To provide an idea about what this book contains, only few pages taken randomly from the book are shown here.

KEY • POINTS
Series

About ChemistryKEY • POINTS

Aims to prepare students for the GCE 'O' Level Examinations. The book covers the latest revised syllabus for Chemistry. Each chapter of the book consists of:

i. TO UNLOCK THE CONTENTS IN THE **OVERVIEW OF THE TOPIC**.

OR

ii. TO SEARCH FOR NEXT SUBJECT.

LEARNING OBJECTIVES

Learning objectives of each chapter based on the latest syllabus are given in this section. Students should make sure that they are able to meet all the basic requirements of the objectives before they sit for the examinations.

OVERVIEW OF THE TOPIC

This table gives students a concept map of the topic. It shows students the structural links between the sub-areas of each topic.

KEY POINTS

This part features concise revision notes to help students concentrate on more important areas. All essential key points are presented to help students to consolidate their knowledge learnt in class.

STOP & THINK (CHALLENGING QUESTIONS WITH ANSWERS AND EXPLANATIONS)

For each sub-topic, challenging questions have been consolidated to check and evaluate students' understanding. This ensures that doubts are better clarified before they proceed to the next section.

EXAMTIPS

Exam Tips in this book summarise all of students' common mistakes, weaknesses and misconceptions shown in past examinations. Some important reminders for students are also listed in this section.

I sincerely hope that this book can facilitate students in their study of Chemistry, especially the Q & A techniques in according to the requirements of the GCE 'O' Level Examinations.

The Editor: A. Loh (B.Sc. (Hons), Dip.Ed.)

CONTENTS

TOPIC 2

KINETIC PARTICLE THEORY

LEARNING OBJECTIVES

Candidates should be able to:

Kinetic particle theory

(a) describe the solid, liquid and gaseous states of matter and explain their interconversion in terms of the kinetic particle theory and of the energy changes involved

(b) describe and explain evidence for the movement of particles in liquids and gases (the treatment of Brownian motion is **not** required)

(c) explain everyday effects of diffusion in terms of particles, e.g. the spread of perfumes and cooking aromas; tea and coffee grains in water

(d) state qualitatively the effect of molecular mass on the rate of diffusion and explain the dependence of rate of diffusion on temperature

OVERVIEW OF THE TOPIC

KINETIC PARTICLE THEORY

INTRODUCTION	What is matter?	
THE THREE STATES OF MATTER	Solid	
	Liquid	
	Gas	
CHANGES IN STATE	Melting and Freezing	
	Boiling and Condensation	
	Sublimation	
DIFFUSION	Evidence for the particulate nature of matter	
	Rate of diffusion	• Effect of molecular mass • Effect of temperature
	Applications of diffusion	

INTRODUCTION

- ☑ Matter is anything that occupies space and has mass.
- ☑ All substances can be classified into three states of matter, namely solid, liquid and gas. A brief summary is given in Table 2.1.

Solid	Liquid	Gas
Fixed volume	Fixed volume	No fixed volume
Fixed shape	No fixed shape. Takes the shape of the container it is in	No fixed shape. Takes the shape of the container it is in

Table 2.1 Three states of matter

- ☑ Scientists have gathered evidence from diffusion experiments, changes in volume and changes in state and hypothesised that matter is made up of small particles. This hypothesis is now accepted and can be explained in terms of ***kinetic particle theory***.

THE THREE STATES OF MATTER

The three states of matter can be explained using the kinetic particle theory. A summary is found in Table 2.2.

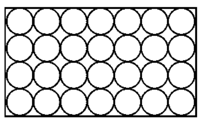
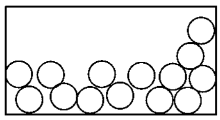
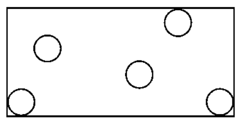
Property	Solid	Liquid	Gas
Packing between particles	Very closely packed	Closely packed	Very far apart
Forces of attraction between particles	Very strong forces of attraction between particles	Strong forces of attraction between particles	Very weak forces of attraction between particles
Motion of particles	Vibrate about a fixed position	Particles can slide over each other	Particles are in random motion
Diagrammatic representation of the particles in each of the physical states			

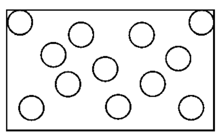
Table 2.2 Differences between solid, liquid and gas

ExamTip

When drawing the diagrammatic representation of a liquid, the particles ought to be drawn "sinking" towards the bottom and not evenly spread throughout the container. This is due to gravitational pull.

Error!!!

An example of **error** in drawing:

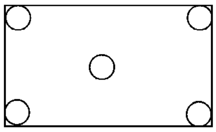


No sign of gravitational pull

When gas arrangement is asked for, the particles must be drawn very far apart, and to represent randomness, the particles cannot be drawn in a systematic and orderly manner.

An example of **error** in drawing:

Error!!!



Too neatly arranged

CHANGES IN STATE

Melting And Freezing

- ☑ A physical change from solid to a liquid state (melting), and from liquid to solid (freezing).
- ☑ During melting, the particles of the solid gain sufficient energy and vibrate till they overcome the forces of attraction between them, moving faster and further apart. There is no rise in temperature at this juncture. The heat energy is utilised to bring about a separation of particles at this temperature. We call this the ***melting point*** of a substance. The temperature remains constant until the whole solid has melted into a liquid.
- ☑ A graphical representation of melting is shown below:

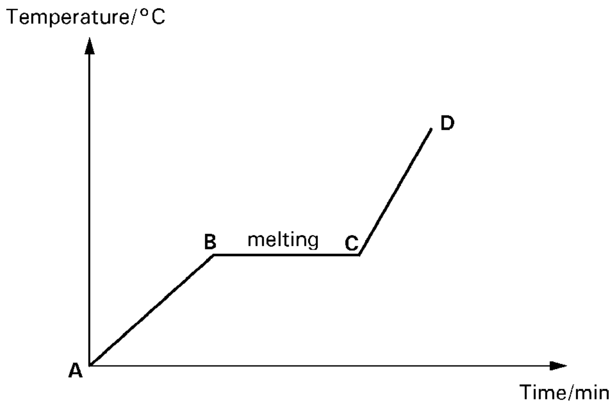


Fig 2.1 Graphical representation of melting

Explanation:

At **AB**, particles are closely packed in a purely solid state with only the ability to vibrate about fixed positions.

At **BC** the particles have gained sufficient energy to move further apart. Two states, solid and liquid exist here.

At **CD** the particles are in a purely liquid state gaining more heat energy and rising in temperature.

- ☑ When the particles lose energy and move closer together at a constant temperature from a liquid state to a solid state, we say that ***freezing*** occurs.

Boiling And Condensation

- ☑ A physical change from liquid to a gaseous state (boiling), and from gas to liquid (condensation).
- ☑ During boiling, the particles of the liquid gain sufficient energy and slide over each other till they overcome the forces of attraction between them, moving randomly and very far apart. Similar to melting, there is no rise in temperature at this juncture. The heat energy absorbed brings about further separation of particles at this temperature. We call this the ***boiling point*** of a substance. The temperature remains constant until the whole liquid has boiled into a gas.

☑ A graphical representation of boiling is shown below:

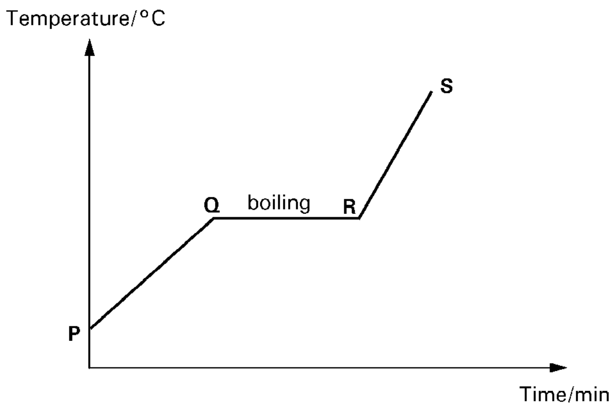


Fig 2.2 Graphical representation of boiling

Explanation:

At **PQ**, particles are quite packed in a purely liquid state with only the ability to slide over each other.

At **QR** the particles have gained sufficient energy to move randomly and separate very far apart.

At **RS** the particles are in a purely gaseous state gaining more heat energy and rising in temperature.

☑ The physical change from a gas into a liquid is called ***condensation***.

ExamTip

At the melting point and boiling point of any pure substance, no change in temperature occurs, that is, a constant temperature is maintained over the period of time that the substance undergoes a change in state. This means that the melting and boiling points of a pure substance are fixed. Hence, the melting point and boiling point of a substance can be used to determine the purity of a substance.

The difference between boiling and **evaporation** is important. Many pupils use the terms interchangeably but there are three main differences:

Boiling	Evaporation
① occurs at a fixed and constant temperature	① occurs at any temperature
② fast process	② slow process
③ occurs throughout the liquid that is being boiled	③ occurs first from the surface of the liquid

The two websites recommended are useful in understanding further on the processes of melting, boiling, freezing and condensation through a graphical interpretation.

Sublimation

☑ A physical change from a solid state to a gaseous state without first becoming a liquid is called sublimation.

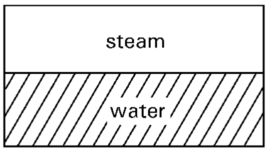
☑ Examples of substances that undergo sublimation are carbon dioxide, mothballs and iodine.

ExamTip

One reason why solid carbon dioxide (dry ice) is used to keep ice cream cool is that dry ice sublimes directly into gaseous state and hence does not melt to produce a messy liquid.

STOP & THINK

[Q] The diagram represents a closed vessel containing equal volumes of water and steam at 100°C and atmospheric pressure.



Which of the following statements is correct?

A Equal numbers of molecules are present in the steam and in the water

B The only type of movement possible for molecules in the water is vibration

C Some of the molecules in the steam split into hydrogen and oxygen molecules

D Molecules can move from the water into the steam and from the steam into the water

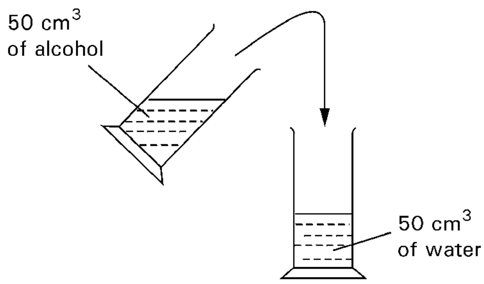
[Ans: D] Water continues to vapourise into the gaseous state at 100°C. Also, at this temperature, steam condenses back to form water. This will eventually come to a state of equilibrium.

ExamTip

The number of molecules in the water is larger than that in the steam as water molecules in the vapour state are much further apart in the same volume given.

STOP & THINK

[Q] A 50 cm^3 sample of alcohol is mixed with 50cm^3 of water.



The volume of the mixed alcohol and water is found to be 97 cm^3. Which of the following is the best explanation?

A Some alcohol molecules evaporate

B The alcohol molecules fit into the gaps between water molecules

C Water and alcohol react to form a gas which escapes

D Water and alcohol react to produce a salt which then dissolves

[Ans: B] The water molecules in a liquid state will have gaps or spaces between them that allow for other particles small enough to occupy the spaces between them. Alcohol is small enough to fit between the water molecules.

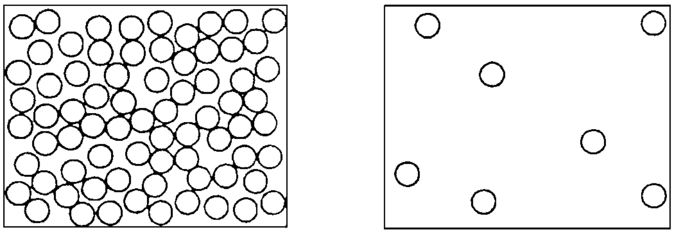
ExamTip

No chemical reaction has occurred as suggested in C or D since this is a physical change. The alcohol and water can be separated back into their pure forms through fractional distillation, a physical separation method.

STOP & THINK

[Q] The diagrams show the spacing of molecules in a substance at a pressure of 1 atm but at two different temperatures.

at −150°C at −100°C



Which substance could the diagrams represent?

Substance	Melting point/°C	Boiling point/°C
A	−183	−89
B	−182	−162
C	−169	−104
D	−114	−85

[Ans: C] The first diagram shows that of a liquid as the particles are rather closely packed but without an orderly arrangement, whereas the second diagram is clearly that of a gas particles randomly arranged, with particles very far apart from each other. Hence the melting point must be lower than −150°C. The boiling point is lower than −100°C but greater than −150°C.

ExamTip

A diagram that represents that of solid would be neatly arranged in straight rows. Although many would claim that the first diagram represents a solid as the particles seem so closely packed but the diagram fails to show the neatness and order in arrangement.

STOP & THINK

[Q] Which of the following correctly describes the particles in a dilute sugar solution at room temperature?

	Sugar molecules	*Water molecules*
A	Widely separated, moving at random	Close together, moving at random
B	Widely separated, moving at random	Close together, not moving
C	Widely separated, not moving	Widely separated, moving at random
D	Close together, moving at random	Close together, moving at random

[Ans: A] A dilute sugar solution would have less sugar particles and more water particles, hence the water particles are close together, moving and colliding randomly with the sugar and other water particles. Sugar particles are also moving due to the collisions but since the number of particles is small, they must be widely spaced.

ExamTip

The term 'random motion' is used here, not because gas particles are involved but due to the collisions, the path of the sugar and water particles becomes uncertain each time they collide with each other. Here, the sugar molecules are widely separated by water molecules, not empty space, hence pupils should not be confused with wide separation in gas particles where the gas particles are separated by empty space.

DIFFUSION

Evidence For The Particulate Nature Of Matter

☑ The idea that matter is made up of particles is evident through diffusion.

☑ Diffusion of a substance is understood as the movement of particles from a region of higher concentration of the substance to a lower concentration of the same substance down a concentration gradient.

EXAMPLES:

① When a crystal of potassium manganate(VII) is dropped into water, the purple colour will spread slowly throughout the liquid until a uniform purple colour is observed.

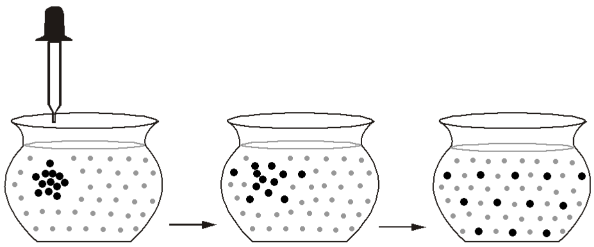


Fig 2.3 Diffusion of solid (potassium manganate(VII) crystals) in water

② When perfume is sprayed in one corner of a room, the particles spread until the scent is detected in all parts of the room. This is evidence of diffusion of a liquid.

③ When a few drops of bromine is put into a gas jar as in Figure 2.4, the bromine will vapourise to fill up the gas jar. A gas jar full of air is then placed on top of the gas jar full of bromine vapour and the jar lids are removed. The reddish brown vapour spreads throughout the two gas jars over a period of time, even though the bromine vapour is denser than air.

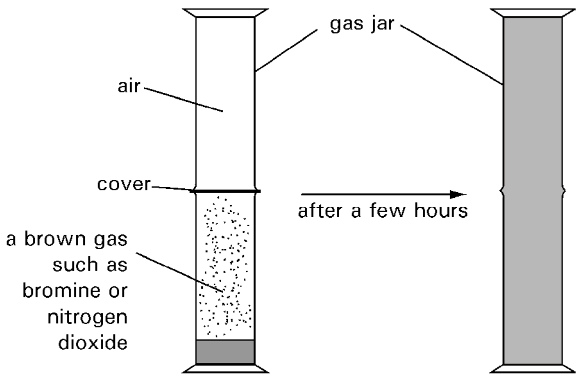


Fig 2.4 Diffusion of gas (bromine)

ExamTip

The particles of bromine move around randomly throughout the gas jars. Some bromine particles move up from the lower jar into spaces between the air particles in the upper jar. Likewise, the air particles would have moved downwards into the bottom jar until the two different kinds of particles get evenly mixed up. Hence, the uniformity in the colour of the particles in both jars is observed over time. This is evidence that matter is made up of particles.

Rate Of Diffusion

☑ The rate of diffusion is dependent on two factors:

Temperature

☑ The higher the temperature, the faster the rate of diffusion. This is due to the fact that particles at a higher temperature have more kinetic energy and hence are able to move at greater speeds from region of higher concentration to a less concentrated region.

Molecular mass of the particle

☑ At a given temperature, lighter particles diffuse faster than heavier particles.

☑ The reaction between hydrogen chloride gas and ammonia gas can be used as evidence.

EXPERIMENTAL PROCEDURE:

① A piece of cotton wool is soaked in concentrated hydrochloric acid. The acid gives off hydrogen chloride gas.

② Another piece of cotton wool is soaked in concentrated ammonia solution which gives off ammonia gas as shown in Figure 2.5.

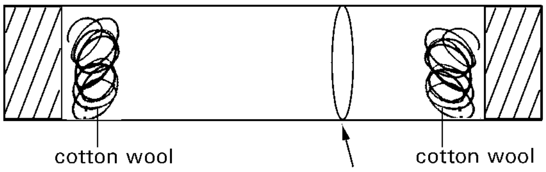


Fig 2.5 Reaction between hydrogen chloride gas and ammonia gas

Observation:

After a few minutes, a white ring of solid appears inside the glass tube. The white ring is closer to the hydrochloric acid end rather than the ammonia solution end.

Explanation:

The hydrogen chloride molecules have a larger relative molecular mass compared to those of the ammonia molecules. Hence the ammonia molecules being lighter, move much faster than the hydrogen chloride molecules in the closed set up, with the two different kinds of molecules meeting nearer at the hydrochloric acid end and reacting to form ammonium chloride, a white solid.

Conclusion:

The larger the relative molecular mass, the slower the rate of diffusion. The smaller the relative molecular mass, the faster the rate of diffusion.

ExamTip

The rates of diffusion of two gases can also be compared by measuring the time taken for each of the equal volumes of the two gases to diffuse through a small hole. Such experiments were set in previous 'O' level papers, hence it is essential to know how to interpret the results.