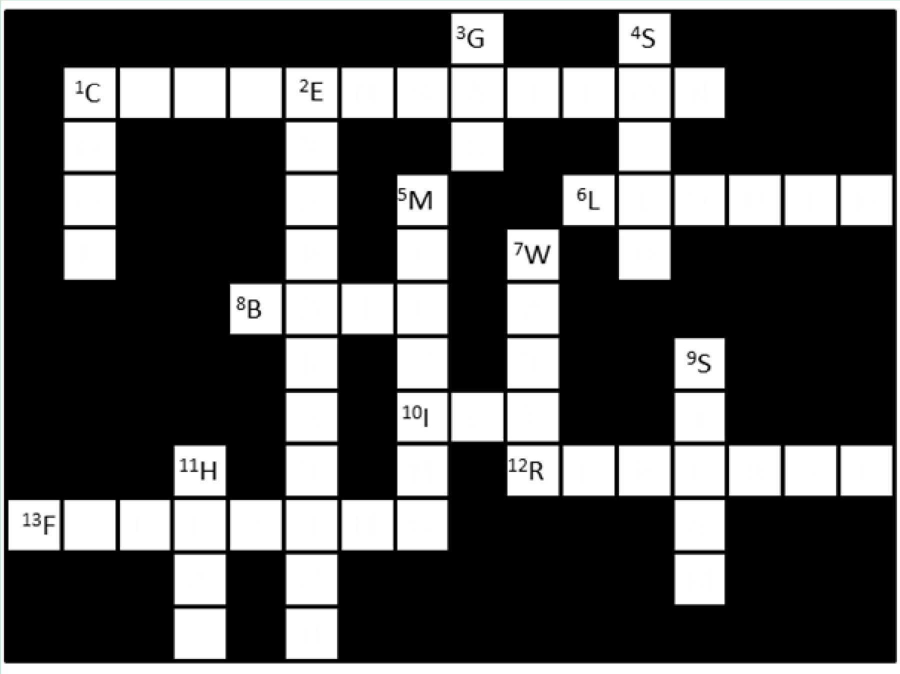
It is always a good idea to learn new things in terms of what we already know. We are going to start this section with a crossword puzzle to revise what we already know about changes of state.

ACTIVITY: Changes of state



INSTRUCTIONS:

1. The crossword puzzle below can be completed by following the clues given below.
2. The 'Down' clues are for the vertical words in the puzzle and the 'Across' clues are for the horizontal words in the puzzle.
3. All the clues have to do with changes of state of materials, and the first letter of every word has been filled in to help you.



Here are the clues:

Down:

1. If we want to turn steam into water we have to __________ it. (4 letters)
2. The process of turning a liquid into a gas is called __________. (11 letters)
3. The particles of a __________ have large spaces between them. (3 letters)
4. The particles of a __________ are locked in position by strong forces. (5 letters)
5. A solid will change into the liquid state at its __________ point. (7 letters)
7. The liquid state of ice is called __________. (5 letters)
9. The gaseous state of ice is called __________. (5 letters)
11. If we want to turn water into steam we have to __________ it. (4 letters)

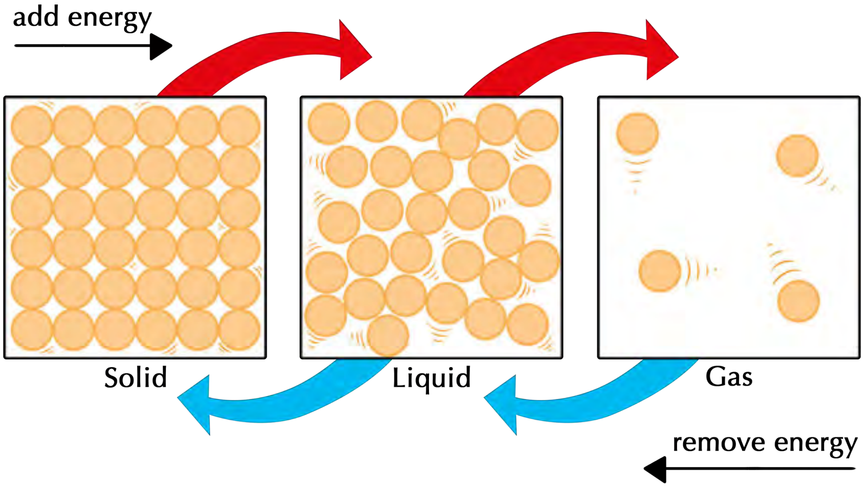
Across:

1. The process of turning a gas into a liquid is called __________. (12 letters)
6. The particles of a __________ are close together but they can flow and slide over each other. (6 letters)
8. The boiling point of a liquid is the temperature at which that liquid will start to __________. (4 letters)
10. The solid state of water is called __________. (3 letters)
12. Freezing and melting are the __________ of each other. (7 letters)
13. __________ water turns it into ice. (8 letters)

How can we change matter from one state to another?

Changes of state involve energy

For matter to change from one state to another, its particles must gain or lose energy. The following diagram shows us that to change the state of a substance, it must either be heated or cooled.



Melting and evaporation are processes that require heating; condensation and freezing are processes that require cooling.

First, let us look at what happens to particles when they are heated.

Melting and evaporation

When a solid is heated to reach its melting point, it will change into a liquid. This is a process that we are all familiar with, because we have seen how ice melts.

A melting ice cube.

For a solid to change into a liquid state, the particles in the solid need to be freed from their fixed positions in the solid state. How could that occur?

Imagine you are holding hands with a group of other learners. Everyone is jumping in place, much like a solid particle vibrating in a fixed position. The more **energetically** and randomly everyone jumps, the more difficult it will be for everyone to keep holding hands.

When a substance is heated, the particles are given more energy. By giving the vibrating particles in a solid more energy, their vibrations will become more and more **vigorous**, until the solid particles are able to shake themselves loose from their fixed positions. The forces between the particles are no longer able to hold them together tightly, and the solid **melts**.

VISIT

Misconceptions about temperature (video).

bit.ly/19Q7VGZ

NEW WORDS

- boiling
- melting
- evaporation
- melting point
- boiling point

What will happen if we add even more energy to the particles? The particles (which are now in the liquid state) will whizz around faster and faster as they heat up. Soon some of the particles near the surface will have enough energy to escape out of the liquid. Once they are free from the forces that hold them together in the liquid state, they enter the gas (or gaseous) state. The gaseous state is sometimes called the **vapour** phase, which forms when a liquid **evaporates**. This is why the gaseous state of water is sometimes called water vapour.

Clothes hanging outside.

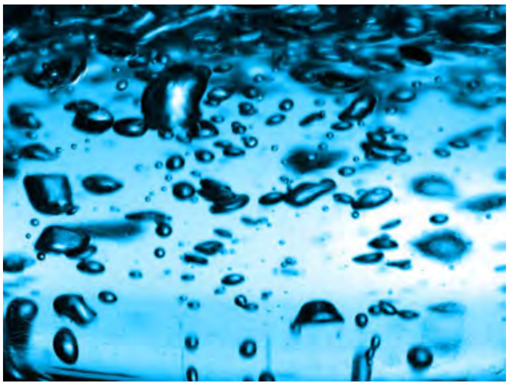
The higher the temperature of the liquid, the faster it will evaporate. A puddle of water will evaporate much faster from the hot pavement than it would from a cool kitchen floor! Why do you think we hang washing outside in the sunshine to dry?

Is there a difference between evaporation and boiling?

Evaporation takes place at all temperatures, while boiling occurs at a specific temperature, called the **boiling point**. When a liquid is heated to its boiling point, bubbles form in the liquid and rise up to the surface. When this happens, we say the liquid is boiling. Evaporation occurs only on the surface of the liquid, while boiling occurs throughout the entire liquid. Can you remember learning about boiling points in Gr. 7?

NEW WORDS

- condensation
- solidifying



Boiling water.

What is the boiling point of water at sea level?

Look carefully at the picture of the boiling water above. What do you think is inside the bubbles?

Next, we will look at the changes of state that can happen when we cool a substance.

Condensation and solidifying

When a gas changes to a liquid, the state change is called **condensation.** Condensation is the opposite of evaporation. Have you noticed the little droplets of water that form on the outside of a cold glass of water? They are formed by condensation.

When the temperature of a gas is lowered, it takes energy away from the gas particles. The movement of gas particles slows down as their energy decreases and they will start to experience attractive forces. These forces cause them to move closer to each other and they eventually return to the liquid state.

Water vapour in the air has condensed on the cold surface of this glass window.

Birds and animals in groups tend to huddle together when they get cold.

DID YOU KNOW?

The volume of water expands about 9 % when it freezes into ice.

What do groups of people, animals, or birds do when they get cold? They huddle together! In the same way gas particles that are cooled down condense and come together to form water droplets.

What would happen if we cooled the liquid even more? By cooling the liquid, we would be removing energy from it. As the liquid particles lose energy, their movement slows down even more. As their movements become slower and slower, the attractive forces between become stronger. The particles eventually 'lock' into position in the solid state. They can no longer move freely and are only able to vibrate in their fixed positions. We say the liquid has **solidified**.

INVESTIGATION: What happens when we heat and then cool candle wax?

AIM: What is your aim for this investigation?

HYPOTHESIS: What do you propose will happen in this investigation? This is your hypothesis.

MATERIALS AND APPARATUS:

- empty tin can or foil pie dish
- bunsen burner or spirit lamp
- tripod stand
- wire gauze
- candle wax
- matches

METHOD:

1. You need to write the method for this investigation. you will either plan this in a group, or your teacher might do the investigation as a demonstration. You must write down the steps for the investigation. They must be clear and allow someone else to repeat your investigation.

2. Draw a diagram of your setup for the investigation in the following space. Remember to give your diagram a heading and to provide labels.

RESULTS AND OBSERVATIONS:

1. What state of matter is the candle wax in at room temperature (at the start of the investigation)?

2. What happened when you heated the candle wax?

3. What happened when you cooled the candle wax?

4. Would you say the melting point of candle wax is higher or lower than room temperature?

CONCLUSION:

Write a conclusion for this investigation. You must make reference to the particle model of matter in explaining the changes of state that occurred.

In the next activity we are going to have some fun with water balloons, but not in the usual way. We are going to blow up a balloon without blowing into it and we will make it rain inside the balloon! Sounds like magic? No, just science!

ACTIVITY: Hot water balloon

MATERIALS:

- large party balloon (plus spares)
- 2 teaspoons of tap water
- microwave oven
- oven gloves
- safety goggles
- large bowl of ice cold water

Let's have some fun with balloons!

INSTRUCTIONS:

1. Before you begin, put on your safety goggles.
2. Pour water into the balloon and squeeze out all the air before tying a knot in the neck of the balloon.
3. Place the balloon in the microwave oven and heat on full power until you see the balloon starting to expand. Only a few seconds of heating should be enough for the balloon to reach its full size (if you heat it for too long it might pop). What do you observe?

4. Remove the heated balloon with the oven glove. Shake it gently. If you are very quiet you will hear something happening inside the balloon. What does it sound like?

5. Place the balloon in the bowl of cold water. What do you observe?

QUESTIONS:

1. Did the balloon have any air inside it at the start of the experiment?

2. What made the balloon expand?

3. What is the name of the gas that made the balloon expand?

4. What did you hear inside the balloon when it started to cool down?

5. What caused the sound?

6. Where did the water droplets inside the balloon come from?

7. What happened to the balloon when it was cooled down in the cold water?

8. Which changes of state did the water undergo in this experiment?

Next, we are going to look at three important properties of matter that are useful to scientists, namely density, mass and volume. These three properties are all related to each other.

2.4 Density, mass and volume

You have probably heard the terms **mass** and **volume** before in Natural Sciences and Mathematics. But what about **density?** Have you ever used this word before? Perhaps you have heard someone describe a cake as very dense? What does this mean?

This section introduces us to **physical quantities** that are important when we study science. Two of these quantities, namely mass and volume, are fundamental properties of matter. We are going to discuss them first, then we will introduce density. Density is another property of matter that is very closely related to the first two.

NEW WORDS

- mass
- volume
- density
- physical quantity

Mass tells us 'how much' matter we have

Look at the picture of a bag of rice. How much rice is in the bag?

___

The mass of an object or a substance tells us how much matter it consists of. The greater the mass of an object, the more matter it contains.

VISIT

An interesting video on how to define a kilogram (by using the world's roundest object!)

bit.ly/19e6zGs

Mass is measured in kilograms (kg). When we measure the mass of small objects or small amounts of matter we often measure in grams (g) or even milligrams (mg).

- One kilogram is the same as 1000 grams.
- One gram is the same as 1000 milligrams.

How many milligrams are in one kilogram?

___

Gold bars each with a mass of 250 g. How much is this in kg?

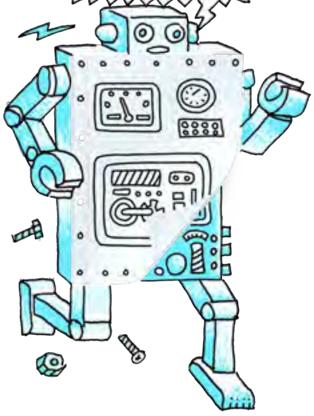
If one gold bar has twice the mass of another gold bar, then it contains twice as many gold atoms. The mass of an object stays the same, no matter where it is. Unless a piece of it is cut off, the same gold bar will have the same number of gold atoms whether it is in Gauteng, Bloemfontein, London, or the Moon. That means the mass will always remain constant.

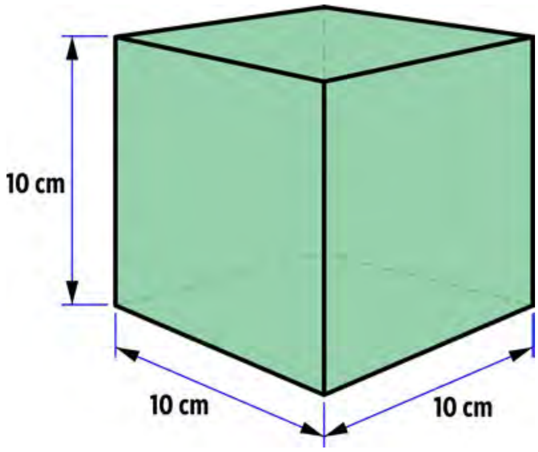
Volume tells us 'how much space' matter takes up

The amount of space that an object occupies is called its volume. Volume is measured in litres and is calculated by multiplying the length, width and height of an object. A litre is the space inside a cube that is 10 cm wide, 10 cm long and 10 cm deep.

TAKE NOTE

When calculating volume, 1 cm x 1 cm x 1 cm = 1 cm^3. This is the same as 1 ml. That means that 10 cm x 10 cm x 10 cm = 1000 cm^3 which equals 1000 ml or 1 litre.





This cube has a volume of 1 litre.

A carton of milk and a bottle of juice.

What is the volume of milk in the carton and the volume of juice in the bottle in the following photo?

___

___

When we measure small volumes we use millilitres (ml) as the volume unit. 1000 millilitres is the same as one litre.

TAKE NOTE

We can also use symbols for density (D), mass (m) and volume (V), so the equation **to calculate** density can be written as $D = m/V$.

Density tells us how 'tightly packed' a material is

Density is a measure of how much mass of a material fits into a given volume. We say density is the ratio of mass to volume. We can write a mathematical relationship to show this ratio as follows:
$density = mass/volume$

A dense piece of cake.

If we have two materials with the same volume, the material with a higher mass will be more dense. It will have a higher density. We can think of density as the 'lightness' or 'heaviness' of objects of the same size.

Think back to the slice of cake that we spoke about as being dense. This is how we can use the word density in everyday language. A piece of cake that is described as dense will feel heavy.

In the next activity we are going to compare different materials that have the same size (or volume), but different densities.

ACTIVITY: Which material is more dense?

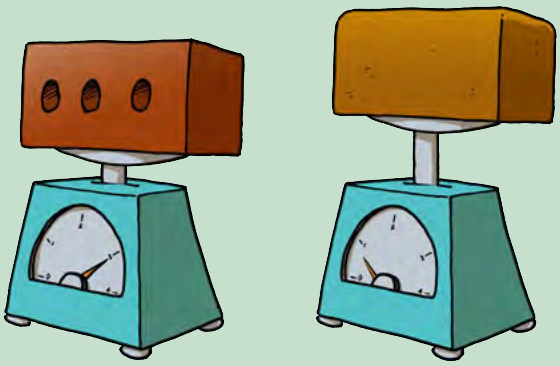
MATERIALS:

A variety of objects that have the same size (volume) but different densities: sponge, polystyrene, wood, metal, brick or stone.

INSTRUCTIONS:

1. Handle all the different materials and compare their masses. You do not have to measure their masses on a scale. You can just feel how heavy they are in your hand.
2. Arrange them in order of increasing density. Do this activity as a group and discuss why some materials are more dense than others.
3. If you do have access to a triple beam balance, measure the masses of each of the objects.

QUESTIONS:



1. Imagine a brick and a loaf of bread that are the same size. Would the brick or the bread have a greater volume?

---

2. Which one, the brick or the bread, has more mass?

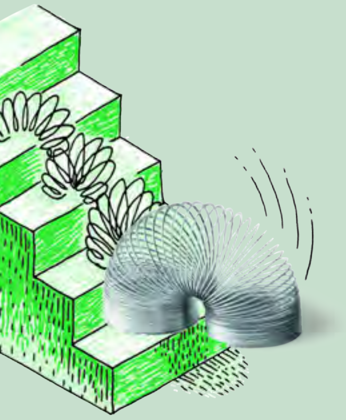
---

3. Which one, the brick or the bread, would have the greater density? Explain your answer.

2.5 Density and states of matter

We have now learnt about the three states of matter and the properties of each. We know one of the ways in which solids, liquids and gases are different from each other has to do with the distances between the particles in each respective state. The particles in gases are much further apart than the particles in liquids or solids.

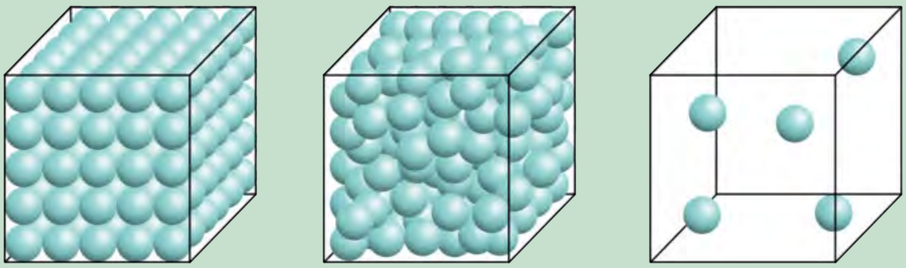
Does this mean the different states of matter have different densities? We will find out in the next activity.



ACTIVITY: Which has the highest density: a solid, a liquid or a gas?

INSTRUCTIONS:

1. Compare the three identical containers below.
2. They all have the **same volume** and contain the **same material**
3. Container A contains a solid material, container B contains the liquid state of that material and container C the gaseous state of the same material.
4. Answer the questions that follow.



A. B. C.

QUESTIONS:

1. Which container (A, B or C) contains the greatest number of particles? Which container contains the smallest number of particles?

___

___

2. Which container (A, B or C) contains the material with the greatest mass? Which container has the smallest mass? Why do you say so?

___

___

3. Which state has the highest density: solid (in container A), liquid (in container B) or gas (in container C)? Which state has the lowest density? Why do you say so?

We have just performed a conceptual activity (a 'thinking' activity) in which we compared the densities of the three states of the same material.

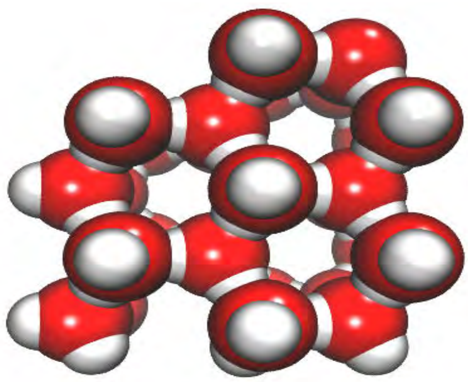
The high density of a solid material explains why it cannot be compressed. The particles in a solid are tightly packed and cannot be squeezed closer together into a smaller volume.

Liquids are also very dense. The density of a liquid is roughly the same as the density of the solid state of the same substance. This is because their particles are close together, even though they are not locked into fixed positions. Most liquids cannot be compressed into smaller volumes.

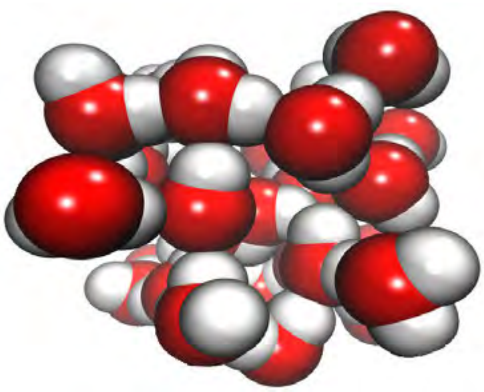
Ice blocks floating in a glass of water.

Liquids are slightly less dense than their solid states but water is an important exception. Have you ever wondered why your ice cubes float on top of the water in your glass?

The solid state of water (ice) is less dense than the liquid, because in ice the water molecules are packed in a unique way. The image below on the left shows shows that water molecules in ice are packed in such a way that there are open spaces between them. On the right, the same water molecules are shown in the liquid state.



Water molecules in the solid state (ice).

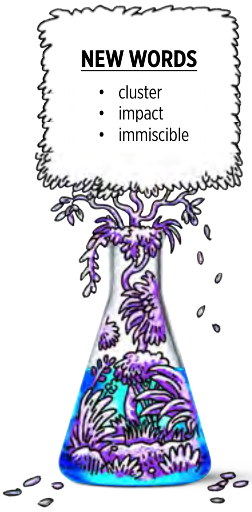


Water molecules in the liquid state.

Do you see how there are bigger spaces between the water molecules in a solid than in a liquid? This also helps to explain why icebergs are able to float in the sea.

Have you ever seen a frozen bottle of water with the ice pushed up out of the bottle? Why did the water push out of the bottle when it turned to ice?

A big floating iceberg in the Arctic.



Gases are not very dense at all because of the large spaces between the gas particles. That means they contain a small number of particles in a large volume. This why gases can be compressed: their particles can be squeezed closer together to fit into a smaller volume. Think back to the air that is compressed to fit inside a gas tank for a scuba diver.

In the activity 'Which has the highest density, a solid, a liquid or a gas?'we compared the densities of different states of the same material. This is an easy comparison because the particles in the different states are identical. By comparing the number of particles in the same volume of each state, we can determine the density of each state.

The densities of different materials are slightly more difficult to compare, because different materials consist of particles with differing masses.

2.6 Density of different materials

We are now going to do a practical activity (a 'doing' activity) to compare the densities of a solid, a liquid and a gas. It would be quite difficult to compare the three states of the same material, as the material would have to be at three different temperatures to be in three different states! For this reason we will compare three different materials: sand, water and air.

INVESTIGATION: Comparing the densities of sand, flour, water and air

INVESTIGATIVE QUESTION:

Which material has the highest density: sand, flour, water or air?

HYPOTHESIS:

What do you predict: Which material has the highest density: sand, flour, water or air?

IDENTIFY VARIABLES:

1. Which variables must be kept constant to make this a fair test?

2. What is the independent variable? (what is it that you have control over to change in this investigation?)

3. What are the dependent variables? (Which variables will you be measuring?)

MATERIALS AND APPARATUS:

- four identical cups (paper or plastic)
- sand
- flour
- tap water
- triple beam balance or scale

METHOD:

You will be designing this investigation yourself. If you are working in groups, you need to first discuss how you are going to conduct (carry out) this investigation. This is the planning. Write down your proposed method in your notebook or on scrap paper. Discuss this with your teacher. Remember to also think about how you are going to record your results. After you have conducted the investigation, write down your method on the lines provided here. Summarise each step in sequence and number the steps.

RESULTS AND OBSERVATIONS:

What were the results of your investigation? Summarise them below. You can draw a table. If you were able to measure the mass of each cup, show your calculations for the density of each material.

ANALYSIS AND EVALUATION:

1. Did anything go wrong during the experiment? If so, what?

2. Can you think of anything that could have improved this experiment?

3. What steps did you include to ensure fair testing?

CONCLUSION:

What is your conclusion? (What is your answer to the investigative question?)

In the last investigation we saw that two solids, namely sand and flour have different densities as they are different materials. But what about liquids? Do all liquids have the same density or does the type of material of the liquid affect the density?

Have you ever noticed that oil floats on water?

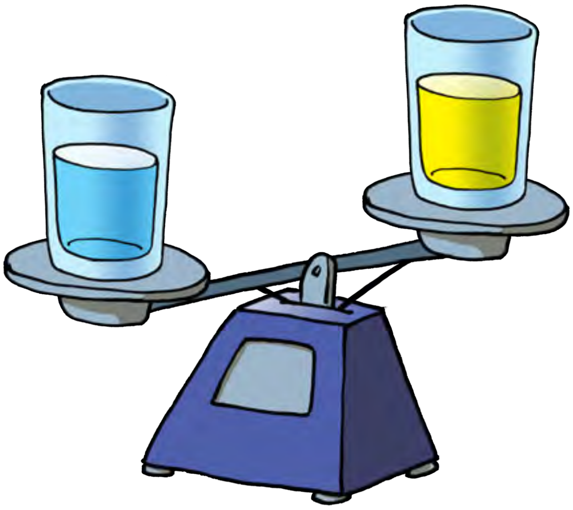
Oil floats on water.

This homemade salad dressing contains oil that floats on top.

When you mix oil and water, as in the picture of the salad dressing the two materials will eventually separate because they do not mix well. They are **immiscible**. When they separate, the oil will always float on top. The two separate layers of water and oil are referred to as 'phases', the oil phase and the water phase.

Oil floats on water for two reasons:

- A cup of oil has less mass than a cup of water. The oil is less dense than water. This makes oil float on water, like a cork or an air-filled rubber duck floats on the surface of the water.



- Oil does not dissolve in water. The oil molecules **cluster** together and float on the surface. If a large amount of oil is poured into water, the oil will spread out and form a layer on the surface of the water. Oil that is spilled into the ocean or a lake spreads over a huge area. It poisons many animals, birds, fish and plants and is very expensive to clean up. That is why oil pollution has an extremely negative **impact** on our environment.

Oil pollution forms a thin layer on the surface of the sea water. The oil can spread out over a huge area as the layer is thin and it floats on top of the water.

A sea bird trapped in the oil from a spill. The oil gets in between the bird's feathers, sticking them together and preventing the bird from flying.

When two substances are in the same container, but not mixed (like oil and water for instance), they will form two layers. In a certain sense, water and ice also form two 'layers'. Which layer will be on top: the one which is more dense or the one which is less dense?

In the next activity we look at how we can layer different liquids on top of each other depending on the densities!

ACTIVITY: Rainbow density column

MATERIALS:

- large glass vase or one litre glass measuring cylinder
- plastic cups
- honey
- golden syrup
- whole milk
- dish washing liquid
- water (can be coloured with food colouring, blue for example)
- vegetable oil
- rubbing alcohol (can be coloured with food colouring, red for example)
- a bolt
- a popcorn kernel
- a cherry tomato
- some plastic beads
- a ping pong ball/polystyrene ball

INSTRUCTIONS:

1. Use the same amount of each liquid. The amount will be determined by the height of the vase or measuring cylinder. Pour equal volumes of each liquid into the cups.
2. If you have access to a scale, measure the mass of each cup with a different liquid. Arrange them in order from heaviest to lightest.

VISIT

A video showing how to make a rainbow density column.

bit.ly/14oGnEu

3. Start with the heaviest liquid (honey) and pour it into the container first. Be careful not to let any of it touch the sides of the container.
4. Next pour in the next heaviest until you have poured all the liquids into the container. If you have a pipette, use it to carefully layer the liquids.
5. Stand the column on a desk and carefully drop in the bolt, popcorn kernel, cherry tomato and beads. Take note of where each object settles in the density column.
6. Finally, drop the ping pong/polystyrene ball on top.

QUESTIONS:

1. Use the space provided to make a drawing of the density column that you made in class. Use coloured pencils if you have them. Label each layer. If you measured the mass of each liquid, write the mass in brackets after each label. Draw in the different objects to show where they dropped to in the density column.

2. Which liquid is the most dense and which is the least dense? Explain your answer.

3. Do you notice any relationship between the mass and density of the different liquids?

4. Arrange the objects from most dense to least dense. Explain how you did this.

5. Why do you think the objects dropped to different levels in the liquid?

6. Which objects are more dense than water? Which objects are less dense than water?

ACTIVITY: Some density calculations

INSTRUCTIONS:

1. Below is a table with some different substances and their densities. Use this information to do the following calculations.
2. Show how you worked out each answer and do not forget to include the units in your answer.

Material	density (g/mL)
water (liquid)	1
ice	0.917
glass	2.6
salt	2.2
chalk	2.36
coal	1.5
cork	0.25

QUESTIONS:

1. You have a 500g block of butter at home. You found out that its volume is 555mL. What is the density of the butter?

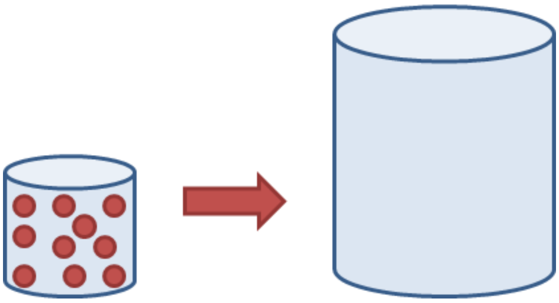
2. Which is more dense, salt or chalk?

3. You have a large glass marble and you want to find out what its volume is. You measure the mass and find it to be 50 g. What is its volume?

4. You have a piece of coal and a piece of cork which are exactly the same size. They have the same volume of 100 mL. Which one will have the greater mass? Calculate the exact mass of each piece.

We have learnt that the density of a material depends on how tightly packed the particles inside the material are. The more tightly packed they are, the more dense we say they are.

The following diagram represents a container (on the left) that contains a small amount of gas. Imagine that all the gas from the small container is moved into the empty container on the right. Draw the gas particles in the container on the right.



A gas will expand to fill whatever space it is in. In the larger container we will still have the same number of gas particles, but now they are filling a much larger space.

If we take a certain amount of gas from one container and place it into another, larger container, the gas expandsto fill the larger container. The same mass of gas is now in a larger volume, the gas now has a lower density.

Solids and liquids cannot behave in this way. Their densities will remain more or less constant no matter in which container they are placed. This is because their particles are relatively close together with strong forces between them. But what happens when we heat them? We have learnt that this is the same as giving them extra energy. How will heating them affect the packing of the particles and the density?

In the next section we are going to look more closely at what happens to the particles inside materials when they expand. We are also going to look at the opposite of expansion, namely contraction.

NEW WORDS

- expand
- contract
- reinforce

2.7 Expansion and contraction of materials

Have you ever been inside a tin-roofed house? On a hot days, you often hear the metal roof panels groan and creak. Do you know why this happens?

Some materials become slightly larger when they are heated. We say they **expand**. Materials can also shrink slightly when they are cooled. We say they **contract**.

A house with a tin roof.

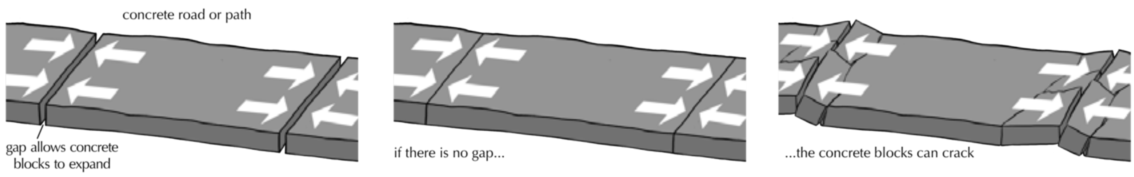
The metal roof panels expand and contract as the outside temperature changes. When this happens, the panels scrape against each other and against the nails that keep them in place. The scraping of metal against metal causes the creaky, groaning noises.

How is it possible for materials to contract and expand? Can you think of an explanation?

To understand this phenomenon, we will look at some examples of expansion. We will then try to explain expansion in terms of the particle model.

Some solids expand more than others. When we choose materials for a new job, it is important to know how much they will expand. This way we can allow for expansion when the materials get hot.

In the following diagram, the picture on the left shows a concrete path or road surface. How have the engineers who built the road allowed for expansion?



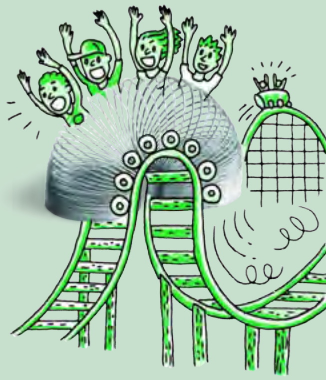
Expansion can create forces strong enough to damage materials.

The picture above shows what could happen if no allowance is made for the expansion of the concrete blocks. The forces created by the expansion of the concrete are so strong that the road surface has cracked!

The expansion joint in a bridge.

This is a very important principle to remember when building bridges. When engineers design a bridge, they must allow for contraction and expansion of the materials used to build the bridge. Have a look at the following photo showing a close-up of the gap between the two road surfaces of a bridge. Can you see the interlocking 'teeth'? These allow the bridge to expand and contract while the teeth slide past each other.

ACTIVITY: How much longer?



In this activity we will compare the expansion of different solid materials by drawing a graph. You will need the following information for your graph:

Material	How far a 100 metre length of the material will expand when the temperature increases by 10°C
Brass	19 mm
Iron	12 mm
Steel	11 mm
Platinum alloy	10 mm
Concrete	11 mm
Ordinary glass	11 mm
Ovenproof glass	3,5 mm

Draw a bar graph with 'Expansion' on the y-axis and 'Materials' as categories on the x-axis. Choose an appropriate title for you graph.

QUESTIONS:

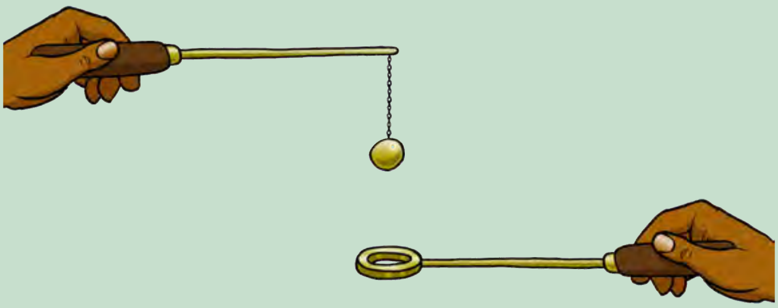
1. Which material expands the most upon heating?

2. Which material expands the least?

3. Which solid would be the best material to **reinforce** concrete? (Hint: the reinforcing material should expand as much as the concrete, otherwise it will damage the concrete during expansion.)

4. A man builds a house with large windows set in beautiful frames made of brass. The house is in a region where it gets very hot during summer. Imagine that the owner of the house has a problem: the windows of the house look beautiful in their shiny brass frames but they keep falling out during the summer months. As a scientist, how would you explain this and what would your advice to the owner of the house be? Should the frames be replaced? If so, with which material? What other solutions can you suggest?

5. The following diagram shows a metal ball and ring apparatus. The ring and ball are both made of brass. At room temperature, the ball is just the right size to pass through the ring.



   Do you think the ball will still fit through the ring when the ball has been heated?

6. Do you think the brass ball will have more mass when it has expanded? Explain your answer.

7. What will happen to the brass ball when its temperature drops back to room temperature? Will it be larger than, smaller than, or the same size as before it was heated? Explain your answer.

Now that we have seen that materials can expand, how can we explain expansion of a material in terms of the behaviour of the particles in that material?

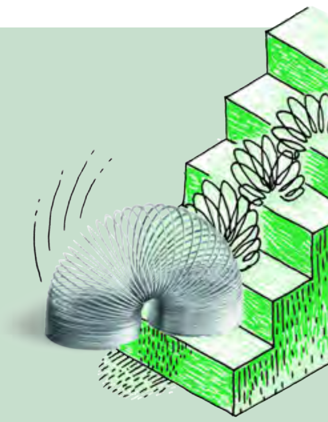
We have learnt that when matter is heated, the particles of that matter will move faster and push further apart from each other. What happens to the particles in matter when it is cooled?

When a substance cools (energy is removed), the particles in that substance will slow down and move closer together. That is why most materials contract when they are cooled.

Expansion and contraction in a thermometer

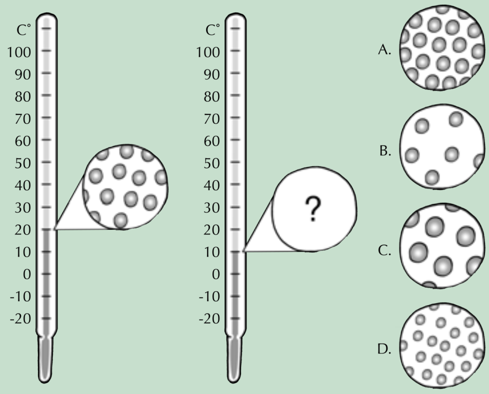
Let's look at a thermometer to understand expansion and contraction.

ACTIVITY: How does a thermometer work?



The common glass thermometer is called a bulb thermometer. All bulb thermometers have a fairly large bulb that is connected to a long, thin tube. The thermometer has a brightly coloured liquid on the inside. Some thermometers contain mercury as it expands and contracts quite a lot when heated or cooled.

Look carefully at the following set of diagrams. They represent the same thermometer at two different temperatures.



QUESTIONS:

1. The drawings represent the particles in the liquid inside a thermometer. What is the temperature measured on the thermometer on the left?

2. The drawing on the right is of the same thermometer, but slightly different. Can you tell the difference?

DID YOU KNOW?

Mercury is the only metal that is a liquid at room temperature.

3. Which of the circles (A, B, C, or D) is the best representation of the liquid in the thermometer on the right? Why did you choose this one?

4. Does a material have less mass when it has contracted? Explain.

5. If the temperature was raised and the thermometer read 30°C, which circle would now best represent the particles in the liquid of the thermometer? Why?

6. How does the volume change when a material is heated? Why?

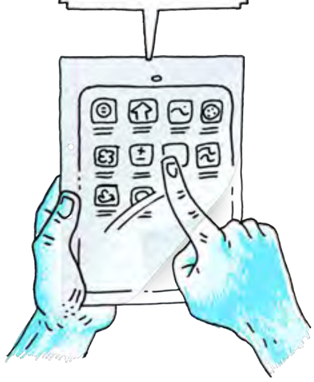
7. How does the density change when a material is heated? Why?

We have learnt that thinking about matter in terms of the particles inside it can help us to understand many interesting phenomena: the physical properties of the different states of matter, changes from one state of matter to another, density, and expansion and contraction.

How can we measure how much of a liquid or a solid we have? If we want to know how much of a material we have, we can measure its mass. What instrument do we use to measure mass?

TAKE NOTE

When a material is heated, its particles move further apart. When the material cools down, the particles move closer again. Heating and cooling cause the volume of the material to change.



We can use a scale to measure the mass of a person or any other object.

Think back to the investigation comparing the densities of sand, water, flour and air. How did you measure the mass of the air in a cup?

We are now going to shift our focus to gases. Gases have much lower densities compared to solids and liquids. That means a large volume of gas will have a small mass. Small masses can be difficult to measure without a special, super-sensitive scale. Scientists have devised a different way of measuring how much of a gas they have.

NEW WORDS

- pressure gauge
- air valve

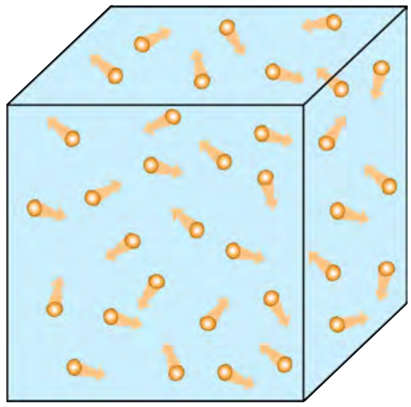
DID YOU KNOW?

Wind is simply moving air! The movement of the air is caused by differences in pressure between one area of the Earth's atmosphere and another. When the wind blows, it is the atmosphere equaling out uneven pressures by moving air from a high pressure area to a low pressure area.

2.8 Pressure

What is gas pressure?

We have learnt that gases contain millions of fast-moving particles. The following picture represents gas particles inside a container.



Gas particles in constant motion, inside a container. They collide with each other and with the inside of the container.

As the particles whizz around, they bump and bounce off each other. They also bump against the inside of the container. The force of the particles bumping against the sides of the container cause a phenomenon called gas pressure. The number of bumps (or collisions) will depend on the number of gas particles in the container. More particles inside the container means more collisions, and more collisions mean a higher pressure.

If we can measure the pressure of the gas, we will have an idea of how much gas is inside the container.

How can gas pressure be measured?

Have you ever seen anyone check the pressure in a car tyre? You may have seen them use a device like those in the photo below. It is called a tyre **pressure gauge** and it is specially designed to measure the air pressure inside a tyre.

A simple tyre pressure gauge.

The round end of the gauge should be pressed against the **air valve** of the tyre. This opens the valve and lets some of the air from the tyre escape into the gauge. The air particles bump against a disc inside the gauge. The force generated by many gas molecule collisions pushes out a bar at the back of the gauge. Can you see it in the picture? For this particular pressure gauge, the pressure inside the tyre is indicated by how far back the bar is pushed out of the back of the gauge. Note the numbers along the bar which allow us to measure the pressure.

Other, more complicated pressure gauges all work in a similar way.

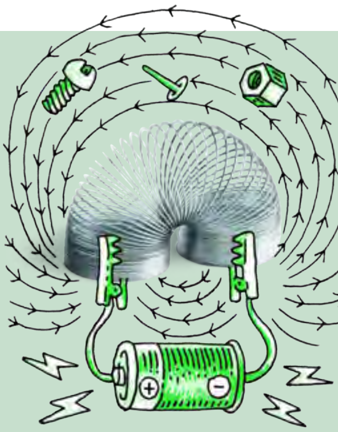
Two more complicated types of tyre pressure gauges for measuring the air pressure inside car tyres. The right one is a digital gauge.

Measuring the pressure inside a tyre using a pressure gauge.

How could we increase or reduce the amount of gas in a container? In the next activity we are going to see if we can understand gas pressure in terms of the particle model of matter.

By blowing air into the balloon, the girl is forcing air particles into it.

ACTIVITY: Understanding gas pressure



MATERIALS:

- brown paper bags (medium size)
- balloons
- empty plastic cold drink or water bottles (2-litre bottles are preferable)
- bicycle pump and tyre

INSTRUCTIONS:

1. This step requires a brown paper bag.
   a) Blow up a brown paper bag until it is fully inflated.
   b) Try blowing it up even more. See if you can make it pop by blowing into it.

c) Write two or three sentences to describe what it feels like to blow into the bag when it is 'empty', compared to when it is 'full' of air. Does it feel different? Is it more difficult to blow into the bag when it is already full?

2. This step requires a balloon.
    a) Blow up the balloon until it is the size of an orange. Pinch it closed but do not tie a knot in the top.
    b) Now blow up the balloon as large as you can.
    c) Try blowing it up even more. See if you can make it pop by blowing into it.
    d) Write two or three sentences to describe what it feels like to blow into the balloon when it is 'empty', compared to when it is 'full' of air. Does it feel different? Is it more difficult to blow into the balloon when it is already full?
    e) Tie a knot in the top of an inflated balloon. Leave the balloon in the classroom and examine it again after one week. Does it look the same as when you inflated it a week ago? Perhaps it looks a bit like this balloon in the following photo:

A deflated birthday balloon.

    f) Remember to write your observations below.

3. This step requires a balloon and an empty plastic bottle.
    a) Stretch the balloon over the top of the bottle, with the balloon hanging down into the bottle.
    b) Blow into the balloon. What do you observe? Can you blow up the balloon?

    c) Now make a small hole in the bottom of the bottle. Blow into the balloon again. What do you observe now?

4. This step requires a bicycle tyre and pump.
   a) Use the pump to pump air into the tyre. Continue to pump until it becomes too difficult to pump any more air into the tyre.
   b) Write 1 or 2 sentences about your observations.

QUESTIONS:

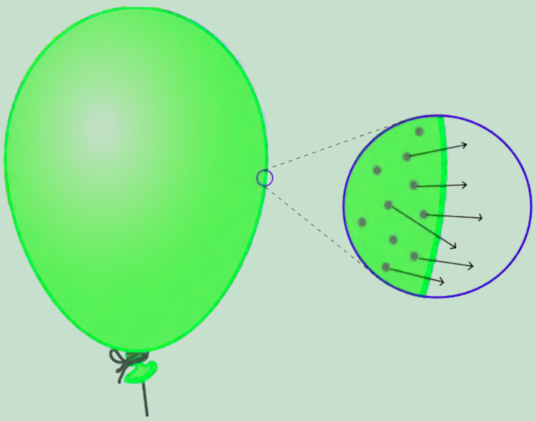
Try to answer the following questions by explaining what is happening to the air particles in each case. Use the words 'particles', 'collisions' and 'pressure' in your answers.

1. What happens when you blow up a paper bag or a balloon, or when you pump air into a tyre?

2. When you blow into a paper bag, why does the bag pop or start to leak air after a while?

3. When you blow into a balloon that is fully inflated, why does the balloon pop?

4. Why do you think the balloon became smaller when it was left for a week? The following diagram should provide a hint:



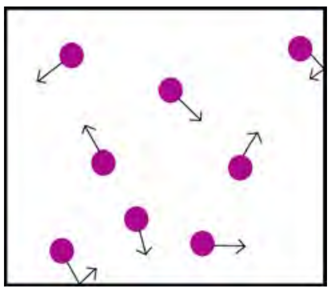
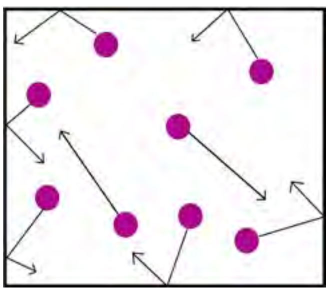
5. Explain why you think it was impossible to blow up the balloon inside the bottle? Why was it possible to blow up the balloon when there was a hole in the bottle?

6. Why does it become more and more difficult to pump air into the bicycle tyre?

How does heating or cooling a gas change its pressure?

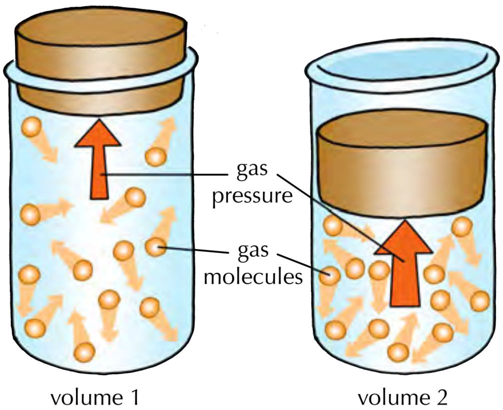
If the gas is heated, the particles will move faster as they gain more energy. That means they will collide with the inside of the container more often and with more force. This causes an increase in pressure.

If the gas is cooled, the particles will move more slowly, because they will have less energy. The gas pressure will decrease, because the particles will bounce against the inside of the container less frequently and with less force. Look at the following table which illustrates this.

Cool gas	Hot gas
	
Fewer and less energetic collisions.	More and more energetic collisions.

How does changing the volume of a gas change its pressure?

When a gas is squeezed into a smaller volume, the particles have less space to move. This is shown in the diagram below. Have you noticed that when people are squashed into small spaces, they bump into things more often? In the same way, the gas particles will collide more often with each other and with the inside of the container if they have less space to move in. More collisions means increased pressure!



We have learnt that a gas will expand to fill all the available space. So, what will happen if we take a certain amount of gas out of one container and place it into another container that is twice as large?

We still have the same number of gas particles, but now they are inside a much larger volume. There is twice as much space between the molecules as there was in the smaller container.

What has happened to the density of the gas? Has it increased, decreased or stayed the same?

In this chapter, we learnt how many different physical properties of matter can be better understood when we think in terms of the behaviour of the particles in the matter.

SUMMARY:

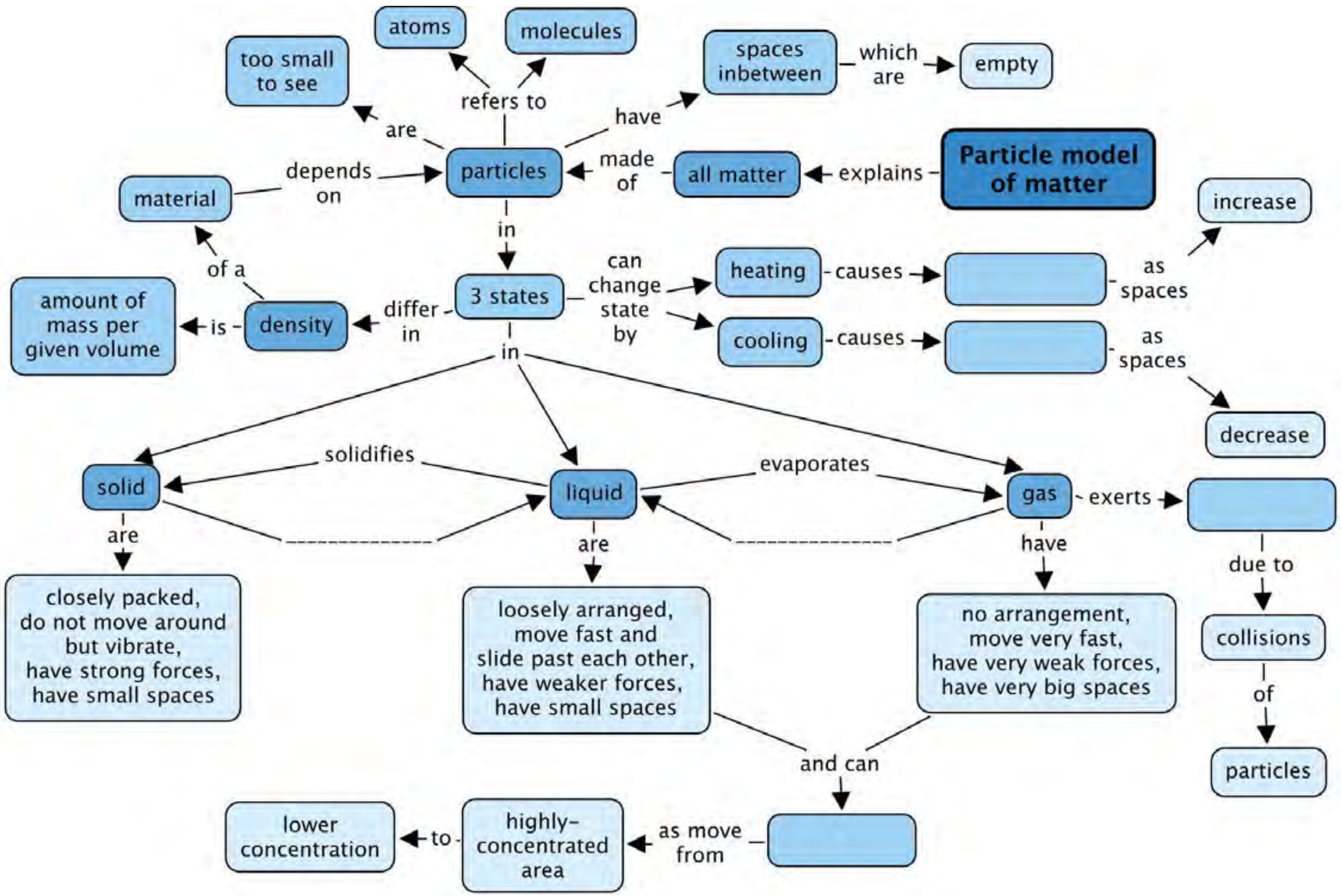
Key Concepts

- All matter can be described in terms of the particles it consists of, and how they are arranged. These extremely small particles are called atoms or molecules, depending on the type of material.
- The theory that describes matter in terms of particles is called the particle model of matter. It helps us to understand the macroscopic properties of a material in terms of the behaviour of the particles in that material.
- The particle model describes the particles in **solids** as follows:
  - They are closely and regularly packed and locked into position;
  - The only movement they are allowed is vibration;
  - They are held together by strong forces; and
  - The spaces between them are very small.
- The particle model describes the particles in **liquids** as follows:
  - They are close together but not locked in position;
  - They are in constant motion and slide past each other;
  - They are held together by moderately strong forces; and
  - The spaces between them are very small (in most cases only slightly larger than the spaces between solid particles).
- The particle model describes the particles in **gases** as follows:
  - They are in constant fast motion;
  - They are not arranged in any way but free to move;
  - The forces between them are weak; and
  - They are far apart with large empty spaces between them.
- Since the particles of liquids and gases are in constant motion they are able to diffuse. Diffusion is a process in which particles spread out, through random movement from high to low concentration, until they are evenly distributed.
- When two substances mix, their particles intermingle until their composition is uniform throughout. This is also called diffusion, and the process is much faster in gases than in liquids, because the particles in gases are further apart.
- Changes of state are usually the result of heating or cooling:
  - When a solid is heated it will change to a liquid (in a process called melting) and, when heated further, the liquid will change to a gas (in a process called evaporation).
  - When a gas is cooled it will change to a liquid (in a process called condensation) and, when cooled even further, the liquid will change to a solid (in a process called freezing).
- The density of a material is a measure of its 'relative heaviness'. Denser materials have a greater mass in relation to their size; that is why they feel 'heavy'.
- The density of a material depends on two things:
  - the mass of the individual particles of that materials - the larger the mass, the denser the material; and
  - the size of the spaces between the particles in the material - the larger the spaces, the less dense the material.
  - These explain how to calculate density, namely density = mass/volume
- Materials with a loose texture (like bread and sponge, for example) have empty spaces or holes inside them, which means they have less mass in relation to their volume. These materials tend to be less dense.
- Materials that are less dense always float on materials that are more dense.

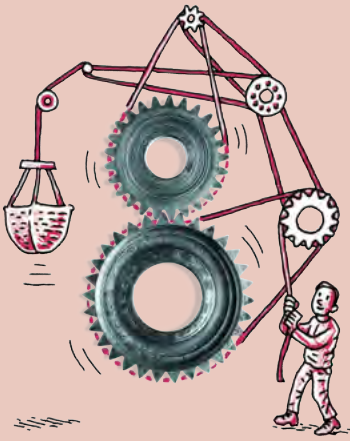
- The particles of matter are constantly moving. In solids these movements are limited to vibrations, but in liquids and gases the particles have more freedom.
- Most materials will expand when they are heated and contract when they are cooled. This is because heating makes the particles move further apart and cooling makes them move closer together.
- When we want to know how much of a gas we have, we can measure its pressure.
- The 'pressure' of a gas is caused by the particles of the gas colliding with the inside of a container and with each other.
- More gas particles inside the container will mean more collisions against the sides, and therefore, more pressure.

Concept Map

Have a look at the concept map that shows how the many concepts relating to the particle model of matter fit together. There are 4 empty blocks which you need to fill in.


Particle model of matter
explains
all matter
made of
particles
refers to
atoms
molecules
are
too small to see
have
spaces inbetween
which are
empty
depends on
material
in
3 states
differ in
density
of a
is
amount of mass per given volume
can change state by
heating
causes
as spaces
increase
cooling
causes
as spaces
decrease
in
solid
solidifies
liquid
evaporates
gas
are
closely packed, do not move around but vibrate, have strong forces, have small spaces
are
loosely arranged, move fast and slide past each other, have weaker forces, have small spaces
have
no arrangement, move very fast, have very weak forces, have very big spaces
exerts
due to
collisions
of
particles
and can
as move from
highly-concentrated area
to
lower concentration

REVISION:



1. Write your own explanation of what you think the particle model of matter tells us. [2 marks]

2. What is unusual about water in terms of the particle model of matter? Explain why water is an exception. [2 marks]

3. Complete the following table with the terms and definitions of different changes of state. [4 marks]

Change of state	Explanation
	When heat is added and a solid changes to a liquid
Condensing	
	When heat is added and the particles at the surface of a liquid change to the gas state
Solidifying	

4. Explain what happens to the particles in a solid when heat is added to the solid and it changes to a liquid. [3 marks]

5. Complete the following sentence by writing it out in full again: During expansion, the spaces between the particles get __________, and during contraction, the spaces between the particles get __________. [2 marks]

6. How can a piece of metal get bigger (expand) and still have the same mass? Explain this in terms of the behaviour of the particles. [2 marks]

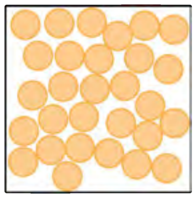
7. Why does oil float on top of water? [1 mark]

8. Draw a picture to show the path of a perfume particle from a flower on one side of a room to your nose on the other. [2 marks]

9. Next time you are at the petrol station, look around for a warning sign that shows you should not light a match or use a cell phone. Why do you think it is dangerous to light a match or use a cell phone anywhere near a petrol station? [2 marks]

10. If you fill a bicycle pump with air, and seal the end with your finger, the plunger can still be pushed in quite a way before the pressure forces air out of the pump. If the pump is filled with water instead of air, the plunger can hardly move. Why is this so? Try to use the words 'particles', 'spaces', and 'compress' in your explanation. [4 marks]

11. The following table represents a summary of the entire chapter. You must complete it, using your own words and or diagrams. Some of the blocks in the table already contain information to help you form your own sentences. [18 marks]

State of matter	Solid	Liquid	Gas
Diagram showing how the particles are arranged			
Arrangement of the particles	Very closely packed. Regular arrangement		
Spaces between particles			Very large
Forces of attraction between particles		Strong, but weaker than in solids	
Movement of particles			Fast and random movement
Shape		No fixed shape Depends on the container	
Volume			No fixed volume Depends on the container
Compressibility	Cannot be compressed		
Diffusion		Diffuses slowly	
Density compared to the other states	Highest density (except in the case of ice)	Almost as dense as the solid	

Total [42 marks]