Topic 3 – Kinetic Particle Theory & Simple Molecular Structure

3.1 Changes in Physical State (1.1, 1.2, 1.3)

<u>States of matter</u>

States of matter

1. **Solid**
2. **Liquid**
3. **Gas**

Properties

State	Properties		
	Shape (fixed)	Volume (fixed)	Compressibility
Solid	√	√	×
Liquid	×	√	×
Gas	×	×	√

Kinetic particle theory

All matter is made up of tiny particles in constant random motion

- Describes *state of matter*
- Explains *differences in properties* of solids, liquids, gases
- Explains *changes in state of matter*

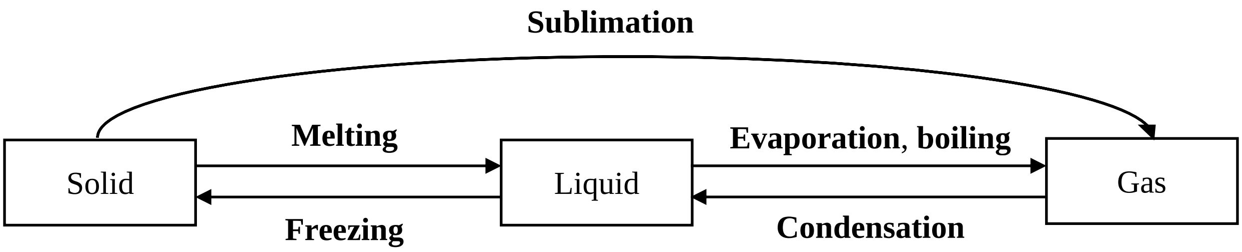
Shape

State	Solid	Liquid	Gas
Arrangement	Closely packed, orderly manner	Disorderly manner	Spread far apart
Forces of attraction	Very strong	Strong	Very weak
Kinetic energy	Very low – vibrate about fixed positions	Low – × held in fixed positions	High – a lot, × held in fixed positions
Movement	× move about freely	Slide past each other throughout liquid	Move about rapidly in any direction

Volume – compressibility

State	Solid	Liquid	Gas
Compressibility	×	×	√
Particles	Very close to one another	• Further away from one another • Still packed quite closely together	• A lot of space between them • Can be forced to move closer together

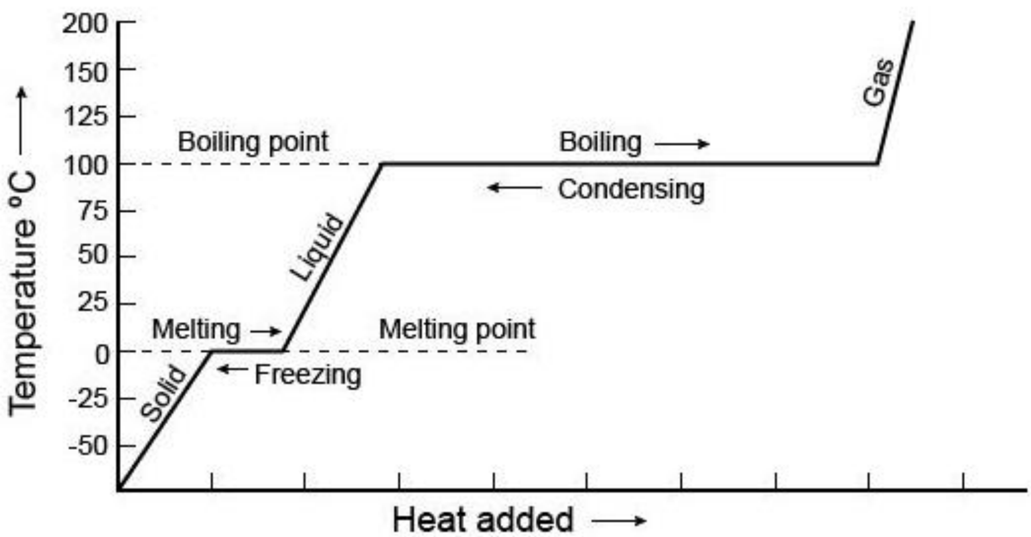
Changes in state of matter



Movement of particles

Process	Start	Change	End
Melting	• Energy absorbed • Energy → kinetic energy • Particles vibrate faster about fixed positions	• Temperature high enough (melting point), vibration sufficient to overcome forces of attraction • Particles break away from fixed positions	• Particles no longer in fixed positions • Substance is now **liquid** • Particles move freely throughout liquid
Freezing	• Energy released • Particles lose kinetic energy, move more slowly	• Temperature low enough (freezing point), × enough energy to move freely • Particles start to settle into fixed positions	• All particles settled into fixed positions • Substance is now **solid** • Particles only vibrate about fixed positions
Boiling	• Energy absorbed • Energy → kinetic energy • Particles start to move faster	• Temperature high enough, enough energy to overcome forces of attraction	• Particles spread far apart • Substance is now **gas** • Particles move about in any direction
Condensation	• Energy released	• Particles lose energy, move more slowly	• Movement of particles slow enough • change → **liquid**
Sublimation	• Energy absorbed	• Particles at surface of solid • enough energy to break away from solid	• Particles escape as **gas**

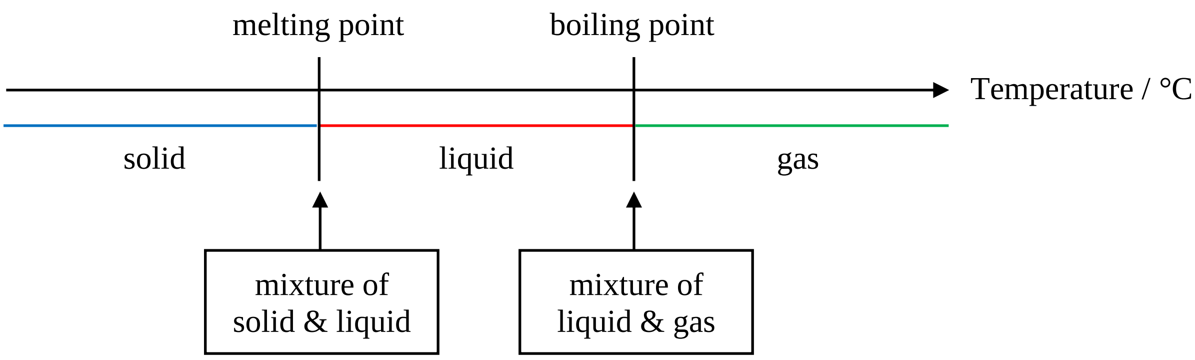
Curve – **heating curve** & **cooling curve**



Differences between boiling & evaporation

Difference	Boiling	Evaporation
Temperature	Only at boiling point	Below boiling point
Part of liquid	Throughout	Only at surface
Rate	Rapid	Slow

Temperature ranges:

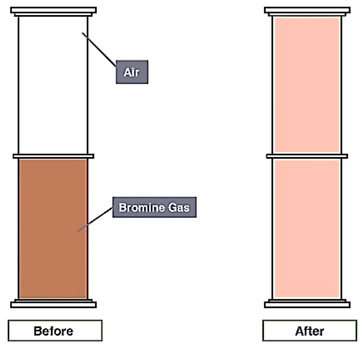


3.2 Diffusion (1.4)

Diffusion: movement of particles from region of high → low concentration

Factors affecting rate of diffusion

Factor	Explanation
1. **Relative molecular mass** (m_r)	Low molecular masses diffuse faster
2. **Temperature**	Particles gain more energy → move faster



Gas: diffusion of bromine gas → air

Experiment	Process
Start	• Gas jar of air (colourless) inverted on top of gas jar of bromine vapour (reddish-brown) • Cover: separate gas jars
End	• Few minutes after removing cover, colour of gas in both gas jars looks same throughout • **Homogenous mixture** of air & bromine ▪ Air & bromine made up of tiny particles moving randomly ▪ Bromine particles $\xleftrightarrow{\text{diffuse into spaces between}}$ air particles

Liquid: diffusion of potassium manganate(VII) → water

Experiment	Process
Start	Put small crystal of potassium manganate(VII) into beaker of water
End	Crystal dissolves → deep purple solution at bottom of beaker Diffusion slowly: solution → uniformly purple

Differences in rates of diffusion of ammonia (NH_3) & hydrogen chloride (HCl)

- Chemical equation of reaction:

$$\boxed{NH_3 + HCl \longrightarrow NH_4Cl \text{ (white ring)}}$$

- White ring: nearer to the end with hydrogen chloride
  → ammonia particles move faster than hydrogen chloride particles

3.3 Simple Molecular Structure and its Physical Properties (7.2)

Simple molecular structures

→ exist as simple molecules

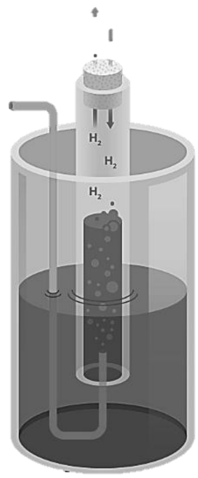
Physical property	Explanation
1. **Melting** & **boiling point**: low	• Molecules held together by weak intermolecular forces → little energy to overcome • Liquids / gases at room temperature • Volatile (evaporate easily)
2. **Solubility**: • water: insoluble • organic solvent: soluble	• Oil: dissolves in dichloromethane, insoluble in water • Exceptions: soluble in water (a) alcohol (b) sugar (c) oxygen gas (d) chlorine gas
3. **Electricity** conductivity: × conduct	1) No charged particles 2) Not free moving / mobile

Typical questions

1. Explain why elements with simple molecular structure cannot conduct electricity.

   Simple molecular structures do not have any 1 free moving 2 ions or electrons to conduct electricity. Simple molecular structures are electrically neutral.

2. A student uses the set up shown below to determine the rate of diffusion of some gases. The time taken for $100cm^3$ of each gas to diffuse through the diffusion plug at room temperature and pressure is shown below.



Gas	Time / s
methane (CH_4)	100
neon (Ne)	114
carbon monoxide (CO)	132
oxygen (O_2)	141
nitrogen (N_2)	?

(a) Suggest the time that 100 cm^3 nitrogen would take to diffuse out from the apparatus. Explain why.

132s. $100cm^3$ nitrogen has the same relative molecular mass as carbon monoxide, i.e. 28. Hence it diffuses the same rate as carbon monoxide, i.e. requires 132s to diffuse out from the apparatus.

(b) Name a gas which will diffuse faster than any of the gases shown in the table.

Hydrogen gas (H_2)

(c) Why is this apparatus unsuitable for finding the rate of diffusion of ammonia gas?

Ammonia gas is **very soluble** in water. It would dissolve in the water instead of diffusing through the porous plug.

(d) The experiment was repeated using 40°C water in the new setup.
Suggest the time taken for 100 cm^3 nitrogen to diffuse out from this new apparatus. Explain why.

Less than 132s.
The higher the temperature, the higher that rate of diffusion. As temperature increases, particles gain more energy. They can move faster, hence increasing the rate of diffusion. Thus, nitrogen will diffuse faster and take a shorter time at 40°C.