Matter
Particle model *and* Separating mixtures

Ideas you have met before

States of matter

Solid, liquid and gas are the three main states of matter, and most materials can be grouped into one of these.

When materials are heated or cooled, they may change from one state to another. Water freezes to become ice at 0 °C, and boils to becomes a gas at 100 °C.

In the water cycle, water evaporates to become a gas, condenses in clouds and forms water droplets. It falls back to Earth as precipitation.

Reversible changes

Physical changes, such as changes of state, are reversible. Water can be frozen to make ice; this can melt to form liquid water.

Dissolving and mixing are also reversible changes – salt can be added to water, which can be evaporated to recover the solid salt.

Dissolving and solubility

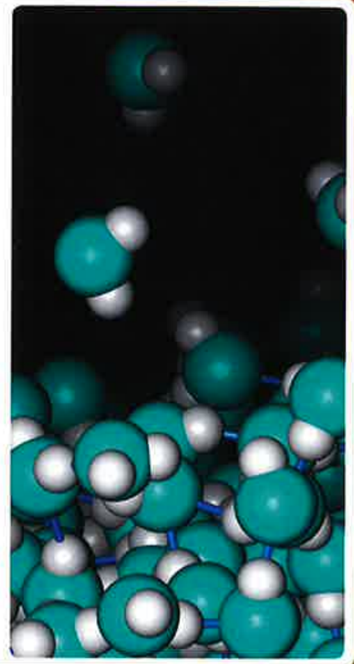
Some materials – such as salt and sugar – can dissolve in water. We say that these are soluble and the mixture forms a solution.

Other materials – such as sand – do not dissolve in water. We say that these are insoluble.

In this chapter you will find out

Using the particle model

- The particle model explains why solids have a fixed shape and cannot flow, and why liquids and gases do not have a fixed shape, and can flow.
- Particles in solids, liquids and gases have their own internal energy – the energy of particles in a gas is far higher than the energy of particles in liquids and solids.
- The effect of temperature can be explained using the particle model. This explains how changes of state take place and how solids, liquids and gases expand on heating.
- We can also explain differences in density, concentration and pressure using the particle model. These differences can account for why perfume spreads in a room.



Separating mixtures

- If solid material has been mixed with water but has not dissolved, we can separate it by using a filter or a sieve.
- If we heat a liquid it will evaporate, turning into a vapour (gas). If we then cool the vapour, it will turn back into a liquid. This process is called distillation.
- We can use information about different boiling points to separate mixtures of liquids. Distillation is used to make perfume and also fuels such as petrol.
- Soluble substances can be made to travel up filter paper by adding a solvent.
- If we do this with coloured dyes or inks, we find that the different colours in the mixture move different distances.
- This technique is called paper chromatography and can be used to separate mixtures and identify chemicals.

Using particles to explain matter

We are learning how to:

- Recognise differences between solids, liquids and gases.
- Describe solids, liquids and gases in terms of the particle model.

Have you ever wondered why it is possible to put your hand through a liquid such as water, or a gas, such as air, but not through a solid wooden door? The answer lies in how the particles are arranged in these states of matter.

Particle arrangement

Anything that takes up space and mass is called 'matter'. All matter is made from **particles**. Particles vary in the ways they are arranged and behave. These are known as different states of matter. Figure 1.5.1a uses a **particle model** to show how particles are arranged in the three most common states of matter – solids, liquids and gases.

1. Name three solids, three liquids and three gases you are familiar with.
2. Describe how the arrangements of particles in solids, liquids and gases differ from each other.

Particles and internal energy

All particles above the temperature known as absolute zero (–273 °C) have internal **energy**. Particles in solids, liquids and gases have different amounts of energy.

- In solids, the particles vibrate in their fixed positions.
- Particles in liquids move randomly from their positions, but are always in contact with other particles.
- Particles in a gas move about randomly and very fast, widely separated from but colliding with other particles.

Temperature affects how fast particles move. At higher temperatures, particles in a solid vibrate faster, while in liquids and gases particles move around faster.

3. Draw a cartoon to describe how the energies of the particles in solids, liquids and gases vary.
4. In which of the following do the particles have the most internal energy – ice, oxygen at room temperature, or steam (over 100 °C)?

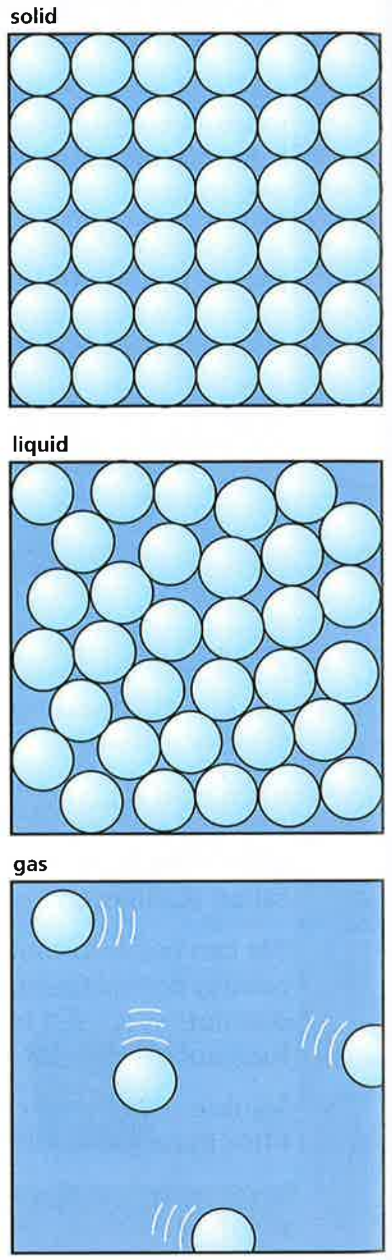


FIGURE 1.5.1a: Solid – particles are in fixed, regular positions.

Liquid – particles are close together and touching. They can move from their position.

Gas – particles have no fixed position and are far away from each other. They can move very fast.

Intermolecular forces

The particles in a solid have very strong, attractive **intermolecular forces** between them, which hold the particles in their positions. Between particles in liquids, the intermolecular forces are still strong, but not as strong as in a solid. This is why the particles are able to move about. The intermolecular forces between the particles of a gas are very weak.

Density is a measure of how much matter there is in a particular volume. The stronger the intermolecular forces are, the more matter can fit into a volume and, therefore, the more dense the substance is.

FIGURE 1.5.1b: How do the intermolecular forces in this solid ice make it rigid?

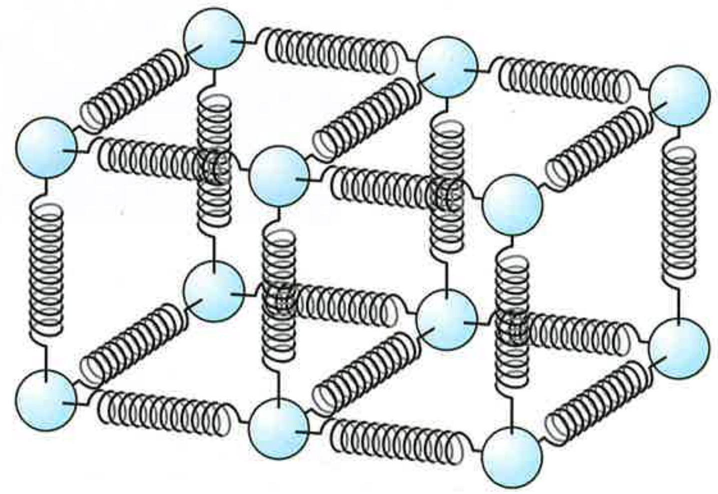


FIGURE 1.5.1c: Forces between particles can be represented by springs. How would you modify this particle model to show a solid with strong intermolecular forces and one with weak intermolecular forces?

Some solids, like metals, have very strong intermolecular forces between the particles – others, like paper, are not nearly as strong.

5. Use ideas about intermolecular forces to explain why you can put your hand through air but not through wood.
6. What can you say about the intermolecular forces between the particles of jelly compared with those of a metal?
7. Compare the density of jelly and the density of solid metal. Explain your answer.
8. Describe the relationship between the energy of the particles and the intermolecular forces holding them together.

Did you know...?

The most common state of matter in the Universe is called 'plasma'. It is known as the fourth state of matter, and is a form of gas. The Sun and space are made of plasma. We can make tools from plasma to cut strong metals.

Know this vocabulary

particle
particle model
energy
intermolecular forces
density

Understanding solids

We are learning how to:

- Describe the properties of solids.
- Relate the properties and behaviour of solids to the particle model.

Some properties are common to all solids and help to define them. Differences between solids can be explained using the particle model.

General properties of solids

Except for mercury, all metals are solid at room temperature. They have high melting points and boiling points, and all conduct heat and electricity well. A few non-metallic solids share these properties, but many others have very different properties.

Flow

Some solids appear as if they can flow, like sand. Seen under a microscope, such a solid is made up of many individual grains. None of the matter in the individual solid grains can flow.

Changing shape

Some solids are **malleable** – they can be hammered into shape without being broken. Solids such as plastic are **brittle** – they will snap if hit. Metals are **ductile** – the layers of particles are able to slide past each other, so they can be pulled into extremely thin wires.

Strength

Strength is the ability of a solid to withstand a force. Metals are generally very strong.

Hardness

Hardness is a measure of how easy it is to scratch a solid – it is not the same as strength. Slate and concrete are very strong solids, but are easily scratched so they are not hard.

Solubility

Some solids, salt for example, dissolve readily in water – they are **soluble**. Others, such as sand, do not dissolve.

Conduction of heat and electricity

Metals will readily **conduct** heat and electricity, whereas **non-metal** solids, like plastic and rubber, will not. The only exception is graphite (a form of carbon), which conducts electricity even better than metals.

FIGURE 1.5.2a: The hardest and strongest material in the world.

Did you know...?

Diamond is the strongest, hardest material in the world. Drills that cut through rock are tipped with diamond.

TABLE 1.5.2: Put these solids in order of hardness.

Substance	Hardness
aluminium	3
carbon (diamond)	10
iron	4
silver	2.5
tin	1.5
copper	3

1. Which property makes copper a good choice for making wires?
2. Use the data in Table 1.5.2 to explain which material you would use on the end of a drill.

What are alloys?

Alloys, such as brass, bronze and chrome, are mixtures of metals. They are often stronger than the individual metals they are made from. Different sizes and colours can be used to represent the different types of atoms in the particle model, as in Figure 1.5.2b.

3. Duralumin is an alloy made from 96 per cent aluminium and 4 per cent copper. What might the particle arrangement look like?
4. Use the particle model to explain why some alloys are less ductile than the metals they are made from.

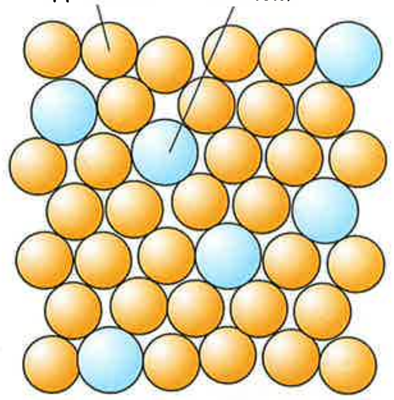


FIGURE 1.5.2b: Bronze is made up of 85 per cent copper and 15 per cent tin.

Explaining properties

Strength, shape, density and hardness all depend on the strength of the intermolecular forces between the particles in a solid.

Solubility also depends on intermolecular forces. In solids which dissolve, forces between the particles of the solid are weaker than the forces between the particles of the solid and the particles of the liquid.

The arrangement of particles in metals is special, accounting for their ability to conduct heat and electricity. This is shown in Figure 1.5.2c.

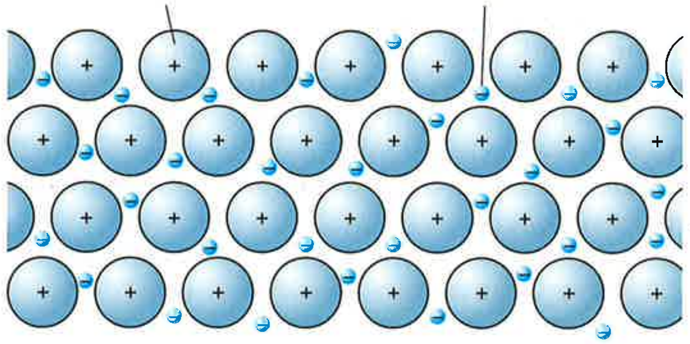


FIGURE 1.5.2c: Metals can conduct heat and electricity because they have small particles (negatively charged electrons) that move freely.

5. How would you modify the particle model to show a solid with strong intermolecular forces and one with weak intermolecular forces?
6. Explain as many differences in the properties of copper and wax as you can, using appropriate particle models.

Know this vocabulary

- **malleable**
- **brittle**
- **ductile**
- **strength**
- **hardness**
- **soluble**
- **conduct**
- **non-metal**
- **alloy**

Understanding liquids and gases

We are learning how to:

- Describe the properties of liquids and gases.
- Relate the properties and behaviour of liquids and gases to the particle model.

We rely on the properties of liquids and gases every day. For example, we rely on the compression of gases to fill a car or bike tyre and in our cans of hairspray or deodorant. Properties of liquids and gases can be explained using the particle model.

Viscosity

Liquids and gases can be poured and can flow. This is because the intermolecular forces holding the particles of a liquid in place are quite strong, but not strong enough to keep the particles in position. They are able to slide over and roll around each other.

Some liquids flow more easily than others. Liquids in which the intermolecular forces are stronger do not flow as easily because it is more difficult for the particles to slide past each other. Resistance to flow is known as **viscosity**. Think of oil and water – oil flows more slowly than water; it is more viscous.

1. Give three applications of liquids and gases that rely on their ability to flow.
2. You want to oil your bike. You decide to investigate three different brands to find out which spreads most easily in the cold.
   a) Which variables must you control?
   b) What would you measure?

FIGURE 1.5.3a: Which of these materials is the most viscous?

The effects of compression

Compression is the process of squashing a material so that the particles move closer together. In a solid and a liquid, there is very little space and, therefore, it is not possible to compress them. In a gas, the particles have space between them and so they can be pushed together more closely. Gases can be compressed.

Figure 1.5.3b shows cylinders that have been filled with gas compressed so much that it has become a liquid. A can of hairspray or deodorant is a smaller version of this. The particles of gas have been forced so close together that they are touching and now are arranged as in a liquid.

3. Explain why oxygen gas is more easily compressed than water or ice.
4. Consider the different substances and compare and explain the particle model for each:
   a) liquid nitrogen and nitrogen gas;
   b) ice, water and steam;
   c) deodorant when it is in the can and as it is sprayed into the air.

Explaining pressure in gases

When gas particles move, they have collisions between themselves and also with the sides of the container they occupy. The **gas pressure** is a measure of the average force of these collisions over the area of the container's sides. The standard units of pressure are **kilopascals** (kPa).

Pressure is increased when there are more particles and, therefore, more collisions with the sides of the container.

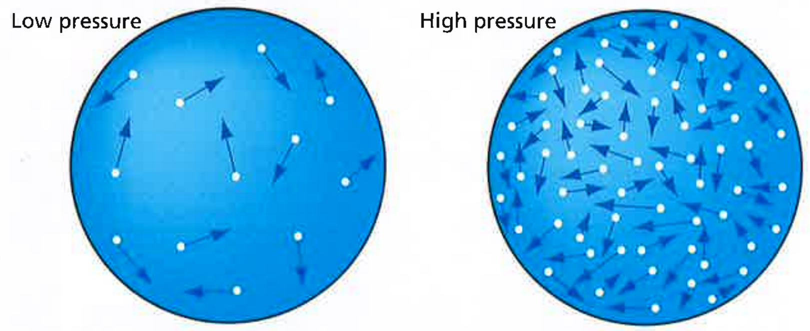


FIGURE 1.5.3c: What do we mean by pressure?

Increasing the temperature causes the particles to move faster. This increases the force of the collisions against the sides of the container, and their frequency, meaning that the pressure is increased.

5. Suggest one reason why atmospheric pressure is lower at the top of a mountain than at sea level.
6. Using the particle model, draw the same gas at three pressures: low, medium and high pressure.

FIGURE 1.5.3b: The cylinders contain gas which has been liquefied. When released, the change in pressure causes the liquid particles to become gas particles again.

Did you know...?

In the world's longest-running experiment, scientists have been measuring the viscosity of pitch tar by timing how long it takes to fall through a funnel. It has taken between 7 and 13 years for each drop to fall and the experiment has been running since 1927!

Know this vocabulary

viscosity
compression
gas pressure
kilopascal

Matter

Exploring diffusion

We are learning how to:

- Use the particle model to explain observations involving diffusion.

Diffusion is a process in which particles move and spread out. Unsurprisingly, gas particles diffuse much faster than particles in other states of matter. What makes diffusion so special?

Examples of diffusion

Diffusion occurs because of the movement of particles in a gas or a liquid. There is hardly any diffusion in solids because the particles cannot move freely. Gas particles move faster and further than liquid particles, so diffusion in gases occurs faster than in liquids.

All smells spread as a result of diffusion. When particles of a gas, like air freshener spray or odours from smelly socks, are released into the air, they spread out. These gas particles move through the air – when they reach your nose they are detected as a smell. This is why we can detect smells from a long distance away.

1. Give another example of diffusion in everyday life.
2. Why do smells become weaker the further you are from the source?

FIGURE 1.5.4a: If a drop of coloured ink is added to water, after several hours the colour will have spread through the water so that it is of equal concentration throughout.

Diffusion and the particle model

Concentration is a measure of the number of particles packed in a certain volume.

Diffusion occurs because particles move from an area of high concentration to an area of low concentration, until the concentration is equal throughout. We call this the point of **equilibrium**. The difference in concentration is known as the **concentration gradient**. The higher the concentration gradient, the greater the rate of diffusion.

Temperature affects the rate of diffusion because it affects the energy of the particles.The higher the temperature, the higher the kinetic energy of the particles, and the faster they move in such a way as to reduce the concentration gradient.

Did you know...?

The animal kingdom is full of amazing examples of how animals make use of diffusion to smell odours. Elephants can detect water sources from up to 20 kilometres away.

3. If a drop of ink is added to some pure water, and a similar drop of ink is added to some dilute ink solution, in which solution would diffusion happen fastest? Explain your answer.
4. Think about these examples of diffusion. Suggest which will reach equilibrium first and explain your answer.
   - **a)** placing a spoonful of cordial in 50 cm^3 of hot water;
   - **b)** adding a spoonful of coffee to 50 cm^3 of cold water.

Explaining diffusion

Look at Figure 1.5.4b. Concentrated hydrochloric acid is placed at one end of the tube and concentrated ammonia at the other end. Particles of ammonia are smaller than particles of hydrochloric acid. When the particles diffuse, they meet and react, forming a white cloud of ammonium chloride.

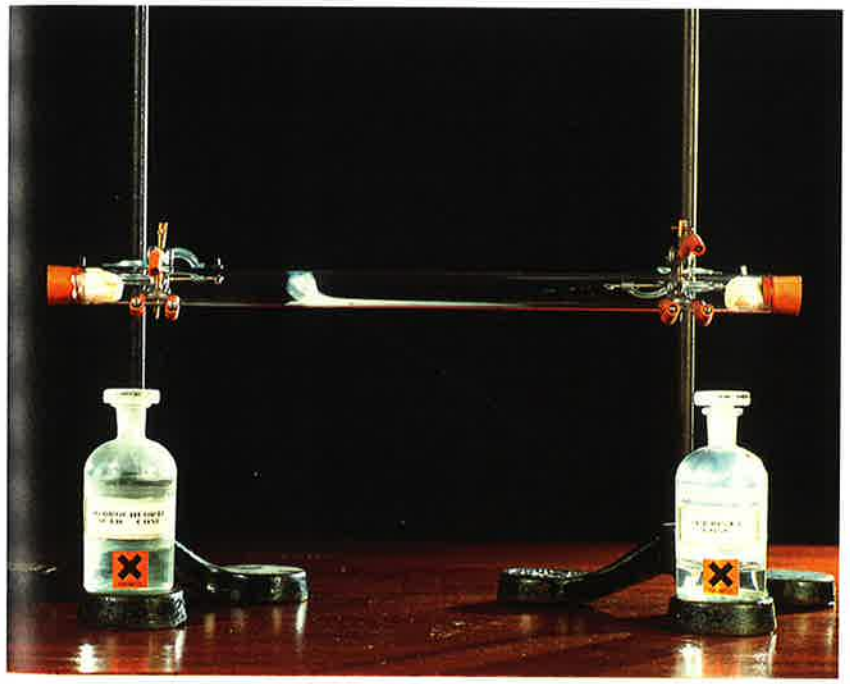


FIGURE 1.5.4b: How do the hydrochloric acid particles and ammonia particles reach each other to react?

5. What would happen if the concentrated solutions were replaced by dilute solutions of both hydrochloric acid and ammonia?
6. How might the formation of the white ring be speeded up? Explain your answer.
7. Why doesn't the white ring in Figure 1.5.4b form in the centre of the tube?

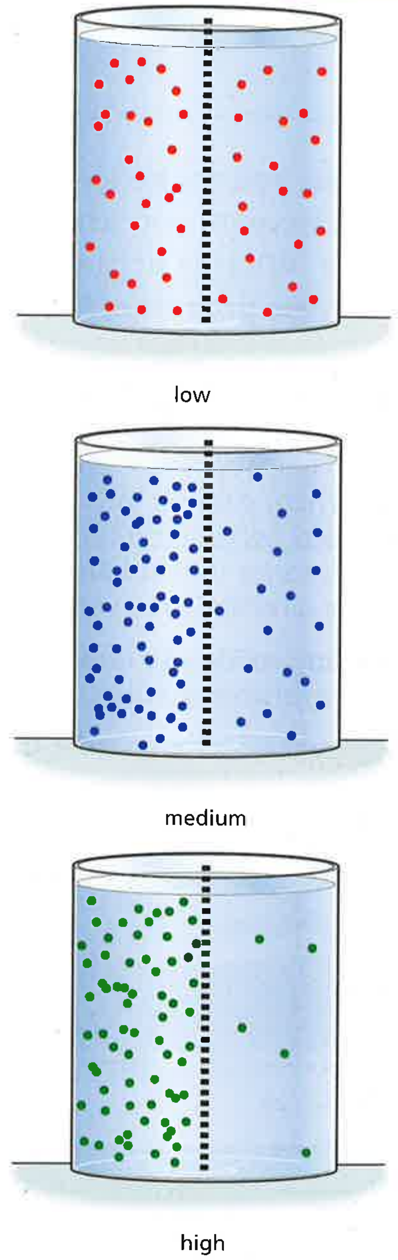


FIGURE 1.5.4c: Compare the concentration gradients in the diagrams. This affects the rate of diffusion.

Know this vocabulary

diffusion
concentration
equilibrium
concentration gradient

Explaining changes of state

We are learning how to:

- Recognise changes of state as being reversible changes.
- Use scientific terminology to describe changes of state.
- Explain changes of state using the particle model and ideas about energy transfer.

When you make ice or **melt** the frost from a windscreen, you are making use of changes of state. What is actually happening to the particles in these processes?

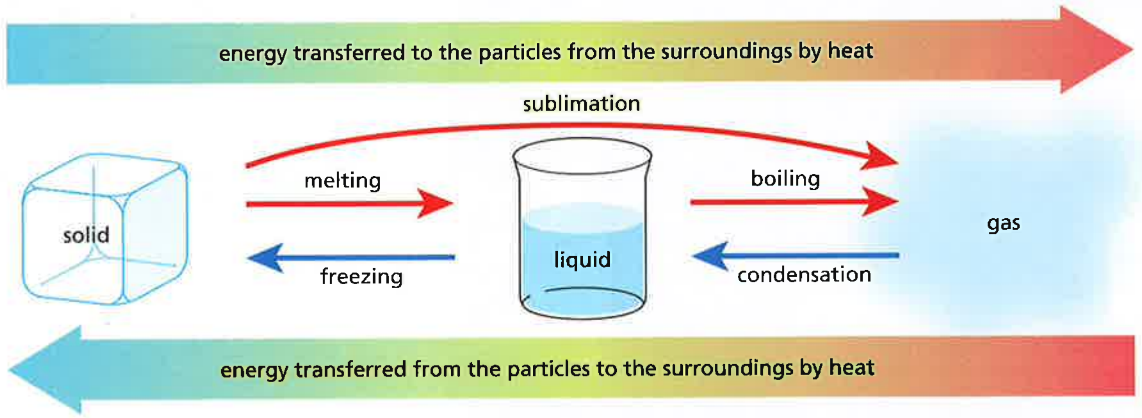
Reversible changes

Have you ever seen 'dry ice'? It is solid carbon dioxide that is turning straight into a gas – there is no liquid state. This is a process called sublimation. Iodine is another example of a substance that **sublimes**. If the gas is cooled sufficiently, it turns directly into a solid.

Turning solids into liquids or gases, and liquids into gases are reversible changes. They are called physical changes.

Figure 1.5.5b summarises the processes by which substances change their state.

FIGURE 1.5.5a: Solid carbon dioxide is known as 'dry ice'.



FIGUE 1.5.5b: The changes of state.

1. Describe how you could show that making water **freeze** is a reversible change.
2. Use Figure 1.5.5b to describe the meaning of the following words:

   a) melting; **b)** condensing; **c)** boiling;
   d) freezing; **e)** sublimation.

Changing state

The temperature at which a pure substance melts or freezes is fixed – it is called the **melting point** or freezing point, depending on the change taking place.

When a pure substance **boils** or condenses, this also occurs at a fixed temperature called its **boiling point**.

Different substances have different melting points and boiling points. These points depend on the strength of their intermolecular forces.

3. Aluminium melts at 660 °C but copper melts at 1064 °C. Explain why, in terms of intermolecular forces.
4. At 0 °C, hydrogen is a gas, mercury is a liquid and water is a solid. What can you infer about the inter-particle forces in each from this data? Explain your answer.

Did you know…?

Helium has the lowest melting point of all elements at –272 °C, whereas diamond (carbon) has the highest melting point, at 3500 °C.

Differences between boiling and evaporation

At the upper surface of a liquid, the liquid **evaporates**. Evaporation occurs at any temperature between the melting point and the boiling point. It occurs only at the surface of the liquid. Some of the surface particles gain enough kinetic energy from heat, from the surroundings, to leave the surrounding particles in the liquid and become a vapour. Over time, all the particles at the surface will evaporate.

FIGURE 1.5.5c: How is evaporation different from boiling?

Some liquids, such as alcohol, have weaker intermolecular forces than others, such as water. Therefore, with the same amount of energy transferred from the surroundings, more alcohol particles than water particles will escape as a gas.

Boiling, however, occurs only at the boiling point, and the whole liquid changes into a gas. The water particles gain sufficient energy from their surroundings to leave the liquid.

5. Is evaporation more likely to take place at temperatures near the boiling point or near the melting point? Explain your answer.
6. What are the main differences between boiling and evaporation?

Know this vocabulary

melt
sublime
freeze
boil
condense
melting point
boiling point
evaporate

Separating mixtures

We are learning how to:

- Recognise the differences between substances and use these to separate them.

If you put different objects together, such as different fruits in a bowl, toys in a box or sweets in a bag, you have a mixture. Air, fruit juice, milk and sea water are also mixtures. Some mixtures are harder to separate than others.

Using size to separate mixtures

A **pure substance** contains only one type of particle – for example, gold is a pure substance. A **mixture** is made up of at least two pure substances – for example, gold and copper together make a mixture.

Gravel and rocks can be removed from sand by sieving. This separation depends on the size of the holes in the sieve. However, if the sand were mixed with water, this method would not work. A **filter** would be needed instead.

FIGURE 1.5.6a: Using a sieve.

Filters are often made of paper or cloth with very small holes that are difficult to see without a microscope. Filters are often used to remove the solids when making coffee. Tea bags act as filters, whereas a tea strainer acts as a sieve. Air and fuel filters are used in cars to remove particles that would damage the engine.

1. What is the difference between a filter and a sieve?
2. Explain how filters and sieves are helpful when making tea and coffee.

Being different

Mixtures can be separated by finding differences in physical properties between the substances. For example, there are only three metals that are attracted by a magnet – iron, cobalt and nickel. We can use this difference to separate these **magnetic** metals from mixtures.

FIGURE 1.5.6b: The physical property of magnetism can be used to separate magnetic from non-magnetic materials.

Rules for mixtures	
1	Mixtures can be separated by physical methods.
2	Mixtures only have the properties of the things in the mixture.
3	Mixtures of substances can be made using different amounts of each one.
4	No chemical change occurs when making mixtures.

TABLE 1.5.6

3. Choose a method to separate flour and rice.
4. Would all of a mixture containing iron filings and lead powder be magnetic?
5. If nickel chloride were mixed with lead, could you use a magnet to separate them? Explain your answer.
6. Use the rules in Table 1.5.6 to explain why mixtures can be separated using known differences between the substances.

Did you know...?

The components of blood can be separated by spinning the blood really fast in a centrifuge. This causes the red blood cells to separate from the plasma because they are denser and move to the bottom.

Separation by filtration

In the laboratory, filter paper can be used to separate some solids from liquids – this process is called **filtration** (Figure 1.5.6c). Substances that do not dissolve in a liquid are described as **insoluble**. Filtration separates out these insoluble solid substances.

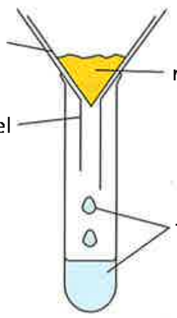


FIGURE 1.5.6c: Separating mixtures by filtration.

Liquids like oil and water do not mix. The oil does not dissolve in the water to make a solution. These liquids are described as **immiscible**. The lighter oil floats on top of the water, and even if you shake the mixture, the two layers will reappear as the two liquids separate again.

The way these two liquids behave means that a separating funnel can be used to split them up (Figure 1.5.6d). The water layer can be removed using the tap at the bottom, leaving the oil layer behind.

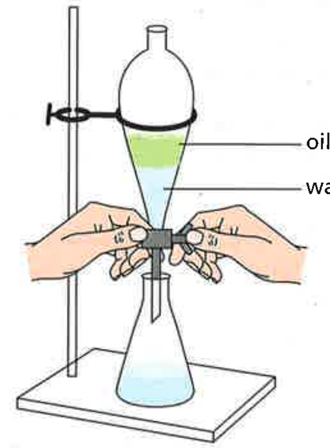


FIGURE 1.5.6d: Using a separating funnel to separate immiscible liquids.

7. Explain why a bottle of salad dressing made from vinegar and olive oil must be shaken before use.
8. Explain why filtration would not separate sugar and water.
9. Create a key or flow diagram to help explain which method of separation to use for a mixture of your choice.

Know this vocabulary

pure substance
mixture
filter
magnetic
filtration
insoluble
immiscible

Exploring solutions

We are learning how to:

- Explain the terms solvent, solution, solute and soluble.
- Separate a soluble substance from water.
- Analyse patterns and present data to explain solubility.

Limestone caves are amazing places. Stalactites grow down from the roof and, where the water drips down and hits the cave floor, stalagmites grow upwards. They are formed as minerals that were once dissolved in the water come out of solution and form solid deposits.

FIGURE 1.5.7a: Even rocks dissolve.

Do you take sugar?

If you stir sugar into a cup of tea or coffee the crystals disappear – they **dissolve**. The water is called the **solvent**, the sugar is the **solute** and the mixture is called a **solution**. The sweeter the taste, the more sugar has dissolved. Substances that dissolve are described as **soluble**.

One way to help things dissolve is to increase the temperature of the water. This is why we wash clothes in warm water. Any soluble stains in the clothes will dissolve better at a higher temperature. The mass of solute that dissolves in a solvent at a particular temperature is called its **solubility**.

Look at the data in Table 1.5.7. The results show the mass of sugar (sucrose) that can dissolve in 100 g of water.

TABLE 1.5.7: Dissolving sugar in water at different temperatures.

Temperature of water (°C)	0	20	40	80
Mass of sucrose that can dissolve (g)	180	200	240	600

1. What is a solution?
2. What does the data in Table 1.5.7 tell you about the solubility of sucrose at different temperatures?
3. How could you display this data to show the pattern more clearly?
4. Estimate the mass of sucrose that will dissolve in 100 g of water at 60 °C.

Did you know...?

These amazing natural gypsum crystals were found 300 metres underground in a mine in Mexico. They have grown undisturbed for thousands of years. Some are as long as 12 metres.

FIGURE 1.5.7b: Naica gypsum crystals.

Using graphs

Soluble substances dissolve more easily in hot water because the water molecules have more energy and move faster. They can break down the solute crystals and separate the solute particles more quickly.

Solubility also depends on the type of solute. The graph in Figure 1.5.7c shows the change in solubility of different salts with temperature.

5. Look at Figure 1.5.7c. Which salt is most soluble at 60 °C?
6. If 50 g of potassium nitrate were added to water at 20 °C, would it all dissolve? How do you know?
7. Using your knowledge of dissolving, explain why there is a connection between the temperature of a solvent and the solubility of a salt.

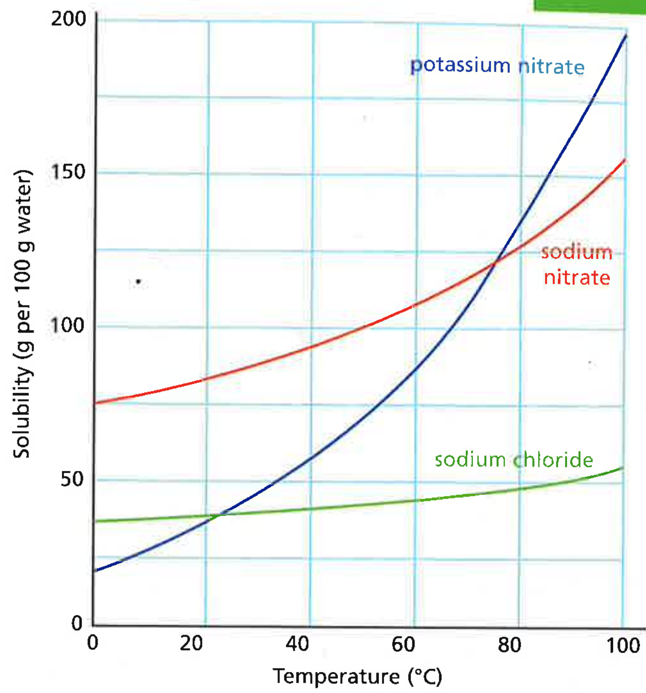


FIGURE 1.5.7c: Solubility graphs.

Explaining solubility

Some substances are more soluble than others. Solute particles have forces of attraction between themselves and the solvent particles. When the forces of attraction between the solute and solvent are stronger than the inter-particle forces between the solute particles, the solute will dissolve. The solute particles fill the spaces between the solvent particles. When all the spaces are filled up, the solution is said to be saturated, because no more solute can be dissolved.

If the temperature is increased, the solvent particles move with more energy, moving further apart and creating more space. More solute can be dissolved at the higher temperature because there are more gaps that can be filled.

8. Adapt the particle model to explain why some solids are more soluble than others.
9. Can the particle model be used to show how temperature affects solubility? What are the strengths and limitations of the model?

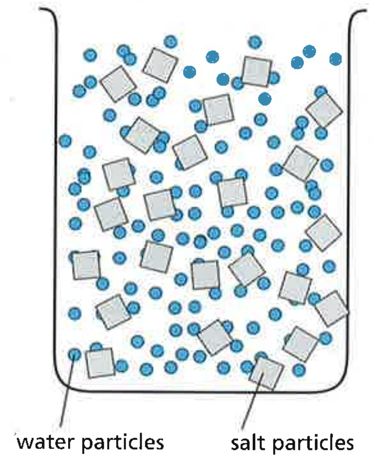


FIGURE 1.5.7d: Solute particles fill the spaces between the solvent particles while dissolving.

Know this vocabulary

dissolve
solvent
solute
solution
soluble
solubility

Matter

Understanding distillation

We are learning how to:

- Use distillation to separate substances.
- Explain how distillation can purify substances.

Distillation is used in making perfumes, fuels (such as petrol) and alcoholic drinks (such as vodka). It is an important separation process involving heating and cooling.

Heating and cooling

On a cold day water **vapour** from a bath or kettle can **condense** on a cold surface. It cools down and turns back to water. This is one of the processes involved in **distillation.** Liquid mixtures can be separated using distillation.

When water boils it is hard to catch all of the water vapour because it mixes into the air. In distillation the vapour is cooled, which allows it to be collected as a liquid.

The distillation apparatus that we use is shown in Figure 1.5.8b. In the Liebig condenser, the hot vapour from the boiling liquid flows through the inner tube, while cold water runs though the outer tube. This keeps the inner glass tube cold and condenses most vapours easily. The liquid collected at the end is called the distillate.

FIGURE 1.5.8a: Condensation is one of the processes involved in distillation.

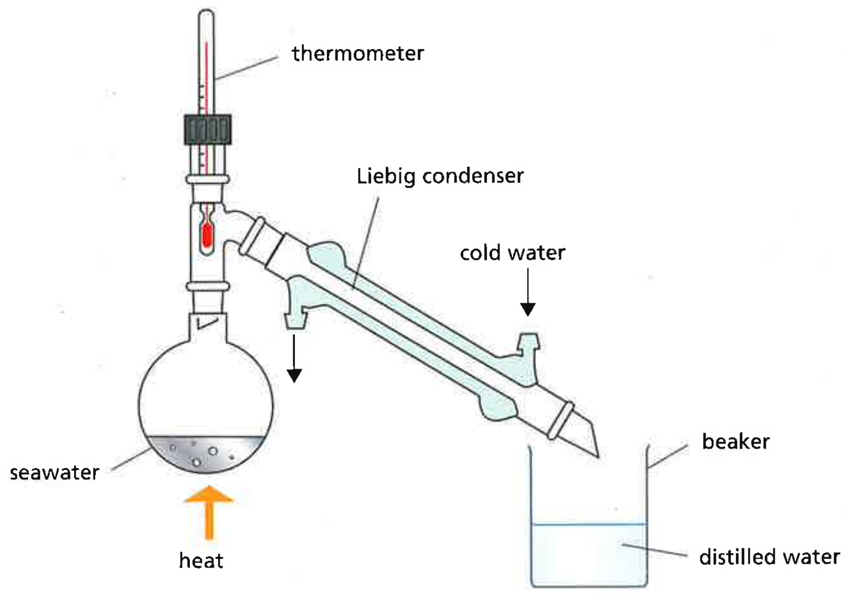


FIGURE 1.5.8b: Distillation apparatus using a Liebig condenser.

Did you know...?

Steam distillation is used to obtain essential oils from plants such as herbs and flowers. The products are used in aromatherapy, flavourings in foods and drinks, and as scents in perfumes, cosmetics and cleaning products.

1. Why does steam turn into liquid water when it touches a window?
2. Describe the structure of a Liebig condenser.
3. Explain why the Liebig condenser uses cold water.

Distilling mixtures

There are two changes of state in distillation. First, a liquid is evaporated by heating and then the cooled vapour is condensed back to a liquid. When salty water is heated, only the water (solvent) changes state and the salt (solute) is left behind. The water produced is called distilled water.

Different liquids boil at different temperatures – for example, ethanol boils at 78 °C and water at 100 °C. This means that mixtures of liquids can be separated using distillation. A thermometer at the top of a distillation flask shows the temperature of the vapour being condensed and hence identifies the substance being separated. Distillation is an effective way of **purifying** ethanol or increasing the concentration of alcoholic drinks. It is also useful for separating flammable liquids like petrol and diesel because the vapours never come into direct contact with the flame.

4. Name three substances that are separated using distillation.
5. Why is a thermometer important in distillation?
6. Explain how water and ethanol are separated.

The challenge of separating

When separating mixtures, the properties of the substances in the mixture must be considered.

For example, salt can be separated from a solution of salt water using evaporation because water evaporates but the salt doesn't. However, if we wanted to preserve the water as well, we would need to use distillation.

A mixture of solids may be separated by using a magnet if only one of the mixture is magnetic, for example, iron, cobalt or nickel.

7. Consider the mixtures that could be made from the pairs of substances in Figure 1.5.8c. Describe how you would separate them, and explain your reasoning.

FIGURE 1.5.8c: How would you separate mixtures of these pairs of substances?

Know this vocabulary

vapour
condense
distillation
purify

Exploring chromatography

We are learning how to:

- Use chromatography to separate dyes.
- Use evidence from chromatography to identify unknown substances in a mixture.

Chromatography is one of the most important separation methods used to identify unknown substances. There are many types of chromatography – some use liquids and some use gases. Chromatography is used by scientists to detect drugs and explosives and to identify dyes and paints.

FIGURE 1.5.9a: Separation by chromatography.

Separating colours

Black ink is not just a black colour mixed with water. Black ink is a mixture of colours. Filter paper and water can be used to separate these colours. This method of separation is called paper **chromatography**. Figure 1.5.9b shows a simple method. Drops of water (solvent) are added to the middle of the paper where the ink spot is placed.

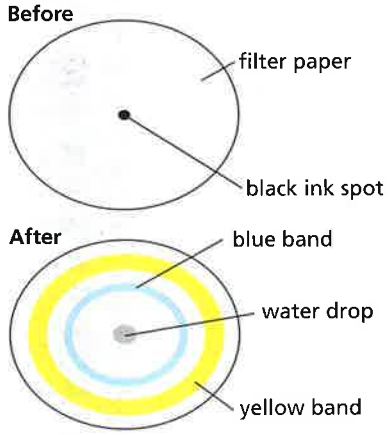


FIGURE 1.5.9b : A simple method of separating ink colours.

1. What evidence is there that black ink is not pure?
2. What causes the ink to spread across the wet filter paper?
3. Describe what we mean by chromatography.

Examples of chromatography

If you cut a section of the filter paper, it can act as a wick. By dipping this wick into water, the liquid is drawn up through the ink and the colours begin to separate.

This method, shown in Figure 1.5.9c, is called ascending paper chromatography, because the water soaks up from the base, carrying the colour spots with it. Some colours move faster than others, which is why the colours separate.

The resulting pattern of colours is a **chromatogram**.

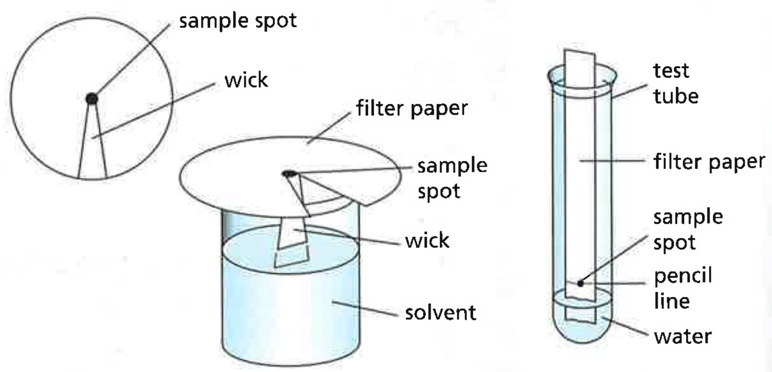


FIGURE 1.5.9c: Another method of paper chromatography.

It is possible to use chromatography for colourless mixtures, but the chromatogram must be developed by spraying the paper with a chemical to make the spots visible, or using an ultraviolet (UV) light to look at the spots.

4. What do we call the pattern of colours on the paper?
5. In Figure 1.5.9c, why is the line drawn in pencil and not in ink?
6. Why would paper chromatography be no good for separating salt from water?

A special separation technique

Samples of DNA gathered at crime scenes can be used to identify or eliminate suspects. DNA is the material in our cells that we inherit from our parents. The sample is treated with special chemicals and then injected into a gel. When an electric current passes through the gel, the components of the DNA separate and spread, just like the ink on the chromatography paper. This is called electrophoresis. The pattern that the DNA produces is unique to an individual person, like a fingerprint.

Scientists can use DNA 'fingerprints' to find out who you are related to. Your DNA fingerprint contains aspects of the DNA patterns of each of your parents.

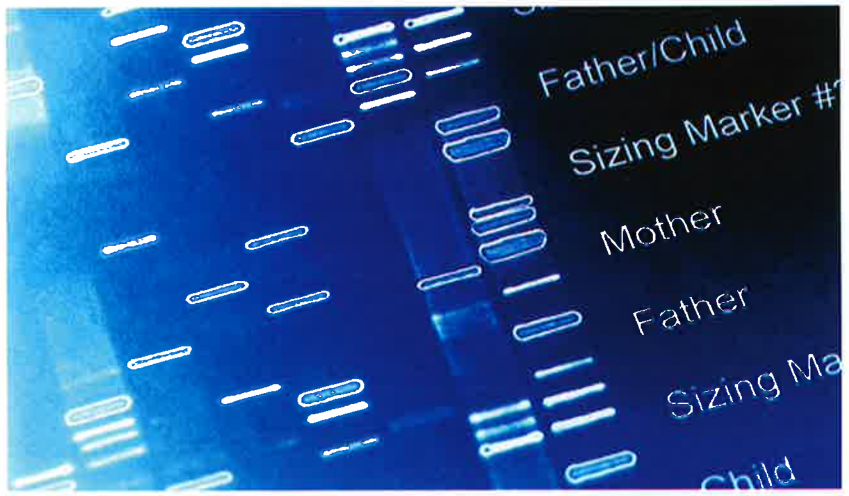


FIGURE 1.5.9e: DNA fingerprinting can help to incriminate suspects or rule them out.

7. Explain how DNA fingerprinting is similar to chromatography.
8. What are the differences between chromatography and electrophoresis?
9. What precautions would forensic scientists have to take when gathering and testing DNA evidence?

Did you know...?

You can separate pigments in leaves by chromatography using ethanol as the solvent. Chlorophylls are green pigments that help plants make food via photosynthesis. The yellow pigment separated here is carotene, which is found in carrots and is used as a food colouring (E160a).

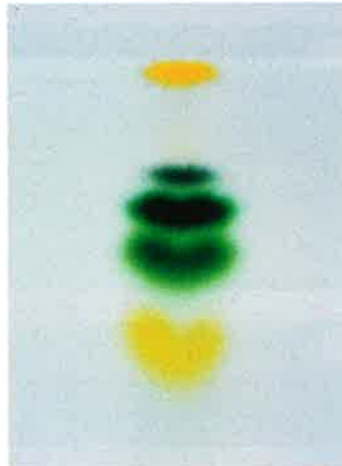


FIGURE 1.5.9d: A plant pigment chromatogram.

Know this vocabulary

chromatography
chromatogram

Checking your progress

To make good progress in understanding science you need to focus on these ideas and skills.

- Compare the properties of solids, liquids and gases.
- Draw particle diagrams to demonstrate the differences between the arrangement of particles in solids, liquids and gases, and describe their different properties.
- Use particle diagrams to explain the differences in energy and forces between the particles in different states of matter, accounting for differences in their properties.

- Use correct terminology and the particle model to describe changes of state, including evaporation.
- Interpret data relating to melting and boiling points.
- Explain data relating to melting and boiling points in terms of intermolecular forces.

- Describe what is meant by the terms 'concentration' and 'pressure'.
- Describe the effects of changing concentration and pressure in terms of particles.
- Explain the effects of changing concentration and pressure in terms of particles, and apply to processes such as diffusion and gas compression.

- Describe some methods to separate mixtures.
- Select and explain appropriate separation techniques.
- Explain the choice and method of separation using correct terms.

- Define solvent, solute, solution and soluble.
- Interpret solubility graphs to compare solubility of different solutes and describe the effect of temperature on solubility.
- Explain solubility and the effect of temperature in terms of particles and intermolecular forces.

- Describe the process of distillation.
- Explain the physical processes involved in distillation.
- Identify the uses and advantages of distillation.

- Identify mixtures using chromatography.
- Explain how to separate a mixture using chromatography.
- Use chromatograms to explain the composition of mixtures; compare chromatography and DNA analysis.

Questions

KNOW. Questions 1–7

See how well you have understood the ideas in this chapter.

1. Which of the following statements is true? [1]

a) Particles in a solid have more energy than particles in a liquid.
b) Particles in a gas have weaker intermolecular forces than particles in a liquid.
c) Particles in a liquid have more internal energy than particles in solids and gases.
d) Particles in a solid do not have any internal energy because they do not move.

2. What does diffusion depend on? A difference in: [1]

a) temperature **b)** state **c)** concentration **d)** mass

3. Describe, using ideas about particles, how temperature affects the viscosity of liquids. [2]

4. When steam hits a cold window, it becomes a liquid. Name this change of state of matter and explain what happens in terms of particles. [2]

5. What do we mean by an insoluble material? [1]

a) It will not dissolve. **b)** You cannot get it back after it has dissolved.
c) It dissolves other things well. **d)** It will dissolve easily.

6. Filtration separates mixtures on the basis of a difference in which property of the substances in the mixture? [1]

a) Solubility **b)** Boiling point **c)** Magnetism **d)** Particle size

7. Describe how you could safely separate salt from salt water, retaining both the salt and the water. [4]

APPLY. Questions 8–13

See how well you can apply the ideas in this chapter to new situations.

8. Iron has a melting point of 1535 °C and a boiling point of 2750 °C. At which temperature will iron be a liquid? [1]

a) 2752 °C **b)** 2751 °C **c)** 1534 °C **d)** 1536 °C

9. The density of water is 1 g/cm^3 and that of syrup is 1.3 g/cm^3. Which of the following statements is false? [1]

a) In a mixture of syrup and water, the water will float on top.
b) The syrup is more dense than the water.
c) In a mixture of syrup and water, the syrup will float on top.
d) There is more mass per unit volume in syrup than in water.

10. Figure 1.5.11a shows the particles of different substances. Which particle diagram represents a shaving foam aerosol? [1]

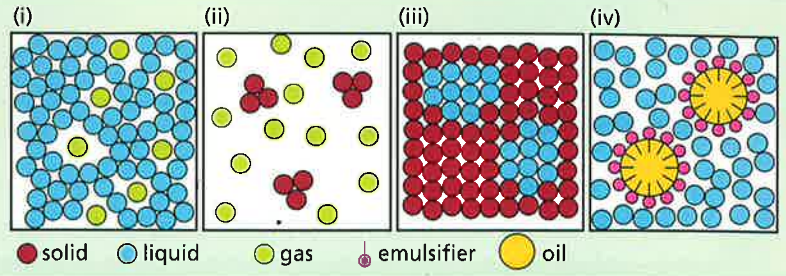


FIGURE 1.5.11a

11. Aerosol cans have a warning on them to prevent their use on fires. Explain reasons for this, using ideas about particles. [4]

12. A good way of separating a mixture of petrol and water is: [1]

a) distillation; **b)** filtering; **c)** crystallisation;
d) chromatography; **e)** using a separating funnel.

13. Marcus and Lisa are investigating how well different brands of sugar dissolve in water. Using Table 1.5.11:

a) Explain what the results show. [2]
b) What do they have to do to make sure it is a fair test? [2]

Brand of sugar	Mass used (g)	Volume water (cm^3)	How many stirs to dissolve it all
Kyle & Tait	10	100	14
Finegrade	10	100	8
Spoonful	20	200	12
Delightful	20	200	7

TABLE 1.5.11

EXTEND. Questions 14–15

See how well you can understand and explain new ideas and evidence.

14. Butane (C_4H_{10}) is camping fuel. Its boiling point is –1 °C. Hydrogen (H_2) is also a fuel, with a boiling point of –252 °C. Both fuels are transported under pressure, turning them into a liquid so that more particles can be carried. Explain which fuel will be easier to transport in this way and why. [2]

15. A vet has been asked to find out if any of four horses, A, B, C and D, have been drugged. She takes urine samples from the four horses and arranges for a lab to prepare a chromatogram to test the samples. What do the results show? [4]

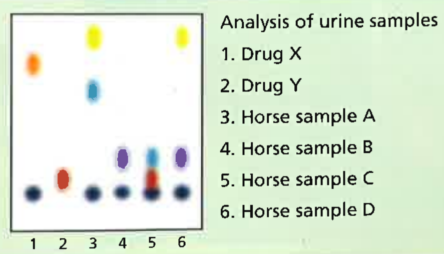


FIGURE 1.5.11b: Chromatogram of horse urine samples.