

Objectives

By the end of this topic you will be able to:

- give a definition of matter
- give the four main ideas of the particulate theory of matter
- explain why scientists find the particulate theory of matter useful
- identify the three main states of matter
- explain the relationship between temperature and the motion of particles.

**Exam tip**

It is important that you know the **definitions** of key terms used in Chemistry. These definitions are provided for you in the 'Key fact' boxes throughout the book.

**Key fact**

Matter is anything that has mass and occupies space.

**Key fact**

The **particulate theory of matter** states that all matter is made up of particles.

Chemistry is the study of the structure and behaviour of matter. Everything around us is made of matter. Matter has both mass and volume. Air, water, sand, human beings and animals are all matter. Matter exists in various states. The three main states of matter are solid, liquid and gas.

A1.1 The particulate nature of matter**Matter**

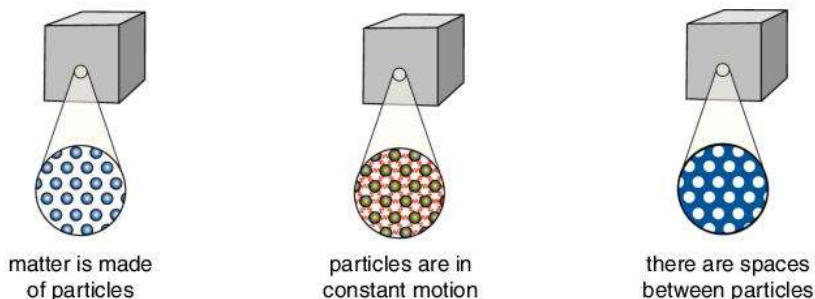
As far back as 460 BC a Greek philosopher called Democritus developed the idea that **matter** consisted of particles. He asked this question: 'If you cut a piece of matter, for example, a piece of gold, in half and then cut it in half again, how many cuts will you have to make before you can cut it no further?' Democritus thought that it ended at some point, the smallest bits of matter, and that these smallest bits of matter, or **particles**, would be the basic building blocks of matter. Today scientists have added to Democritus' idea and now describe matter and its properties using the particulate theory of matter.

The particulate theory of matter

The **particulate theory of matter** states that all matter is made of particles. This theory is very useful because it helps us to explain both the physical properties of matter and also the differences between the three states of matter. We will be looking at the three states of matter in detail in Unit A1.3.

The particulate theory of matter has *four* main ideas:

- all matter is made of particles
- the particles are in constant, random motion
- there are spaces between the particles
- there are forces of attraction between the particles.



▲ **Figure 1.1.1** The particulate theory of matter

The particulate theory of matter can be used to explain many physical phenomena that we observe in our everyday lives. Examples of some of these are given on the next page. It explains:

- The difference in density of solids, liquids and gases, e.g. why pebbles sink and bubbles rise in water.
- How cooling a liquid can cause it to change into a solid, e.g. when water is placed in a freezer it forms ice.
- Why a smell can move throughout a room, e.g. when chicken is frying, it can be smelt at the other side of the kitchen.
- Why the pressure of a gas increases with an increase in temperature, e.g. car tyres get harder as you drive.
- Why certain vegetables become crisper when soaked in water, e.g. raw potatoes.
- Surface tension in liquids, e.g. certain insects can 'walk' on water.



▲ Figure 1.1.2 Pebbles sink in water

States of matter

Matter can exist in various forms or **states**. The three states of matter that are the most common are the **solid**, **liquid** and **gaseous** states. The difference between these states lies in the energy and arrangement of the particles.

Particles in the solid state have the least amount of energy, they simply vibrate in their fixed position and they are packed closely together. Particles in the liquid state have medium amounts of energy, they move about slowly and they have small spaces between them. Particles in the gaseous state have the greatest amount of energy, they move about rapidly and they have large spaces between them. You will study this in greater detail in Unit 1.3.

The energy of the particles is directly related to the temperature of the particles and matter can change from one physical state to another by changing its temperature. This change of state occurs because increasing the temperature of a substance increases the **kinetic energy** of the particles in the substance. The greater the kinetic energy the particles possess, the faster they move.

Changing state by changing temperature is a **physical change**. A physical change occurs when the form of the substance is changed without changing its chemical composition, for example, water as a solid, i.e. ice, has exactly the same chemical particles as water in the liquid state and as water in the gaseous state, i.e. water vapour.



▲ Figure 1.1.3 The drinks illustrate the three states of matter

Summary questions

- 1 State the three main ideas of the particulate theory of matter.
- 2 If a crystal of potassium manganate(VII) is dropped into a beaker of water, the purple colour spreads throughout the water. What features of the particulate theory of matter does this observation provide evidence for?
- 3 Explain why scientists find the particulate theory of matter useful.
- 4 What are the three states of matter?
- 5 What is the relationship between temperature and the movement of particles?

Objectives

By the end of this topic you will be able to:

- explain evidence which supports the particulate theory of matter
- explain the processes of diffusion and osmosis
- describe experiments which demonstrate diffusion and osmosis
- explain the uses of salt and sugar to control garden pests and preserve food items.



Key fact

Diffusion is the movement of particles from an area of higher concentration to an area of lower concentration until they are evenly distributed.



Exam tip

It is very important when answering questions in tests or examinations to distinguish between **observations** and **conclusions**. If you are asked to give your observations, then you must describe what you would see while the experiment is being performed. If you are asked to state what you would conclude from the experiment, then you must give what you can deduce from the observations. A deduction is made by using data from the experiment to arrive at a conclusion.

A1.2 Evidence for the particulate theory of matter

In the previous unit we mentioned that scientists find the particulate theory of matter very useful because it allows them to explain the physical properties of matter. At the same time though, scientists have to provide evidence to support their ideas. There are simple practical activities involving **diffusion** and **osmosis** which we can perform to provide evidence for the existence and movement of particles.

Diffusion

We have all had experience of being aware of a smell, whether it is walking into a bakery, a cosmetic shop or climbing into a car that contains an air freshener. All of these smells are produced at a point in the shop or car, but the smell seems to travel through the air. This process of the smell travelling through the air is as a result of **diffusion**. Diffusion occurs because particles of matter are in constant motion and will move from a region of higher concentration to one of lower concentration.



Practical activity

Investigating the particulate theory of matter

Your teacher may use this activity to assess:

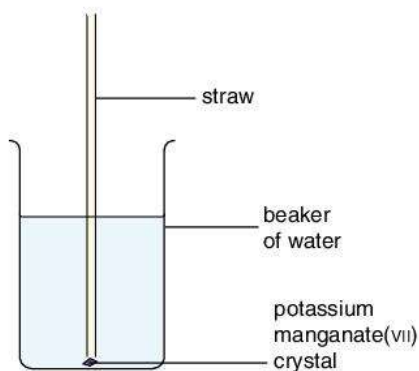
- observation, recording and reporting
- analysis and interpretation.

You will be supplied with a straw, a beaker containing distilled water and a potassium manganate(VII) crystal.

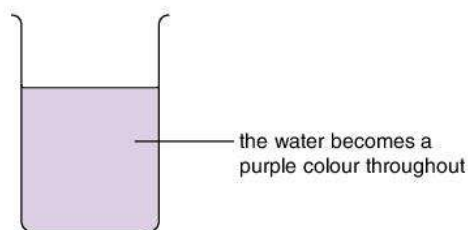
Method

- 1 Place the straw vertically in the beaker of water until it touches the bottom of the beaker.
- 2 Drop the crystal of potassium manganate(VII) into the straw without moving the straw.
- 3 Very carefully remove the straw trying to disturb the water as little as possible.
- 4 Observe how the purple colour immediately begins to spread throughout the water.
- 5 Leave the beaker and observe after a few days. Note that the purple colour has spread throughout all the water in the beaker. What conclusion can you draw about:
 - a the spaces between the water particles
 - b the movement of the potassium manganate(VII) particles?

The potassium manganate(VII) crystal and the water used in the experiment illustrated in Figures 1.2.1 and 1.2.2 are both composed of *minute particles*. The particles in the crystal are packed closely together and those in the water have very small spaces between them. When the crystal is in the water, the minute crystal particles slowly separate from each other and diffuse into the spaces between the water particles. This continues until all the particles have separated from the crystal and have diffused between the water particles.

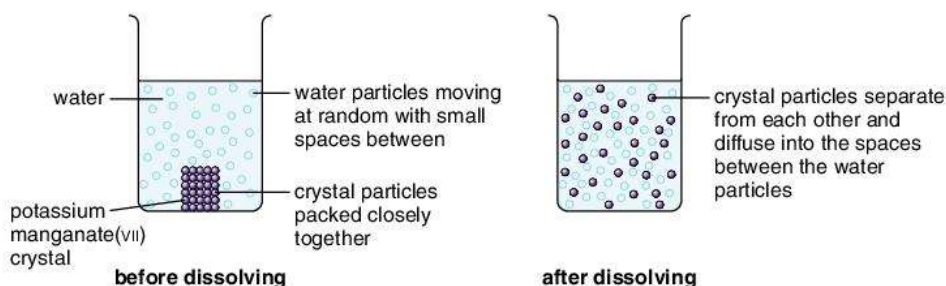


▲ **Figure 1.2.1** Potassium manganate(VII) crystal being placed in water



▲ **Figure 1.2.2** After a while the purple colour spreads throughout the water

The crystal gradually **dissolves** and an aqueous solution is formed, i.e. a solution where water is the solvent. Figure 1.2.3 illustrates the process of diffusion occurring in the experiment.



◀ **Figure 1.2.3** Explanation of diffusion



Practical activity

Investigating diffusion in gases

Your teacher may use this activity to assess:

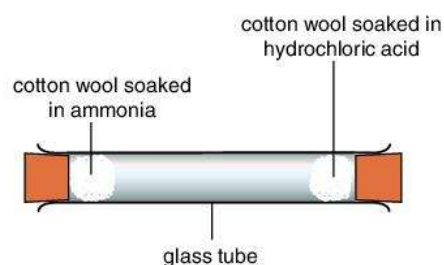
- observation, recording and reporting
- analysis and interpretation.

Your teacher will perform the following experiment:

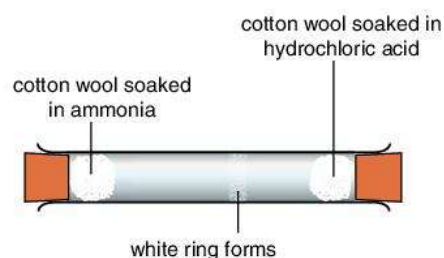
Method

- 1 Place a glass tube at least 1 m in length between two retort stands.
- 2 Soak separate pieces of cotton wool in concentrated ammonia solution and concentrated hydrochloric acid and place them simultaneously at each end of the glass tube.
- 3 Seal the ends of the glass tube with rubber stoppers.
- 4 Allow time for the ammonia and hydrogen chloride vapours to diffuse. Observe any changes.
- 5 Use your observations to explain what happened during the experiment.

During the experiment illustrated in Figures 1.2.4 and 1.2.5, the ammonia solution gives off a gas called *ammonia* gas and the hydrochloric acid gives off a gas called *hydrogen chloride* gas. The ammonia and hydrogen chloride particles diffuse through the air in the glass tube towards each other. When the particles meet, they collide and react to form a white solid known as *ammonium chloride*. The ammonium chloride forms a ring inside the glass tube.



▲ **Figure 1.2.4** Ammonia and hydrogen chloride gas diffuse towards each other

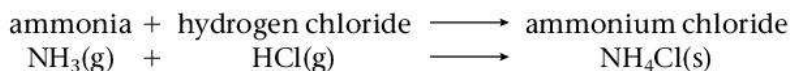


▲ **Figure 1.2.5** After a while a white ring forms inside the glass tube

! Key fact

Osmosis is the movement of water molecules from a region with a lot of water molecules, e.g. a dilute solution or pure water, to a region with fewer water molecules, e.g. a concentrated solution, through a differentially permeable membrane.

We can represent the reaction between the ammonia and hydrogen chloride as a chemical equation where (g) and (s) indicate the state of the chemicals involved, (g) indicating a gas and (s) a solid:



The ammonium chloride forms closer to the cotton wool soaked in hydrochloric acid because the ammonia particles are lighter than the hydrogen chloride particles. Therefore, the ammonia particles move much *faster* through the air than the hydrogen chloride particles.

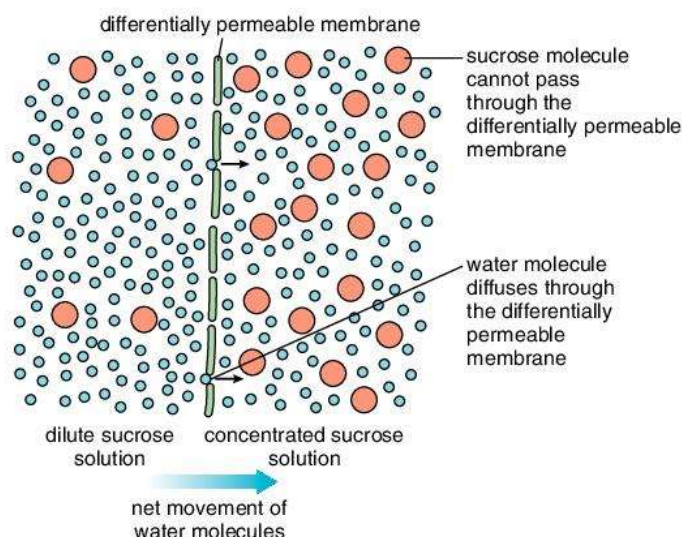
This experiment provides the following evidence for the particulate theory of matter:

- Particles are able to move – the ammonia and hydrogen chloride particles must have moved towards each other to form the white ring.
- There are spaces between particles – there must have been spaces between the air, ammonia and hydrogen chloride particles to allow them to move between each other.

Osmosis

Osmosis is a special case of diffusion, which involves the movement of water molecules through a **differentially permeable membrane** from a region with a lot of water molecules to a region with fewer water molecules. A differentially permeable membrane is a membrane that allows some substances to pass through but not others. You may also find the membrane being called a semi-permeable or selectively permeable membrane. The cell membrane that surrounds biological cells is differentially permeable.

A differentially permeable membrane contains minute pores. Water molecules are able to pass through these pores. However, the particles of many other substances, which may be dissolved in the water, are unable to pass through. When two solutions, e.g. sucrose solutions, which have different concentrations, are separated by a differentially permeable membrane, the water molecules will diffuse through the pores in the membrane from the more dilute solution to the more concentrated solution. The sucrose molecules, however, do not move because they are unable to pass through the pores in the membrane. The volume of the more dilute solution decreases and the volume of the more concentrated solution increases.



► **Figure 1.2.6** Theoretical explanation of osmosis



Practical activity

Investigating osmosis in green paw-paw

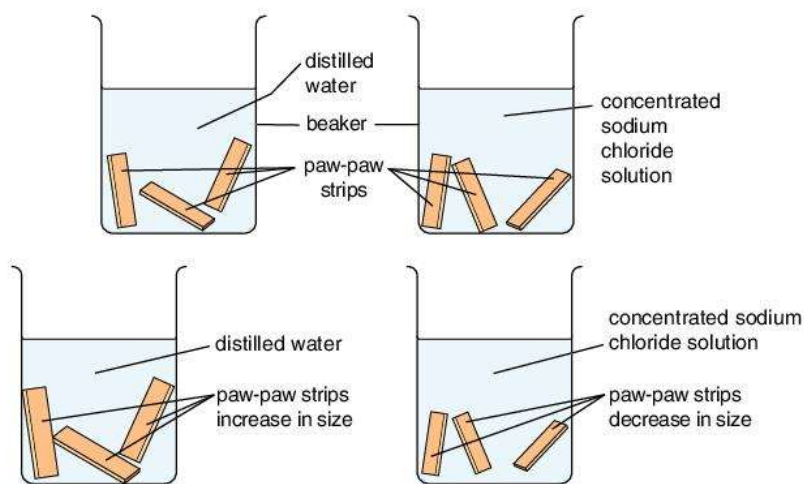
Your teacher may use this activity to assess:

- manipulation and measurement
- analysis and interpretation.

You will be supplied with a piece of green paw-paw (the experiment may be done with potato or yam), one beaker filled with distilled water and one beaker filled with concentrated sodium chloride solution.

Method

- 1 Cut the piece of green paw-paw into six strips of equal length.
- 2 Measure and record the length of each strip.
- 3 Place three of the strips into the beaker containing distilled water and place the other three strips into the beaker containing the concentrated sodium chloride solution.
- 4 Allow the strips to remain in the solutions for one hour.
- 5 Remove the strips from the beakers. Feel the strips and take note of the texture of each strip.
- 6 Measure and record the length of each strip.
- 7 Explain why the paw-paw strips placed in distilled water become more rigid and have increased in length (consider the direction in which the water molecules move, from the paw-paw into the distilled water or from the distilled water into the paw-paw).
- 8 Explain why the paw-paw strips placed in concentrated sodium chloride solution become floppy and softer and decrease in length (consider the direction in which the water molecules move, from the paw-paw into the sodium chloride solution or from the sodium chloride solution into the paw-paw).



▲ **Figure 1.2.8** After a while the strips in water increase in length and those in the concentrated sodium chloride solution decrease in length

◀ **Figure 1.2.7** Paw-paw strips in distilled water and concentrated sodium chloride solution



Did you know?

Osmosis works in the same way in your cells as it does in the paw-paw. If you **sweat** a lot you lose water. This lowers the amount of water in your blood and osmosis takes place and starts to pull water out of your cells. For this reason it is very important to drink lots of water on a hot day or when you exercise.

During the experiment illustrated in Figures 1.2.7 and 1.2.8, the cell membranes of the paw-paw cells act as differentially permeable membranes. Water can pass through the cell membranes, either into or out of the cells:

- Distilled water has a higher water content (or lower sodium chloride concentration) than the paw-paw cells, therefore water moves *into* the cells by osmosis, resulting in the paw-paw strip becoming longer and more rigid.
- The paw-paw cells have a higher water content than the concentrated sodium chloride solution, therefore water moves *out of* the cells by osmosis, resulting in the paw-paw strip becoming shorter and softer.

Practical uses of osmosis

We use the principles of osmosis in various ways. These include controlling garden pests and preserving food items.

Controlling garden pests

Slugs and snails, being herbivores, are serious garden pests which ravage many of our precious plants. The skin of these pests is a lot more permeable than the skin of most other animals. This means that they need to keep themselves moist to prevent water evaporating from their bodies causing them to dehydrate and die. We make use of these facts to control slugs and snails in our gardens by using sodium chloride (table salt).



▲ **Figure 1.2.9** Snails are serious garden pests

Sodium chloride is **deliquescent**, which means that it absorbs water readily and dissolves. When sodium chloride is sprinkled on slugs and snails, it absorbs some of the moisture surrounding their bodies and dissolves forming a concentrated solution. This causes water inside their bodies to move out and into the solution by osmosis. If the slugs and snails lose more water than their bodies can tolerate, they die from dehydration.

Preserving food items

Both sodium chloride and sugar are used to preserve food items, e.g. meat, fish, fruits and vegetables. We are all familiar with salt fish, salt pork, crystallised fruits, guava jelly and glacé cherries. Both salt and sugar work in the same way to preserve foods:

- They withdraw water from the cells of the food items by osmosis. This makes the water unavailable for the chemical reactions in cells which cause decay. Without these reactions occurring, the food items do not decay.
- They also withdraw water from the microorganisms that bring about decay, e.g. bacteria and fungi. This prevents these organisms from growing and causing the food items to decay.



(a)



(b)

▲ **Figure 1.2.10** (a) Salt fish and (b) crystallised fruits are examples of preserved food items

Summary questions

- 1 For each of the experiments described below, state the feature(s) of the particulate theory of matter for which the experiment provides evidence:
 - a If a crystal of potassium manganate(VII) is dropped into a beaker of water, the purple colour spreads throughout the water.
 - b If bottles of concentrated ammonia solution and concentrated hydrochloric acid are opened and placed next to each other, a white cloud forms between the two bottles.
- 2 State any similarities and differences between osmosis and diffusion.
- 3 Why do we say that osmosis is a special case of diffusion?
- 4 When a 5.0 cm long raw potato chip was placed in water and left for 30 minutes, its length was found to have increased to 5.5 cm. Use your knowledge of the particulate theory of matter to explain this.
- 5 Explain how sodium chloride is used:
 - a to control slugs in a garden
 - b to preserve fish.

A1.3 The three states of matter

You have learnt already that matter exists in three states: solid, liquid and gas. The three states of matter have noticeable differences in their physical properties. **Physical properties** are characteristics that can be observed or measured without changing the chemical composition of a substance. Shape, volume, density, compressibility, solubility, melting point and boiling point are all examples of physical properties. The different physical properties of the three states can be explained by the particulate theory of matter.

Table 1.3.1 summarises the physical properties of the three states of matter and the arrangement of particles in the three states.

We can use the arrangement of particles in the three states of matter to explain the physical properties of the different states:

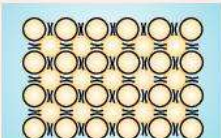
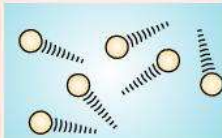
- Solids have a fixed shape because their particles are arranged in a regular way and they are unable to move out of their fixed positions.
- Solids have a fixed volume and are very difficult to compress because their particles are packed very closely together and cannot be pushed any closer together.
- Liquids flow because their particles are able to move past each other.
- Liquids can be compressed slightly because their particles have small spaces between them enabling them to be pushed closer together.
- Gases take the shape and volume of the container they are in because their particles move freely and rapidly. They have only weak forces of attraction between them, therefore they spread out to fill any available space.
- Gases are easy to compress because their particles have large spaces between them, therefore they can be pushed closer together.

Objectives

By the end of this topic you will be able to:

- explain the difference between the three states of matter in terms of energy and arrangement of particles, and forces of attraction between particles
- account for the physical properties of the three states of matter in terms of energy and arrangement of particles, and forces of attraction between particles
- explain the changes of state in terms of energy and arrangement of particles
- understand melting, evaporation, boiling, condensation, freezing and sublimation
- understand and interpret heating and cooling curves.

▼ **Table 1.3.1** The properties of the three states of matter

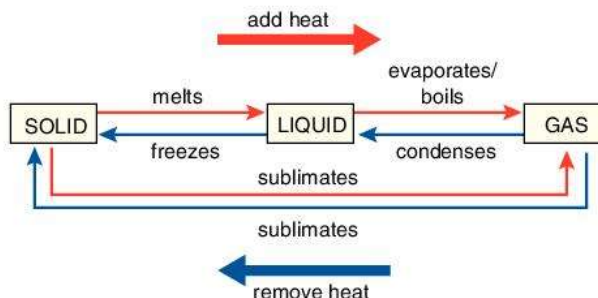
Property	Solid	Liquid	Gas
Shape and volume	Solids have a fixed shape and a fixed volume.	Liquids do not have a fixed shape, but they have a definite volume. Liquids take the shape of the part of the container that they occupy and the surface is always horizontal.	Gases do not have a fixed shape or volume. A gas will take up the space of the container it is placed in. The shape and volume of a gas is, therefore, the shape and volume of the entire container it is in.
Density	Most solids have a high density.	The density of liquids is usually lower than the density of solids.	Gases have a low density.
Compressibility	Solids are very difficult to compress.	Liquids can be compressed very slightly when pressure is applied.	Gases are easy to compress.
Arrangement of the particles	The particles are packed closely together, usually in a regular pattern.	The particles are randomly arranged and have small spaces between them.	The particles are randomly arranged and have large spaces between them.
Forces of attraction between the particles	The particles have very strong forces of attraction between them.	The forces of attraction between the particles are not as strong as those between the particles of a solid.	The particles have very weak forces of attraction between them.
Energy and movement of the particles	Particles in a solid have very small amounts of kinetic energy. The particles vibrate in their fixed position.	Particles in a liquid have more kinetic energy than particles in a solid. The particles move about slowly.	Particles in a gas have large amounts of kinetic energy. The particles move about freely and rapidly.
Arrangement of particles			

? Did you know?

SCUBA divers make use of the fact that gases are very easy to compress. An average sized SCUBA diving tank holds about 2250 litres of **compressed air**. To understand this, think of a milk carton. Most milk cartons hold one litre of milk, therefore, a SCUBA diving tank holds the same volume of air as 2250 empty milk cartons!

Changing state

Matter can be changed from one state to another by heating or cooling. A change of state is, therefore, caused by a change in temperature and consequently a change in the kinetic energy of the particles. For example, in order to change water into ice we need to put the water into the freezer, i.e. we need to remove heat energy. Changing the state of a substance without changing its chemical composition is a **physical change**. The different changes of state are summarised in Figure 1.3.1.



► **Figure 1.3.1** Summary of the changes of state

We will now look in more detail at each of the processes that cause the changes in state in Figure 1.3.1.

Melting

When a solid is heated, the particles gain kinetic energy and begin to vibrate more vigorously. Eventually the particles are able to overcome the strong forces of attraction between them and they move more freely and further apart forming a liquid, i.e. the solid **melts**. The temperature remains constant while the solid is melting because all the heat energy being supplied is used to overcome the forces of attraction between the solid particles. This constant temperature is known as the **melting point**.

Evaporation

When a liquid is heated, the particles gain kinetic energy and move faster. Some of the particles near the surface of the liquid have enough kinetic energy to overcome the forces of attraction between them and are able to leave the liquid and become a vapour. These particles are said to **evaporate**. The particles that leave the liquid take lots of energy with them, leading to a cooling of the liquid.

Boiling

When a liquid is heated its temperature eventually reaches a certain point where it starts to **boil**. At this point the liquid particles have gained enough kinetic energy and started to move fast enough to change into a gas both within the liquid and at its surface. The temperature remains constant while the liquid is boiling because the heat energy being supplied is used to overcome the forces of attraction between the liquid particles. This constant temperature is known as the **boiling point**.

Boiling differs from evaporation in two ways.

- Boiling occurs at a specific temperature, whereas evaporation can take place at any temperature.
- Boiling takes place throughout the liquid, whereas evaporation takes place only at the surface of the liquid.

Condensation

When the temperature of a gas is lowered, the particles lose kinetic energy and begin to move more slowly. The forces of attraction between the particles become stronger causing the particles to move closer together forming a liquid, i.e. the liquid **condenses**.

Freezing

When the temperature of a liquid is lowered, the particles lose kinetic energy and begin to move more slowly. The forces of attraction between the particles become stronger causing the particles to move even closer together forming a solid, i.e. the liquid **freezes**. The temperature at which this occurs is called the **freezing point**.

The freezing point of a pure substance has the same value as the melting point, e.g. water has a melting point and a freezing point of 0°C .

Sublimation

When the forces of attraction between the particles in a solid are weak, the addition of a small amount of heat can cause the solid to change directly into a gas, without passing through the liquid state. If the gas is then cooled it will change directly back to the solid. When a substance changes directly from a solid to a gas or a gas to a solid it is said to **sublime**.

! Key fact

Melting point is the constant temperature at which a solid changes into a liquid.

? Did you know?

When we sweat and the water in the sweat **evaporates** from our skin, it takes energy with it causing our bodies to feel cooler. If we put alcohol on our skin, it evaporates even faster than water because it has a lower boiling point than water. This makes our skin feel even colder than when we sweat.

! Key fact

Boiling point is the constant temperature at which a liquid changes into a gas.

✓ Exam tip

If you are asked to give a **difference** between two things, it is essential that you describe the specific property of each, using the word 'whereas' to link the two. Do not describe just one.

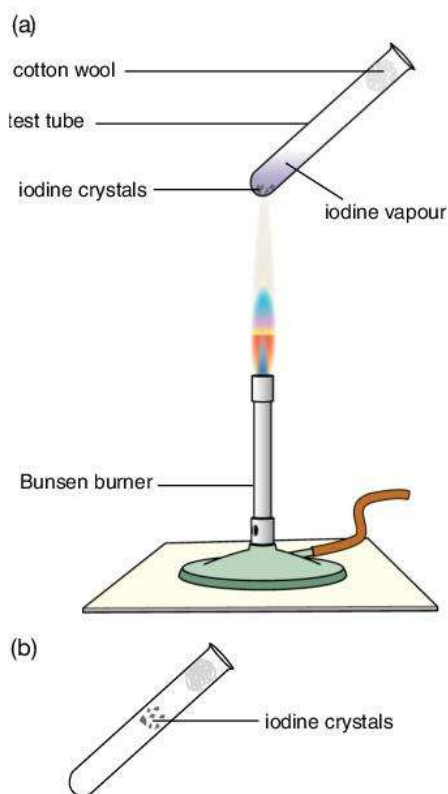
! Key fact

Freezing point is the constant temperature at which a liquid changes into a solid.

Examples of substances which undergo sublimation are iodine, carbon dioxide (known as 'dry ice'), ammonium chloride and naphthalene. Moth balls or camphor balls are made of naphthalene. Solid air fresheners also sublime releasing their fragrances into the air.



► **Figure 1.3.2** Solid air fresheners sublime



▲ **Figure 1.3.3** Iodine sublimates (a) when heated and (b) when cooled



Practical activity

Observing sublimation in iodine

Your teacher may use this activity to assess:

- observation, recording and reporting.

You will be supplied with a test tube, a small iodine crystal, a piece of cotton wool and a pair of tongs.

Method

- 1 Place the iodine crystal into the test tube and place the cotton wool into the mouth of the test tube.
- 2 Hold the test tube with tongs at a 45° angle and heat the bottom of the tube in the flame of a Bunsen burner until all the iodine crystal has sublimed.
- 3 Observe what happens as the iodine is heated.
- 4 Remove the tube from the flame and let it cool.
- 5 Observe what happens as the tube is cooling.

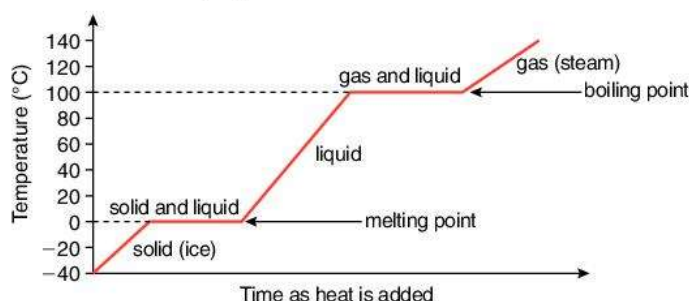
During the experiment illustrated in Figure 1.3.3, as the iodine crystal is heated, it sublimates and forms purple iodine vapour which diffuses up the test tube. The top of the tube is much cooler and when the vapour reaches the top, it sublimates back to a solid, forming a ring of iodine crystals around the inside of the tube.

Heating and cooling curves

If the temperature of a pure solid is measured at intervals as it is heated and changes state to a liquid and then to a gas, and the temperature is plotted on a graph against time, a **heating curve** is obtained. The heating curve for water is shown in Figure 1.3.4.

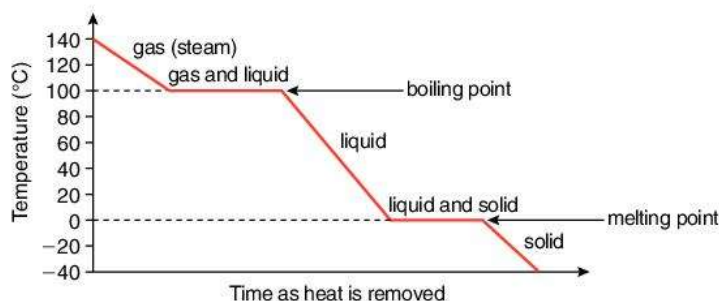
The curve shows that as heating occurs, the temperature of the substance increases. However, the graph has two horizontal sections where the temperature remains constant for a period of time even though heating

continues. These happen when there is a *change of state*. The first change of state is where *melting* occurs and the temperature remains constant at the melting point of the substance until all the substance has melted, e.g. for water this is 0°C . The second change of state is where *boiling* occurs and the temperature remains constant at the boiling point of the substance until all the substance has boiled, e.g. for water this is 100°C .



▲ **Figure 1.3.4** The heating curve for water

If the temperature of a gas is measured at intervals as it is cooled and changes state to a liquid and then to a solid, and the temperature is plotted on a graph against time, a **cooling curve** is obtained. The cooling curve for water is shown in Figure 1.3.5.



▲ **Figure 1.3.5** The cooling curve for water

Like heating curves, cooling curves have two horizontal sections. The first is where the state changes from gas to liquid and the second is where it changes from liquid to solid.

Summary questions

- 1 Complete the table below. The first row is completed as an example of what is required.

Change of state	Name given to change of state	Energy added or removed to change state
Solid to liquid	Melting	Added
Liquid to gas		
Gas to liquid		
Liquid to solid		
Solid to gas		

- 2 What are the main differences between evaporation and boiling?
- 3 a Explain what occurs during sublimation.
b Give three examples of solids which undergo sublimation.
- 4 Explain what a heating curve shows.

Key concepts

- Matter is defined as anything that has mass and occupies space.
- The properties of matter can be explained by the **particulate theory of matter**, which states that:
 - all matter is made of particles
 - the particles are in constant, random motion
 - there are spaces between the particles
 - there are forces of attraction between the particles.
- Matter exists in three states: **solid**, **liquid** and **gas**.
- The difference between the three states is due to the arrangement and energy of the particles.
- The energy of the particles is directly related to the temperature of the particles.
- **Diffusion** and **osmosis** provide evidence to support the particulate theory of matter.
- Diffusion is the movement of particles from an area of higher concentration to an area of lower concentration until they are evenly distributed.
- Osmosis is the movement of water molecules from a region with a lot of water molecules, e.g. a dilute solution or pure water, to a region with fewer water molecules, e.g. a concentrated solution, through a differentially permeable membrane.
- The principles of osmosis are used to control garden pests with sodium chloride and preserve food items with sodium chloride and sugar.
- The energy and arrangement of particles in solids, liquids and gases account for the physical properties of the three states.
- Matter can change from solid to liquid to gas with the addition of heat.
- Matter can change from gas to liquid to solid with the removal of heat.
- The names given to the processes which cause the change from one state to another are melting, evaporation, boiling, condensation, freezing and sublimation.
- Melting and boiling occur at specific temperatures known as the **melting point** and the **boiling point**, respectively.
- Evaporation of a liquid occurs at any temperature and leads to the cooling of the liquid.
- **Sublimation** is the change in state straight from a solid to a gas, or vice versa, without passing through the liquid state. It occurs in compounds with weak forces of attraction between their molecules.
- When the temperature of a pure substance is measured as it is heated and changes state from solid to liquid to gas, and the temperature is plotted against time, a **heating curve** is obtained.
- When the temperature of a pure substance is measured as it is cooled and changes state from gas to liquid to solid, and the temperature is plotted against time, a **cooling curve** is obtained.

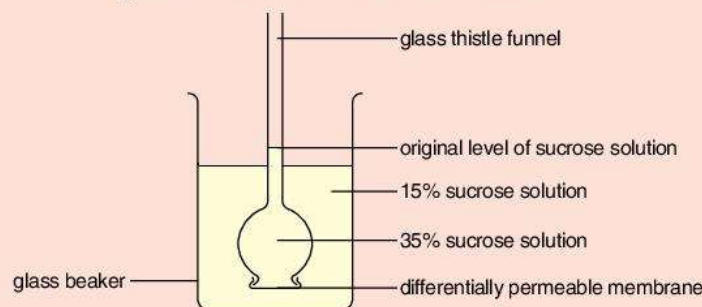
Practice exam-style questions

Multiple-choice questions

- 1 Which of the following provide(s) evidence that matter is made of particles?
 - I Osmosis
 - II Decomposition
 - III Diffusion
 - A I, II and III
 - B II and III only
 - C I and III only
 - D I only
- 2 Particles in a solid:
 - A are packed closely together
 - B are capable of random movement
 - C have large spaces between them
 - D have weak forces of attraction between them.
- 3 Liquids differ from gases in that:
 - A the particles in a liquid can move more freely than those in a gas
 - B the particles in a gas are closer together than those in a liquid
 - C the particles in a liquid possess more kinetic energy than those in a gas
 - D the particles in a gas have weaker forces of attraction between them than those in a liquid.
- 4 The conversion of a gas to a liquid is described as:
 - A melting
 - B evaporation
 - C condensation
 - D boiling.
- 5 Which of the following lists consist of substances which show sublimation?
 - A Aluminium chloride, iodine, carbon dioxide.
 - B Ammonium chloride, iodine, carbon monoxide.
 - C Ammonium chloride, naphthalene, iodine.
 - D Aluminium sulfate, carbon dioxide, naphthalene.

Structured question

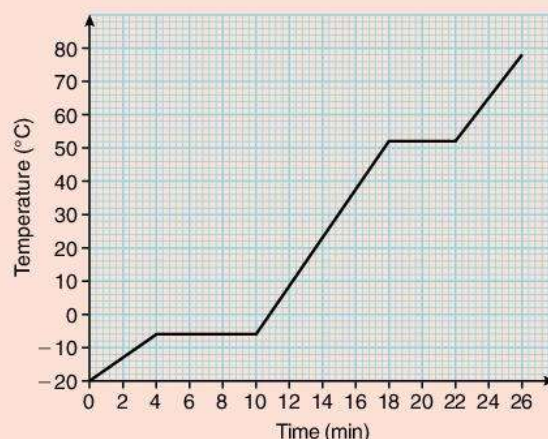
- 6 a In order to investigate the particulate nature of matter, a student set up the apparatus shown in Figure 1 below and left it for 30 minutes.



▲ **Figure 1** Apparatus used to investigate the particulate nature of matter

- i) State what you would expect to have happened to the level of the sucrose solution in the thistle funnel after 30 minutes. (1 mark)
- ii) Explain the reason for your observations. (4 marks)
- iii) Name the process occurring in the apparatus. (1 mark)

- b A second student measured the temperature of an unknown substance X as it was heated from the solid state through the liquid state to the gaseous state. Her results are plotted in Figure 2. Use the information in the Figure to answer the following questions.



▲ **Figure 2** Graph showing the temperature of substance X during heating against time

- i) What state is X in at 68 °C? (1 mark)
- ii) Over what temperature range does X exist in the liquid state? (2 marks)
- iii) From the time X starts to melt, how long does it take until it has completely melted? (1 mark)
- iv) Describe, in terms of energy and behaviour of particles, what is happening to substance X as it melts. (3 marks)
- v) Using ● to represent a particle of substance X, draw TWELVE particles as they would appear in X at -15 °C. (2 marks)

Total 15 marks

Extended response question

- 7 a Describe TWO pieces of evidence to support the particulate theory of matter. (4 marks)
- b Water can exist as a solid, a liquid and a gas. Explain the differences between these three states in terms of arrangement of their particles, forces of attraction between them and their kinetic energy. (6 marks)
- c By reference to particles, explain clearly the reason for EACH of the following:
 - i) steam can be converted to liquid water by reducing its temperature (3 marks)
 - ii) a crystal of potassium chloride has a very definite shape. (2 marks)

Total 15 marks