Marshall Cavendish Education

Cambridge Assessment International Education

Endorsed for full syllabus coverage

Cambridge IGCSE™ Chemistry

STUDENT'S BOOK

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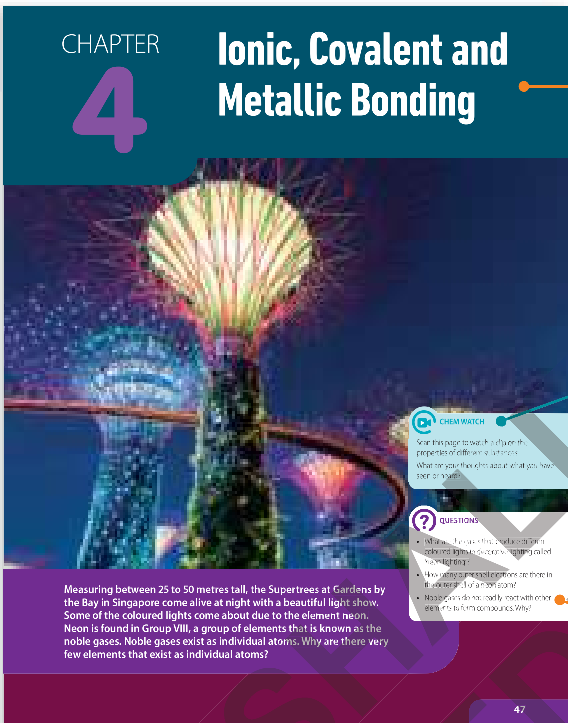
How to Use This Book

This book is designed to help you to build your knowledge and understanding of essential scientific concepts. It will also enable you to appreciate the application of Chemistry in your everyday life and in the world around you. This Student's Book is part of the Marshall Cavendish Education suite of resources that will support you as you follow the Cambridge IGCSE™ Chemistry (0620/0971) syllabuses and prepare for your examinations.

Note:

- Features indicated as 'Option' provide additional content and context to help enhance and enrich your learning, including some contexts that extend beyond the requirements of the syllabus. You can decide to skip 'Option' content and still fulfil the syllabus requirements.
- Content in some features within the book includes elements that are beyond the syllabus. This is indicated by an asterisk (*).



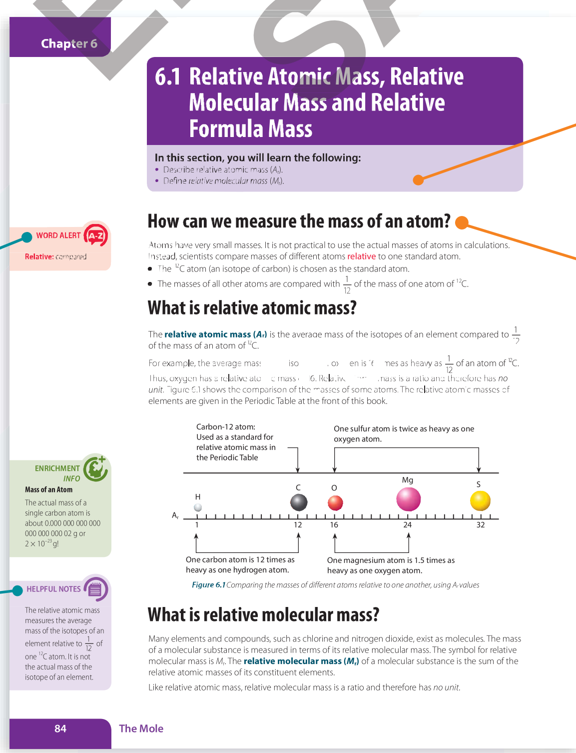
Chapter opener page [Option] introduces the topic and links concepts to real-life examples.

CHEM WATCH* [Option]

provides multimedia resources, such as videos, animations and simulations, making learning 'come alive'. The resources can be launched from a smartphone or a tablet by scanning a page using the ***MCE Cambridge IGCSE App***. Please refer to www.mceapps.com for user guide and further information.

QUESTIONS [Option]

assesses your prior knowledge on the topic.



WORD ALERT

provides information on words or explains words in a simpler way to help you understand their meanings in context. This also helps you to be more familiar with the words and be confident in using them.

HELPFUL NOTES

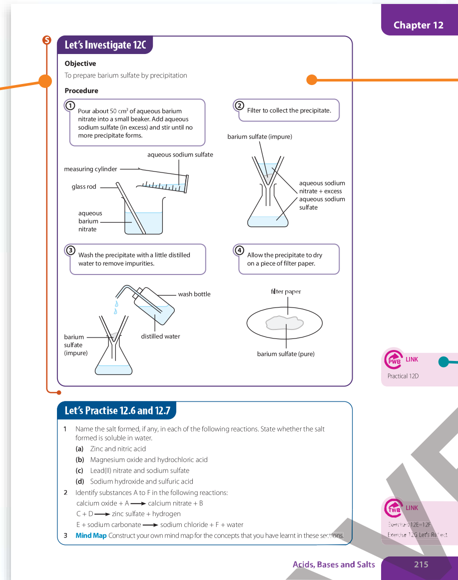
supports your learning by providing tips, such as mnemonics, and highlighting important notes that you need to be aware of.

Learning aims help you identify areas of focus and serve as a checklist.

Headings are often posed as questions so that information is always directed towards helping you to answer essential questions about the topic.

How to Use This Book

Supplement content is clearly marked for those studying the extended syllabus.

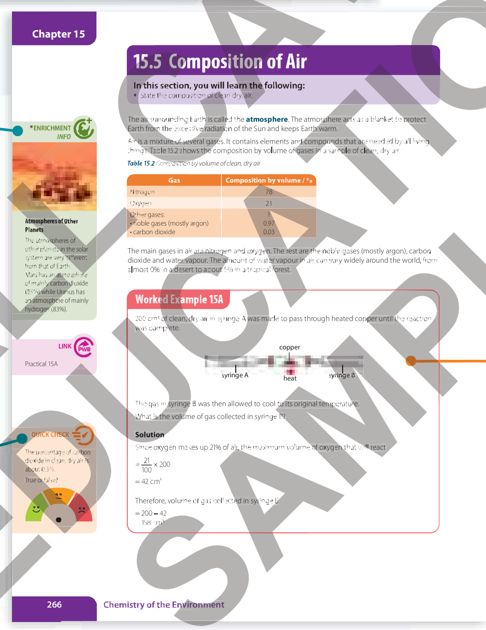


Let's Investigate introduces experimental skills and techniques, and allows you to see how concepts are formed and tested.

PWB LINK leads you to practicals in the Practical Workbook.

[Option] ENRICHMENT *INFO*

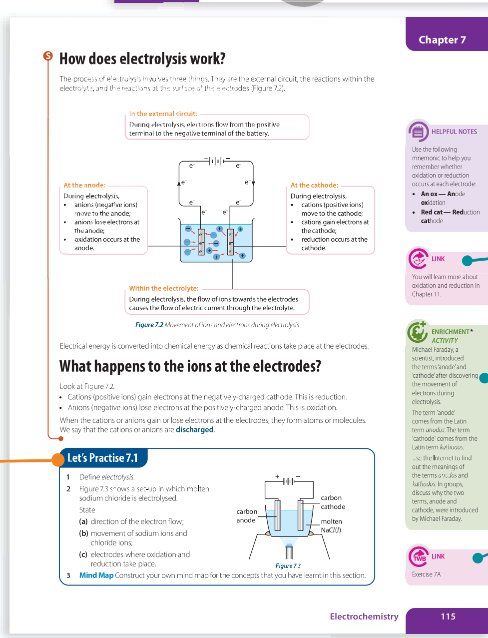
offers snippets of information to supplement your general knowledge and provide additional context related to the topic.



[Option] QUICK CHECK

serves as a checkpoint to check your understanding of concepts by posing a short question. Rate your confidence level in your answer by drawing a pointer on the confidence meter. Relating your answer and confidence level to the correct answer helps you to detect any lack of knowledge or potential misconceptions. For example, high confidence in an incorrect answer could suggest a misconception and low confidence in a correct answer could suggest a lack of knowledge.

Worked Example demonstrates how to solve problems by applying concepts learnt.



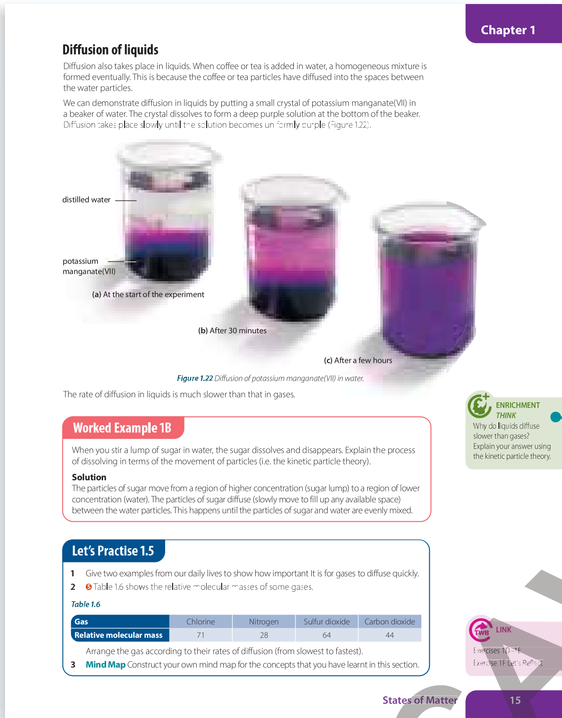
LINK helps you make connections between sections or chapters.

ENRICHMENT [Option] *ACTIVITY*

provides individual and group activities that encourage deeper thought to help reinforce your learning.

Let's Practise provides formative assessment questions at the end of sections to test your ability to recall and apply concepts learnt.

TWB LINK leads you to the revision exercises in the Theory Workbook.



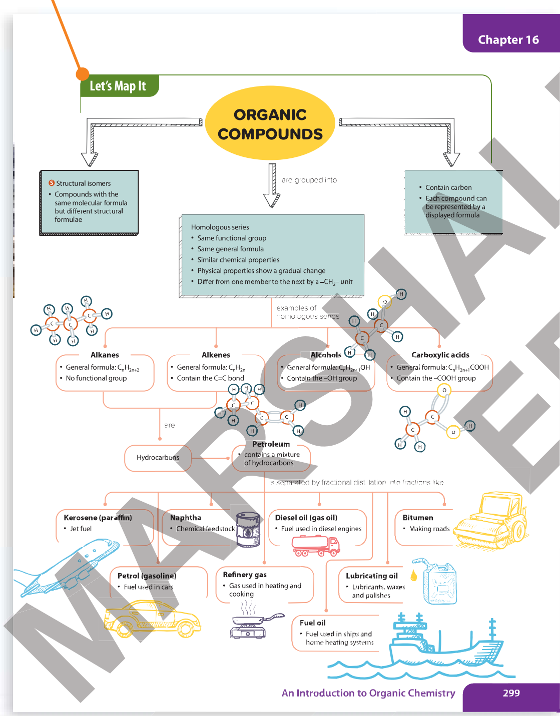
Let's Map It provides a visual summary of the concepts covered to help you integrate your learning and form connections between different concepts.

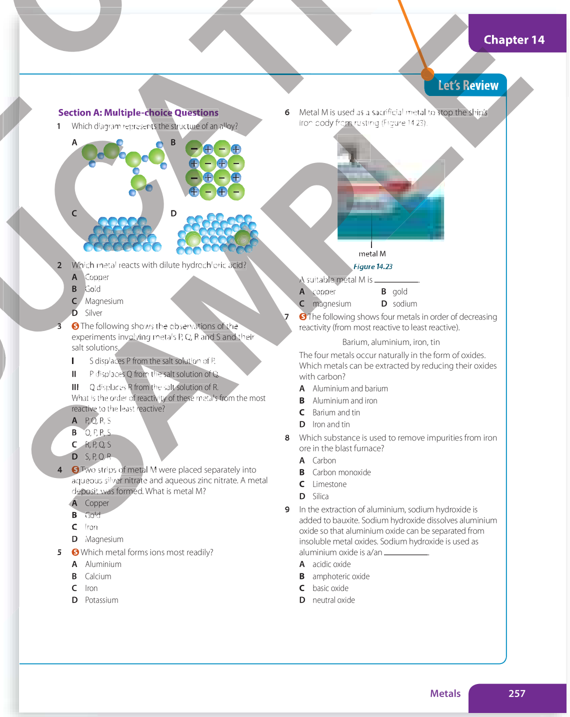
![ENRICHMENT [Option] THINK]

ENRICHMENT [Option]
THINK

poses challenging questions that encourage you to apply the concepts learnt to various contexts and prompts higher-level critical thinking.

Let's Review offers summative assessment questions to test your understanding and gives you practice in answering exam-style questions.





The following are also included at the end of the book:

- **Notes to Chemistry Practical Work** – provides information on laboratory safety, some common experimental contexts in practical work and the practical skills involved in the planning of experiments and investigations
- **Quick Revision Guide** – lists each chapter's key concepts and formulae for easy revision
- **Answers** – provided for questions in Quick Check, Let's Practise and Let's Review (only numerical and short answers are included)
- **Index** – provided to help you search for key terms and phrases in the book

Contents

The Periodic Table of Elements

I	II											III	IV	V	VI	VII	VIII
							1 H Hydrogen 1										2 He Helium 4
3 Li Lithium 7	4 Be Beryllium 9											5 B Boron 11	6 C Carbon 12	7 N Nitrogen 14	8 O Oxygen 16	9 F Fluorine 19	10 Ne Neon 20
11 Na Sodium 23	12 Mg Magnesium 24											13 Al Aluminium 27	14 Si Silicon 28	15 P Phosphorus 31	16 S Sulfur 32	17 Cl Chlorine 35.5	18 Ar Argon 40
19 K Potassium 39	20 Ca Calcium 40	21 Sc Scandium 45	22 Ti Titanium 48	23 V Vanadium 51	24 Cr Chromium 52	25 Mn Manganese 55	26 Fe Iron 56	27 Co Cobalt 59	28 Ni Nickel 59	29 Cu Copper 64	30 Zn Zinc 65	31 Ga Gallium 70	32 Ge Germanium 73	33 As Arsenic 75	34 Se Selenium 79	35 Br Bromine 80	36 Kr Krypton 84
37 Rb Rubidium 85	38 Sr Strontium 88	39 Y Yttrium 89	40 Zr Zirconium 91	41 Nb Niobium 93	42 Mo Molybdenum 96	43 Tc Technetium 99	44 Ru Ruthenium 101	45 Rh Rhodium 103	46 Pd Palladium 106	47 Ag Silver 108	48 Cd Cadmium 112	49 In Indium 115	50 Sn Tin 119	51 Sb Antimony 122	52 Te Tellurium 128	53 I Iodine 127	54 Xe Xenon 131
55 Cs Caesium 133	56 Ba Barium 137	57–71 Lanthanoids	72 Hf Hafnium 178	73 Ta Tantalum 181	74 W Tungsten 184	75 Re Rhenium 185	76 Os Osmium 190	77 Ir Iridium 192	78 Pt Platinum 195	79 Au Gold 197	80 Hg Mercury 201	81 Tl Thallium 204	82 Pb Lead 207	83 Bi Bismuth 209	84 Po Polonium	85 At Astatine	86 Rn Radon
87 Fr Francium –	88 Ra Radium –	89–103 Actinoids	104 Rf Rutherfordium –	105 Db Dubnium –	106 Sg Seaborgium –	107 Bh Bohrium –	108 Hs Hassium –	109 Mt Meitnerium –	110 Ds Darmstadtium –	111 Rg Roentgenium –	112 Cn Copernicium –	113 Nh Nihonium –	114 Fl Flerovium –	115 Mc Moscovium –	116 Lv Livermorium –	117 Ts Tennessine –	118 Og Oganesson –

57 La Lanthanum 139	58 Ce Cerium 140	59 Pr Preseodymium 141	60 Nd Neodymium 144	61 Pm Promethium –	62 Sm Samarium 150	63 Eu Europium 152	64 Gd Gadolinium 157	65 Tb Terbium 159	66 Dy Dysprosium 163	67 Ho Holmium 165	68 Er Erbium 167	69 Tm Thulium 169	70 Yb Ytterbium 173	71 Lu Lutetium 175
89 Ac Actinium –	90 Th Thorium 232	91 Pa Protactinium 231	92 U Uranium 238	93 Np Neptunium –	94 Pu Plutonium –	95 Am Americium –	96 Cm Curium –	97 Bk Berkelium –	98 Cf Californium –	99 Es Einsteinium –	100 Fm Fermium –	101 Md Mendelevium –	102 No Nobelium –	103 Lr Lawrencium –

Key:

a X b

a = proton (atomic) number
X = atomic symbol
b = relative atomic mass

The volume of one mole of any gas is 24 dm^3 at room temperature and pressure.

CHAPTER

1 States of Matter

CHEM WATCH

Scan this page to take a short quiz on states of matter.

QUESTIONS

- Imagine that you are close to a geyser. What would you feel when the geyser erupts?
  Name two other forms of water.
- What are two other everyday examples of changes of state?

Have you ever seen a geyser? It is a hot spring which shoots out jets of hot water and steam from a hole in the ground. There are about 1000 geysers in the world. The water and steam from the Lady Knox Geyser in New Zealand can rise to a great height of 10 to 20 metres. Water is in the liquid state, while steam is water in the gaseous state. The white fumes from the geyser are actually tiny water droplets that are formed when steam comes into contact with the cooler surrounding air. Why does steam change into water droplets when it comes into contact with the cooler air?

1.1 States of Matter

In this section, you will learn the following:
- State the properties of solids, liquids and gases.

Matter is a substance that has mass and occupies space. All living and non-living things are matter.

Matter can exist as a solid, a liquid or a gas. These three forms of matter are called the states of matter. The three states of matter have very different properties (Table 1.1).

Table 1.1 *Properties of solids, liquids and gases*

Property	Solid	Liquid	Gas
Shape	Fixed	Not fixed	Not fixed
Volume	Fixed	Fixed	Not fixed
Compressibility	Cannot be compressed	Cannot be compressed	Can be compressed

Substances can exist in different states of matter under different temperature and pressure conditions. Changes in temperature and pressure can change the states of matter. For example, on freezing, water becomes ice; on boiling, water becomes steam. We will learn more about the changes of state of matter in Section 1.3.

*ENRICHMENT INFO

Other States of Matter

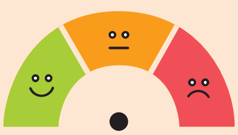
Besides solids, liquids and gases, there are two other states of matter — plasma and the Bose–Einstein condensate. Plasma is made of particles that are electrically charged. A Bose–Einstein condensate is a state of matter that has been cooled to a very low temperature.

1.2 Kinetic Particle Theory

In this section, you will learn the following:
- Describe the structures of solids, liquids and gases.

QUICK CHECK

Gases do not have mass. True or false?



The differences in the properties of the states of matter can be explained based on the kinetic particle theory. The **kinetic particle theory** states that all matter is made up of *tiny particles* that are in *constant random motion*.

The word 'kinetic' refers to motion. Moving particles have kinetic energy, hence the name 'kinetic particle theory'. The kinetic particle theory
- describes the states of matter;
- explains the differences in the properties of solids, liquids and gases;
- explains the changes of state of matter.

Why does a solid have a fixed shape?

According to the kinetic particle theory, the particles of a solid
- are closely packed in an orderly manner (Figure 1.1);
- are held together by very strong forces of attraction;
- have enough kinetic energy to vibrate and rotate about their fixed positions only;
- cannot move about freely.

Hence, a solid has a fixed shape.

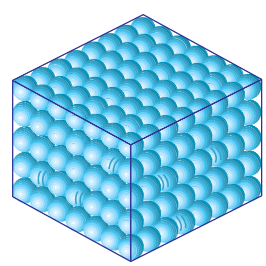


Figure 1.1 *Particles are closely packed together in a solid.*

Why does a solid have a fixed volume?

A solid cannot be compressed since its particles are already very close to one another. Thus, a solid has a fixed volume.

WORD ALERT

Compressed: squeezed into a smaller space

Why does a liquid not have a fixed shape?

Compare the arrangement of the particles of a liquid (Figure 1.2) with that of a solid (Figure 1.1). In a liquid, there is more space between the particles.

According to the kinetic particle theory, the particles of a liquid

- are arranged in a disorderly manner;
- have weaker forces of attraction than the particles of a solid;
- have more kinetic energy than particles of a solid, and are not held in fixed positions;
- move freely throughout the liquid.

This is why a liquid has no fixed shape.

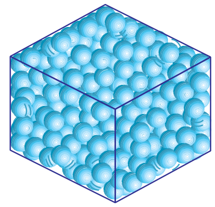


Figure 1.2 *Particles of a liquid are not held in fixed positions.*

Why does a liquid have a fixed volume?

The particles of a liquid are further away from one another than the particles of a solid. However, the liquid particles are still packed quite closely together. Thus, a liquid cannot be compressed and has a fixed volume.

Why does a gas not have a fixed shape?

According to the kinetic particle theory, the particles of a gas

- are spread far apart from one another (Figure 1.3);
- have weaker forces of attraction than the particles of a liquid;
- have more kinetic energy than the particles of a liquid, and are not held in fixed positions;
- can move about rapidly in any direction.

Thus, a gas has no fixed shape.

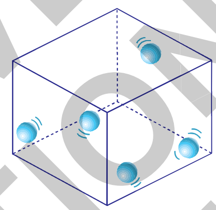


Figure 1.3 *Particles of a gas are not held in fixed positions. They move rapidly in all directions.*

Why does a gas not have a fixed volume?

The particles of a gas have a lot more space between them compared to the particles of a liquid or a solid (Figure 1.4(a)). The large space between the particles allows the gas to be easily compressed when pressure is applied (Figure 1.4(b)). In other words, the particles of a gas can be forced to move closer together. Since a gas can be compressed, it has no fixed volume.

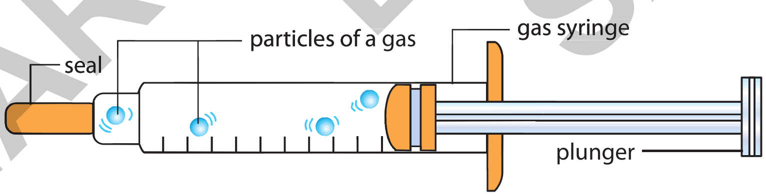


Figure 1.4(a) *Particles of a gas are far apart.*

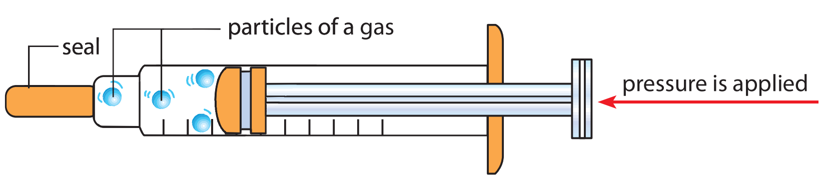


Figure 1.4(b) *Particles of a gas become closer together when compressed.*

LINK

You will learn more about the effect of pressure on the volume of a gas in Section 1.4 of this chapter.

QUICK CHECK

In which state of matter do the particles have the greatest kinetic energy?

ENRICHMENT* *ACTIVITY*

Use the Internet to search for an animation of the kinetic particle model.

Worked Example 1A

mercury oil water vapour common salt

At 20°C, which of the substances above

(a) does not have a fixed shape and volume, and can be compressed;

(b) contains the most orderly arrangement of particles?

Solution

(a) Water vapour

(b) Common salt

Let's Practise 1.1 and 1.2

1 State whether each of the following substances is a solid, a liquid or a gas at room temperature.

(a) Air **(b)** Carbon dioxide **(c)** Coal **(d)** Cooking oil

(e) Oxygen **(f)** Petrol **(g)** Rock **(h)** Steel **(i)** Water

2 **(a)** In which state of matter can the particles move most freely?

(b) In which state of matter are the particles closest together?

(c) Sketch a simple diagram to compare the arrangements of the particles in **(a)** and **(b)**.

3 **Mind Map** Construct your own mind map for the concepts that you have learnt in these sections.

LINK TWB

Exercise 1A

1.3 Changes of State of Matter and the Kinetic Particle Theory

In this section, you will learn the following:

- Describe changes of state in terms of melting, boiling, evaporating, freezing and condensing.
- S Explain changes of state in terms of the kinetic particle theory.

What are the changes of state?

Have you ever wondered why water droplets form on a cold surface and why water changes to ice in a freezer? These changes happen due to a change of state of water.

Matter can change from one state to another when it is heated or cooled. When you lick a popsicle, it changes from a solid to a liquid. Heat from your tongue is transferred to the popsicle, causing it to melt. Changes of state are reversible (Figure 1.5). There is no gain or loss of matter when there is a change of state.

WORD ALERT A-Z

Reversible: change back to the original form

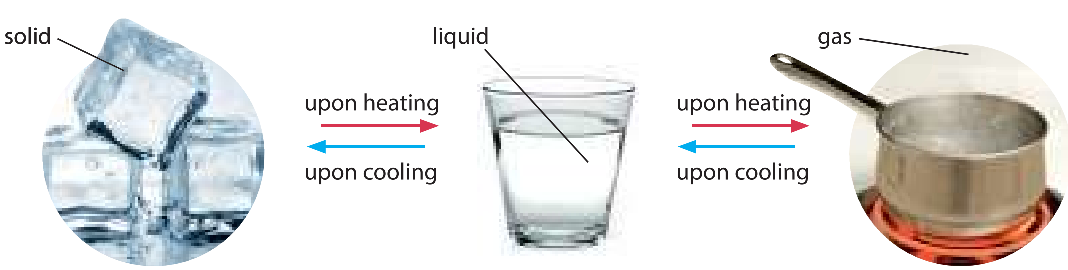


***Figure 1.5** Changes of state of water*

Table 1.2 shows the processes that involved a change of state.

***Table 1.2** Changes of state*

Process	Change of state
Melting	Solid to liquid
Freezing	Liquid to solid
Boiling	Liquid to gas
Evaporation	Liquid to gas
Condensation	Gas to liquid

The temperature at which
- a solid melts is called its **melting point**;
- a liquid freezes is called its **freezing point**;
- a liquid boils is called its **boiling point**.

Differences between boiling and evaporation

Both boiling and evaporation involve a liquid changing to a gas. However, these processes are not the same.

Boiling takes place only at the boiling point. When a liquid boils, bubbles of gas are seen (Figure 1.6). These bubbles are formed when the liquid changes to a gas. They also consist of other gases dissolved in the liquid. The bubbles rise to the surface and escape into the air. Evaporation takes place if the liquid changes to a gas below its boiling point.

Table 1.3 shows the differences between boiling and evaporation.

***Table 1.3** Differences between boiling and evaporation*

Boiling	Evaporation
Occurs only at boiling point	Occurs at temperatures below boiling point
Occurs throughout the liquid	Occurs only at the surface of the liquid
Occurs rapidly	Occurs slowly

Determining the state of a substance at a particular temperature

Different substances have different melting points and boiling points (Table 1.4).

***Table 1.4** Melting and boiling points of oxygen, ethanol, water and iron*

Substance	Oxygen	Ethanol	Water	Iron
Melting point / °C	–219	–114	0	1535
Boiling point / °C	–183	78	100	2750

Pure substances have fixed melting and boiling points. If we know the melting and boiling points of a substance, we can determine whether a substance is a solid, liquid or gas at a particular temperature. The temperature ranges for which a substance exists as a solid, liquid or gas are shown in Figure 1.7.

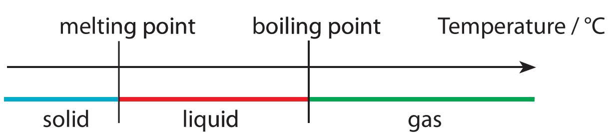


***Figure 1.7** Line showing the temperature ranges for which a substance is a solid, liquid or gas*

HELPFUL NOTES

The melting point of a pure substance is the same as its freezing point.

***Figure 1.6** Bubbles containing water vapour are seen when water boils.*

HELPFUL NOTES

At room temperature, a substance exists as a gas if its boiling point is lower than the room temperature. A substance can also exist as a gas at a temperature below its boiling point when it evaporates. It is called a vapour. For instance, water evaporates at temperatures below 100°C, and exists as water vapour.

LINK

How can the melting and boiling points of a substance be used to determine the purity of the substance? Find out in Chapter 20.

How can we determine the states of oxygen, ethanol, water and iron at 20°C? First, we can draw lines and mark out the melting and boiling points of each substance (Figure 1.8).

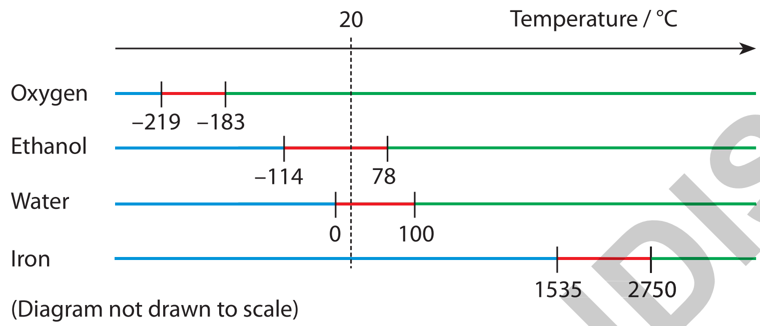


Figure 1.8 *Determining the state of oxygen, ethanol, water and iron at 20°C*

Based on Figure 1.8, we can determine that oxygen is a gas, ethanol is a liquid, water is a liquid and iron is a solid at 20°C.

S How does the kinetic particle theory explain the changes of state?

What happens to the particles when a substance changes from one state to another?

According to the kinetic particle theory, particles of matter are in constant motion — they have kinetic energy. When matter is heated or cooled, heat is taken in or given out. This causes the kinetic energy of the particles to change. As a result, there is a change of state. Let us look at what happens to the particles, and how the temperature of a substance changes during a change of state.

Melting

Figure 1.9 shows what happens to the particles of a solid that is heated until it melts.

1
- Heat is absorbed by the particles of the solid.
- The particles start to vibrate faster about their fixed positions. There is an increase in their kinetic energy.

2
- When the temperature is high enough, the vibrations of the particles become sufficient to overcome the forces of attraction between them.
- The particles begin to break away from their fixed positions.

3
- The particles are no longer in their fixed positions.
- The substance is now a liquid.
- The particles can move freely throughout the liquid.

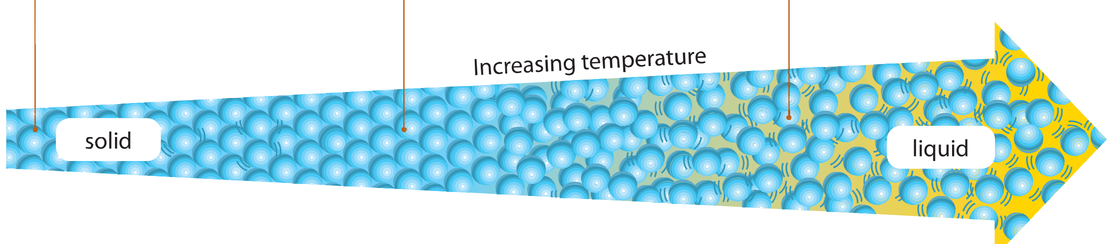
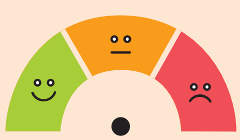


Figure 1.9 *Effect of heat on the particles of a solid*

QUICK CHECK

When a solid is heated, its particles vibrate faster.

True or false?



We can use liquid naphthalene to study how temperature changes when a liquid freezes. When a graph of temperature against time is plotted, Figure 1.12 is obtained. This graph is known as the cooling curve. A **cooling curve** shows how the temperature of a pure liquid changes as it is cooled to its freezing point (and beyond).

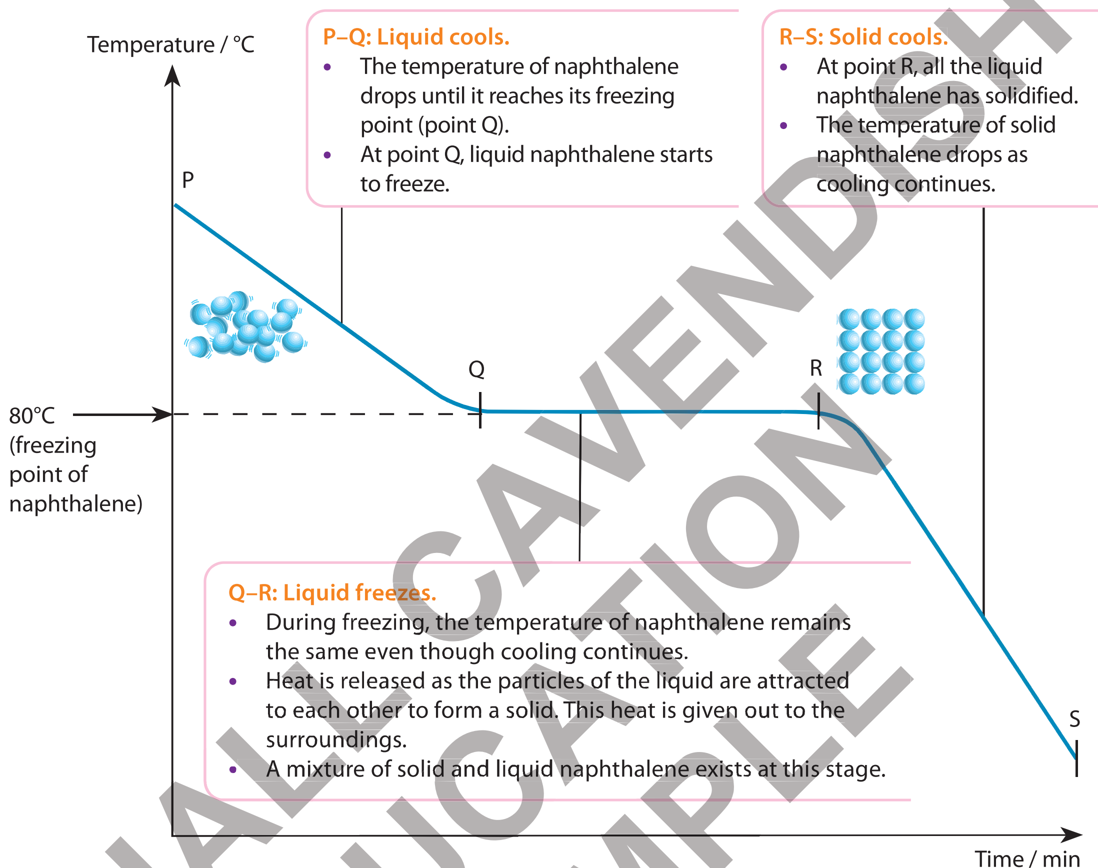


Figure 1.12 *Cooling curve of naphthalene*

Boiling

Figure 1.13 shows what happens to the particles of a liquid that is heated until it boils.

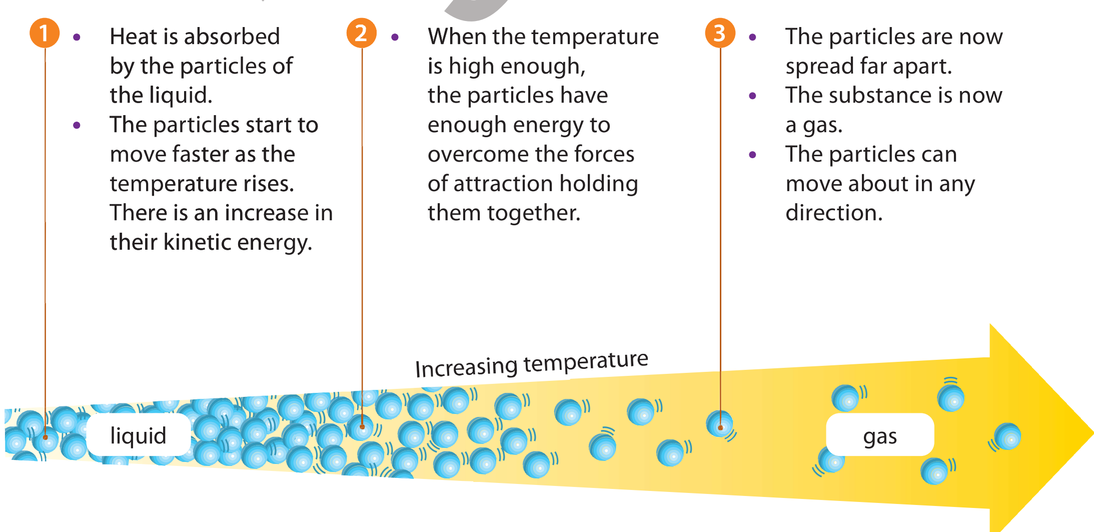


Figure 1.13 *Effect of heat on the particles of a liquid*

S

If we record the changes in temperature as a liquid is heated until it boils, we can plot a graph like the one shown in Figure 1.14. Tetrachloromethane, a colourless and non-flammable liquid, is being studied here.

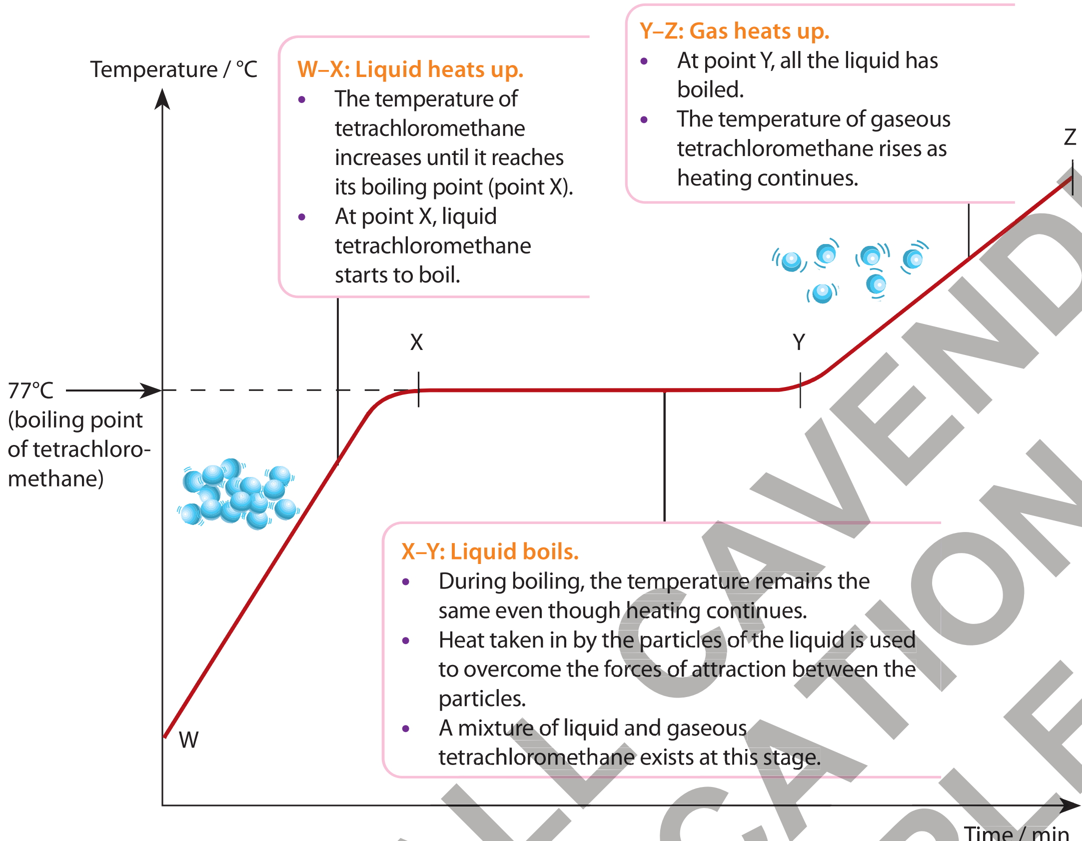


Figure 1.14 *Heating curve of tetrachloromethane*

Evaporation

Evaporation occurs because some particles have enough energy to escape as a gas from the surface of a liquid. The liquid particles left behind have less kinetic energy. The average kinetic energy of the liquid particles decreases and so the average temperature of the liquid decreases.

At a higher temperature, the liquid particles have more energy. More particles have enough energy to escape as a gas from the surface of the liquid. Hence, evaporation occurs more quickly at a higher temperature (Figure 1.15).

Liquids that evaporate quickly at room temperature are called **volatile liquids**. They usually have boiling points just above room temperature. Petrol and perfumes are examples of volatile liquids.

QUICK CHECK

Water can evaporate only when the air is dry.

True or false?

LINK

PWB

Practical 1A

Figure 1.15 *Clothes dry faster on a hot day.*

Condensation

When water vapour touches a cold surface, condensation occurs and liquid water is obtained (Figure 1.16).

Figure 1.16 Water vapour condenses on a cold surface.

During condensation, heat is given out by the gas particles. As the temperature drops, the particles lose energy and move more slowly. Eventually, the movement of the particles becomes slow enough for the gas to change to a liquid.

ENRICHMENT ACTIVITY

We cannot live without water. If we were lost in a desert, we could use condensation to help us survive! In groups, design your own apparatus for obtaining water. Use some or all of the following materials:

- One large container
- One plastic sheet
- One collecting vessel
- One small plant
- Some sand
- Some stones

Explain how your apparatus helps you obtain water.

Let's Practise 1.3

1 What process is taking place in each of the following observations?
   - **(a)** Water changes to steam at 100°C.
   - **(b)** Water changes to ice in the freezer.
   - **(c)** Molten metal solidifies in a mould.
   - **(d)** A small puddle of water gradually dries up in warm weather.
   - **(e)** Bubbles of ethanol vapour form in liquid ethanol.
   - **(f)** Water droplets form on a surface near some boiling water.

2 Stearic acid is used for making soap. The melting and boiling points of stearic acid are 70°C and 287°C respectively. Sketch a graph to show the changes in temperature when molten stearic acid is cooled to room temperature.

3 **Mind Map** Construct your own mind map for the concepts that you have learnt in this section.

LINK TWB

Exercise 1B

1.4 Effects of Temperature and Pressure on the Volume of a Gas

In this section, you will learn the following:
- Describe in terms of kinetic particle theory the effects of temperature and pressure on the volume of a gas.
- S Explain in terms of kinetic particle theory the effects of temperature and pressure on the volume of a gas.

We learnt that the particles of a gas have a lot more space between them as compared to the particles of a liquid or solid. What will happen to the volume of a gas when it is heated or compressed?

What is the effect of temperature on the volume of a gas?

When a gas is heated, its temperature increases. The particles have more energy and the space between the particles increases (Figure 1.17). The volume of the gas thus increases.

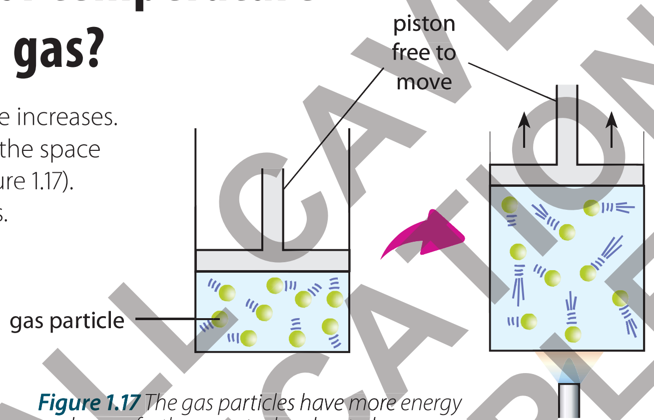


Figure 1.17 The gas particles have more energy and move further apart when heated.

S How does the kinetic particle theory explain the effect of temperature on the volume of a gas?

When a gas is heated, the particles have more kinetic energy. The particles
- collide with one another and with the wall of the container more often and at a greater force;
- move further apart from one another.

The higher the temperature, the faster the particles move and the greater the volume of the gas.

What is the effect of pressure on the volume of a gas?

When pressure is applied to a gas, the particles move closer to one another (Figure 1.18). The volume of the gas decreases.

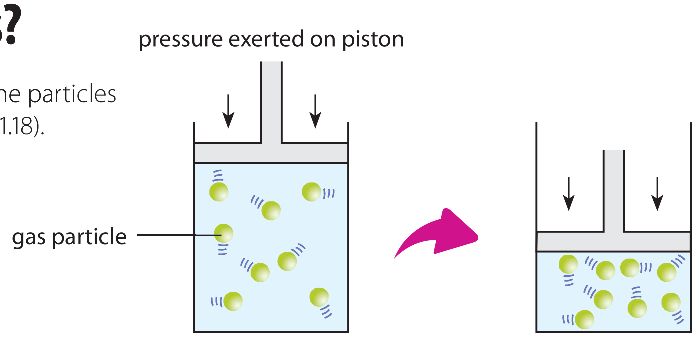


Figure 1.18 The gas particles are closer together when compressed.

Ⓢ How does the kinetic particle theory explain the effect of pressure on the volume of a gas?

The particles of a gas are spread far apart from one another. When we exert pressure on the gas by pushing in the piston of the container in Figure 1.18 on page 11, the particles

- collide with one another and with the wall of the container more often;
- move closer together.

Thus, when pressure is exerted on the gas, its volume decreases. If the gas particles are close enough, the forces of attraction between them become stronger and the gas will change into a liquid.

LINK TWB

Exercise 1C

Let's Practise 1.4

1 Butane is a gas used for cooking. It is stored in a gas cylinder as a liquid under a high pressure. When the pressure is released, butane changes to a gas and escapes from the cylinder. Describe the changes in the arrangement and motion of the butane particles when the pressure is released.

2 Ⓢ Explain, in terms of the kinetic particle theory, why a gas at constant pressure increases greatly in volume when it is gently heated, but a solid does not.

3 **Mind Map** Construct your own mind map for the concepts that you have learnt in this section.

1.5 Diffusion

In this section, you will learn the following:

- Describe and explain diffusion in terms of kinetic particle theory.
- Ⓢ Describe and explain the effect of relative molecular mass on the rate of diffusion of gases.

What is diffusion?

When a bottle of perfume is left open for some time, the scent of the perfume soon spreads throughout the entire room. Similarly, if someone is cooking curry in the kitchen, we will soon be able to detect the smell of spices in every room.

Gas particles escape from the surface of perfume and spices. These particles move at random into the spaces between the air particles. They eventually spread throughout the entire room. The process by which particles move freely to fill up any available space is called diffusion.

Diffusion is the movement of particles from a *region of higher concentration* to a *region of lower concentration*.

CHEM WATCH

Scan this page to watch a clip on diffusion.

What can you conclude?

Will the smell of curry spread in the house if there is no wind?

Diffusion of gases

Diffusion provides evidence for the kinetic particle theory. We can demonstrate diffusion in the laboratory using the set-up in Figure 1.19.

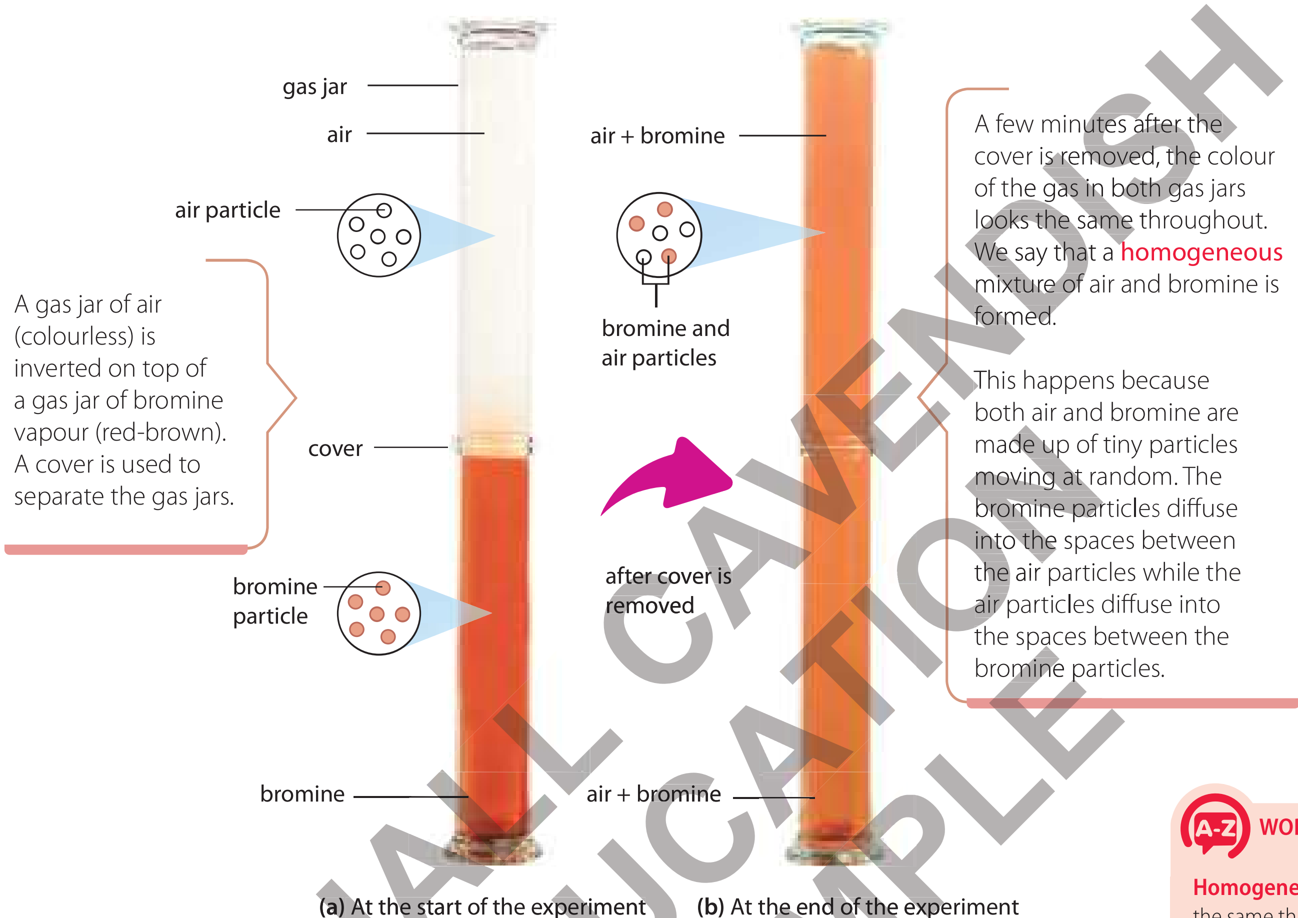


Figure 1.19 *Diffusion of bromine*

S Effect of relative molecular mass on the rate of diffusion of gases

The rate at which a gas diffuses depends upon its relative molecular mass. The **molecular mass** of a gas refers to the mass of the particles of the gas. Table 1.5 shows the relative molecular masses of some gases.

Table 1.5 *Relative molecular masses of some gases*

Gas	Relative molecular mass	Gas	Relative molecular mass
Hydrogen	2	Nitrogen	28
Helium	4	Oxygen	32
Methane	16	Hydrogen chloride	36.5
Ammonia	17	Carbon dioxide	44
Carbon monoxide	28	Chlorine	71

WORD ALERT

Homogeneous: become the same throughout

LINK

How is the relative molecular mass of a substance calculated? Find out in Chapter 6.

ENRICHMENT* THINK

What other factor do you think affect the rate of diffusion? Explain how this factor affects the rate of diffusion.

We can demonstrate the difference in the rates of diffusion of ammonia and hydrogen chloride using the experiment shown in Let's Investigate 1A.

Let's Investigate 1A

Objective

To compare the rates of diffusion of two gases with different molecular masses

Procedure

1 Soak one piece of cotton wool in concentrated aqueous ammonia and another piece of cotton wool in concentrated hydrochloric acid using tweezers.

2 Place the piece of cotton wool soaked in hydrochloric acid in one end of the tube and place the cotton wool soaked in ammonia in the other end of the tube.

3 Immediately after step 2, close both ends of the tube with rubber stoppers.

4 Set up apparatus as shown in Figure 1.20. Ensure that the glass tubing is horizontal.

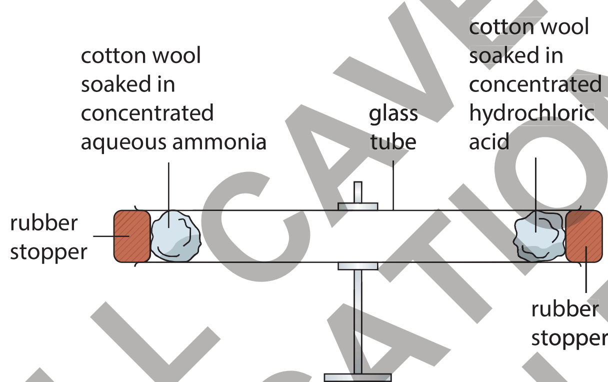


***Figure 1.20** Experimental set-up to compare the rates of diffusion of two gases*

5 Observe where a white ring is formed in the tube (Figure 1.21). Record the distances of the white ring from the end with ammonia and from the end with hydrochloric acid.

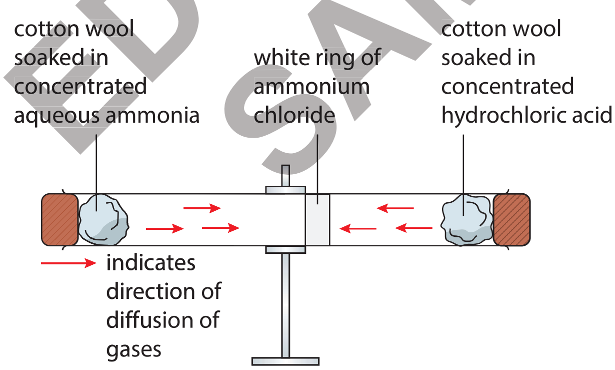


***Figure 1.21** Formation of a white ring due to the reaction between ammonia gas and hydrogen chloride gas*

When ammonia gas (from concentrated aqueous ammonia) and hydrogen chloride gas (from concentrated hydrochloric acid) react, a white ring of ammonium chloride is formed. Since the white ring is formed nearer to the end with hydrogen chloride, it means that the ammonia particles move faster than the hydrogen chloride particles.

Ammonia gas diffuses faster than hydrogen chloride gas because ammonia has a lower molecular mass than hydrogen chloride. Gases with lower molecular masses *diffuse faster* than those with higher molecular masses.

LINK PWB

Practical 1B

ENRICHMENT THINK

Refer to Figure 1.21.

1 Why must the tube be horizontal and stoppered?

2 Why does the white ring not appear immediately?

QUICK CHECK

The greater the molecular mass of a gas, the slower its rate of diffusion.

True or false?

Diffusion of liquids

Diffusion also takes place in liquids. When coffee or tea is added in water, a homogeneous mixture is formed eventually. This is because the coffee or tea particles have diffused into the spaces between the water particles.

We can demonstrate diffusion in liquids by putting a small crystal of potassium manganate(VII) in a beaker of water. The crystal dissolves to form a deep purple solution at the bottom of the beaker. Diffusion takes place slowly until the solution becomes uniformly purple (Figure 1.22).

Figure 1.22 *Diffusion of potassium manganate(VII) in water.*

The rate of diffusion in liquids is much slower than that in gases.

Worked Example 1B

When you stir a lump of sugar in water, the sugar dissolves and disappears. Explain the process of dissolving in terms of the movement of particles (i.e. the kinetic particle theory).

Solution
The particles of sugar move from a region of higher concentration (sugar lump) to a region of lower concentration (water). The particles of sugar diffuse (slowly move to fill up any available space) between the water particles. This happens until the particles of sugar and water are evenly mixed.

ENRICHMENT
THINK
Why do liquids diffuse slower than gases? Explain your answer using the kinetic particle theory.

Let's Practise 1.5

1 Give two examples from our daily lives to show how important It is for gases to diffuse quickly.

2 (S) Table 1.6 shows the relative molecular masses of some gases.

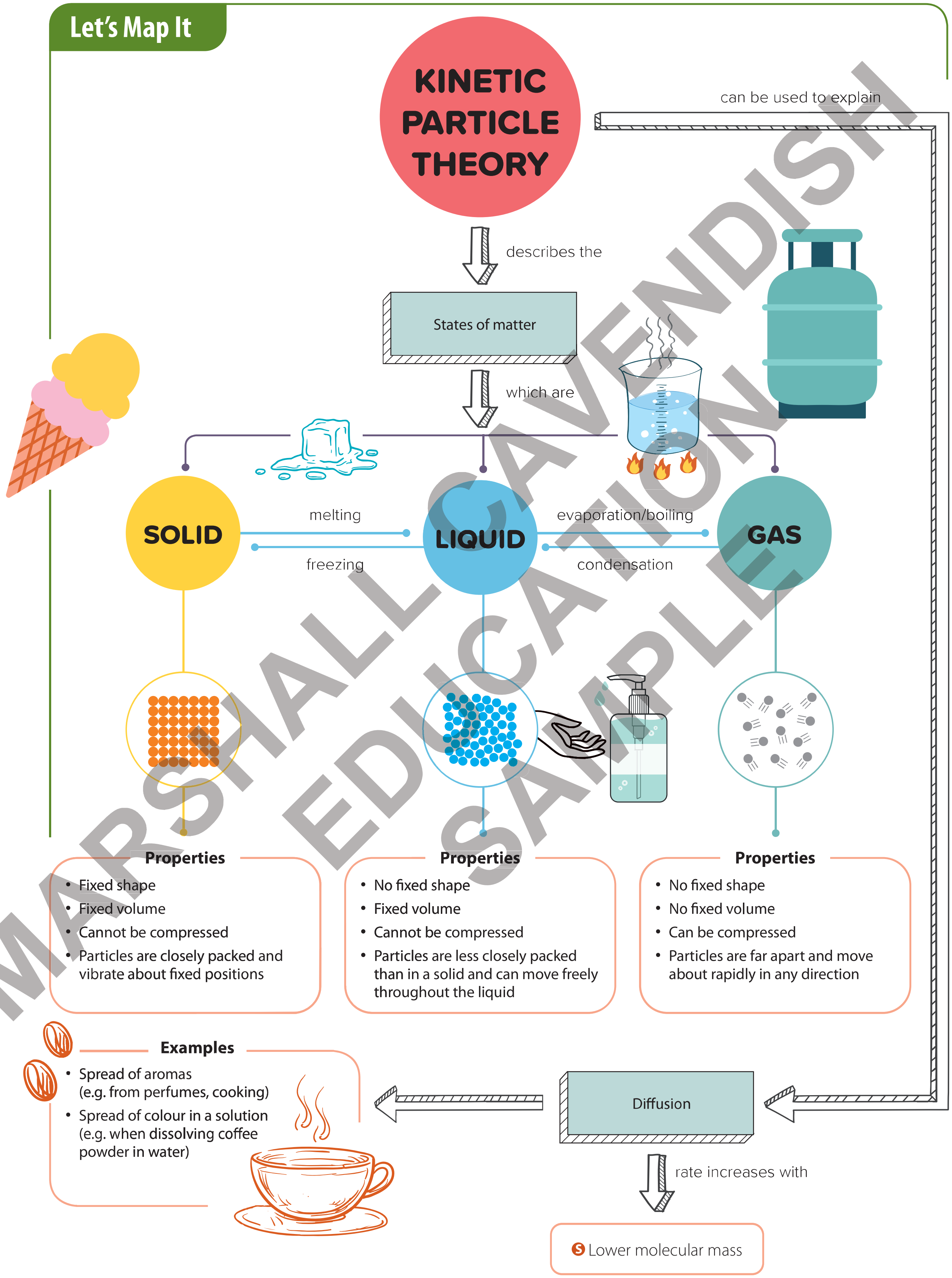
Table 1.6

Gas	Chlorine	Nitrogen	Sulfur dioxide	Carbon dioxide
Relative molecular mass	71	28	64	44

Arrange the gas according to their rates of diffusion (from slowest to fastest).

3 **Mind Map** Construct your own mind map for the concepts that you have learnt in this section.

LINK
TWB
Exercises 1D–1E
Exercise 1F Let's Reflect

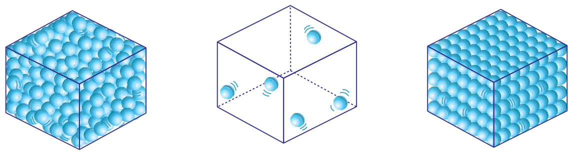


Let's Map It
KINETIC PARTICLE THEORY
can be used to explain
describes the
States of matter
which are
SOLID
LIQUID
GAS
melting
freezing
evaporation/boiling
condensation
Properties
• Fixed shape
• Fixed volume
• Cannot be compressed
• Particles are closely packed and vibrate about fixed positions
Properties
• No fixed shape
• Fixed volume
• Cannot be compressed
• Particles are less closely packed than in a solid and can move freely throughout the liquid
Properties
• No fixed shape
• No fixed volume
• Can be compressed
• Particles are far apart and move about rapidly in any direction
Diffusion
rate increases with
Lower molecular mass
Examples
• Spread of aromas (e.g. from perfumes, cooking)
• Spread of colour in a solution (e.g. when dissolving coffee powder in water)

Let's Review

Section A: Multiple-choice Questions

1 Figure 1.23 shows the particles of a substance in three states, R, S and T.



State R State S State T

Figure 1.23

Which of the following statements is true?

A The change of the substance from state R to S is called diffusion.

B The change of the substance from state T to R is called melting.

C The particles do not move in state T.

D The substance has a fixed volume in state S.

2 Hydraulic brakes in cars are filled with liquids and not gases. This is because gases are easily compressed but liquids cannot be compressed.

Which statement supports this explanation?

A The forces of attraction between the gas particles are stronger than that between the liquid particles.

B The gas particles are smaller than the liquid particles.

C The gas particles are spaced further apart than the liquid particles.

D The gas particles have less energy than the liquid particles.

3 Condensation occurs when ___________.

A a liquid turns into a solid

B a liquid turns into a vapour

C a solid turns into a liquid

D a vapour turns into a liquid

4 When bubbles of gas form in a liquid, which physical change is taking place?

A Boiling B Condensing

C Evaporating D Melting

5 A boiling tube containing a colourless liquid W was placed in a beaker of boiling water. Liquid W started to boil. The boiling point of W is ___________.

A lower than 0°C

B between 0°C and room temperature

C between room temperature and 100°C

D above 100°C

6 S Jason, Siti and Megan were discussing the kinetic particle theory. Jason said that in a solid, the particles are close together. Megan said that the particles of a substance in different states move at a constant speed. Siti said that the higher the temperature, the faster the particles move.

Who are correct?

A Jason and Megan only

B Jason and Siti only

C Megan and Siti only

D Jason, Megan and Siti

7 Which two statements are correct?

1 The volume of a gas decreases when temperature increases.

2 The volume of a gas increases when temperature increases.

3 The volume of a gas decreases when pressure is exerted.

4 The volume of a gas increases when pressure is exerted.

A 1 and 3 B 1 and 4

C 2 and 3 D 2 and 4

8 A teacher was demonstrating diffusion using nitrogen dioxide, which is a brown gas that is denser than air. She inverted a gas jar of nitrogen dioxide on top of a gas jar containing air. Which option correctly describes the colours inside the gas jars after a long period of time?

	Top jar	Bottom jar
A	Brown	Brown
B	Colourless	Dark brown
C	Dark brown	Light brown
D	Light brown	Dark brown

9 S Table 1.7 shows the relative molecular mass of four gases.

Table 1.7

Gas	Carbon dioxide	Carbon monoxide	Methane	Oxygen
Relative molecular mass	44	28	16	32

Which gas will diffuse the fastest?

A Carbon dioxide B Carbon monoxide

C Methane D Oxygen

Let's Review

Section B: Short-answer and Structured Questions

1 State the process in which the change of state is opposite to that in
(a) boiling; [1]
(b) freezing. [1]

2 Figure 1.24 represents particles of a substance at room temperature.

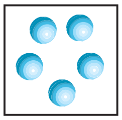


Figure 1.24

What is the state of the substance at room temperature? Explain your answer. [1]

3 Table 1.8 shows the melting and boiling points of three substances.

Table 1.8

Substance	Sodium	Chlorine	Sodium chloride
Melting point / °C	98	−101	801
Boiling point / °C	883	−34	1465

(a) State the temperature at which sodium will change from a solid to a liquid. [1]
(b) Deduce the state of each substance at 100°C. [3]

4 S Zara left a glass of water in her room. Five days later, all the water disappeared.
(a) Describe what happened to the water in the glass. [2]
(b) On another occasion, Zara left the same volume of water in the same glass in her room. The water disappeared after three days.
Explain why the water disappeared more quickly on this occasion. [2]

5 The melting and boiling points of five elements, A to E, are shown in Table 1.9.

Table 1.9

Element	Melting point / °C	Boiling point / °C
A	−219	−186
B	−189	−183
C	−7	58
D	29	222
E	666	2450

(a) At room temperature (30°C), state which element(s) exist(s) as
(i) a solid; [1]
(ii) a liquid; [1]
(iii) a gas. [1]
(b) S Describe what will happen to the particles of element C when it is cooled from 80°C to −10°C. [6]

6 S A liquid, X, was allowed to cool in air. The temperature was measured every five seconds. Figure 1.25 represents the cooling curve of X.

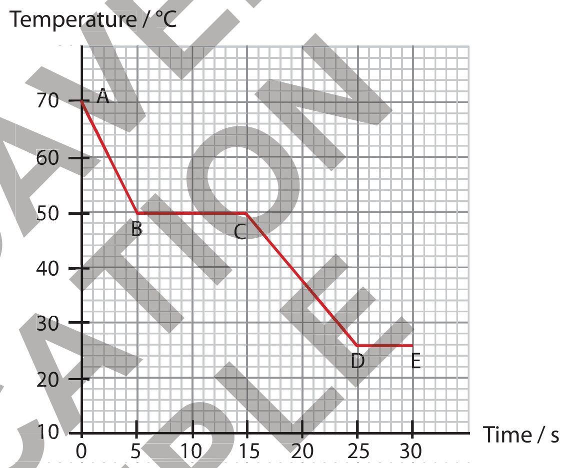


Figure 1.25

(a) State the melting point of X. [1]
(b) What is the room temperature? Explain your answer. [1]
(c) State the parts of the graph where energy is being given out to the surroundings. [3]
(d) X has a boiling point of 128°C. Explain, in terms of the kinetic particle theory, what happens to the particles of X as it is heated from 100°C to 150°C. [4]
(e) Sketch a graph of temperature against time for X when it is heated from 30°C to 140°C. [5]

7 When a person wearing perfume enters a room, the fragrance is soon smelt in other parts of the room. Explain why. [3]

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