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Topic 1

The Particulate Nature of Matter

Learning Objectives

Core

- State the properties of solids, liquids and gases.
- Describe the structure of solids, liquids and gases in terms of particle arrangement and movement.
- Describe changes of state in terms of melting, boiling, evaporation, freezing, condensation and sublimation.
- Describe qualitatively the pressure and temperature of a gas in terms of the movement of its particles.
- State Brownian motion as evidence for the kinetic particle (atoms, molecules or ions) model of matter.
- Describe and explain diffusion.

Extended

- Explain changes of state in terms of the kinetic theory.
- Describe and explain Brownian motion and state evidence for Brownian motion.
- Describe and explain dependence of rate of diffusion on molecular mass.

The Kinetic Particle Theory states that:

- All matter consists of tiny moving particles like atoms, molecules or ions.
- There is forces of attraction between the particles and the particles possess kinetic energy to vibrate or move about.
- All matter can exist as solids, liquids or gases depending on the arrangement of the particles.

States of matter

Solid:

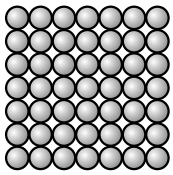
- In the solid state, the particles are closed to one another and they are arranged in regular arrangement. This gives solid a definite shape and definite volume. There is strong attractive forces of attraction between the particles so they can only vibrate in fixed positions.

Liquid:

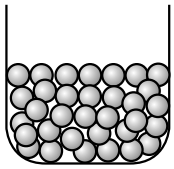
- In the liquid state, the particles are further apart compared to the solid state and they are not arranged in a regular arrangement. A liquid will take the shape of its container. A liquid has a definite volume and cannot be compressed. The forces of attraction between the liquid particles is weaker than the forces of attraction between the solid particles, hence liquid particles are able to move around and slide past one another.

Gas:

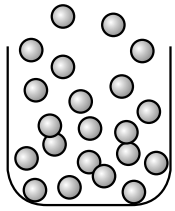
- In the gaseous state, the particles are furthest apart. A gas does not have any definite shape or volume and gases can be compressed easily. The forces of attraction in gases is weaker than in liquids, hence gas particles are able to move around freely.
- All gases exert a pressure due to the constant collision between the gas particles as well as against the walls of the container. The pressure of a gas depends on the temperature and volume of the container. At a higher temperature, the gas particles possess greater kinetic energy; they move faster and hit against the wall of container more frequently, resulting in greater pressure. For the same amount of gas at a fixed temperature, the pressure of the gas is inversely proportional to the volume of its container.



Regular arrangement of particles in a solid



Liquid particles move further apart and slide past one another

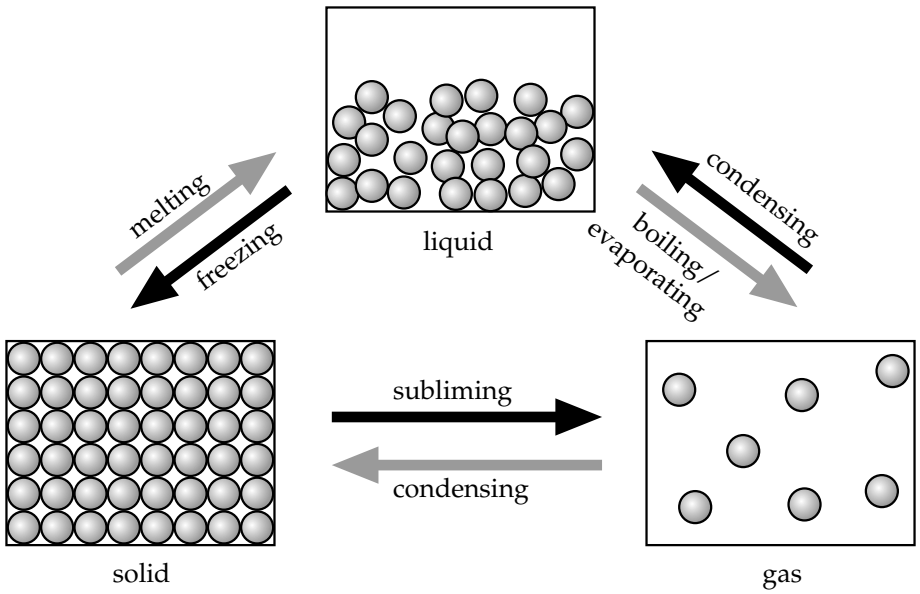


Gas particles move freely and quickly.

	Solid	Liquid	Gas
Particles arrangement and movement	Particles are held closely in a regular arrangement. Particles vibrate in fixed position.	Particles are further apart compared to the solid state and they are free to move.	Particles are further apart compared to the liquid state and they are free to move.
Volume and shape	Has a definite shape and volume.	Has a definite volume but takes the shape of its container.	Has no definite volume and takes the shape of its container.

Changes of state

According to the Kinetic Theory of Matter, when matter is heated, the particles gain more kinetic energy and move faster or vibrate more. The matter also expands as its particles move further apart. Physical changes between the different states can occur when heat energy is given out (exothermic) or taken in (endothermic) from the surroundings as shown in diagram below:



(I) Melting: Conversion of solid into liquid state

Melting is an endothermic physical change where heat is taken in from the surroundings. When a solid is heated, its particles vibrate faster. At the melting point, the solid particles gain enough energy to break free from the regular arrangement and change into liquid.

(II) Evaporation and Boiling: Conversion of liquid into gaseous state

Evaporation and boiling are endothermic physical changes where heat is taken in from the surroundings. When a liquid is heated, the liquid particles gain more energy. Some of the attractive forces between particles is broken and particles move further apart to form a gas. Evaporation occurs on the surface of liquids at any temperature while boiling occurs only at the boiling point of the liquid. During evaporation, the high energy particles escape from the surface of the liquid, even at temperatures below its boiling point.

(III) Condensation: Conversion of gas into liquid state

Condensation is an exothermic physical change where heat is given out to the surroundings. When a gas is cooled, the gas particles lose their kinetic energy and move slowly. The attractive forces hold the particles closer to form a liquid.

Practice Questions

Multiple choice questions

1. When steam condenses to water at 25 °C, what happens to the water molecules?

(A) They move faster and come close together.

(B) They move faster and move further apart.

(C) They move slower and come close together.

(D) They move slower and move further apart. ( )

2. Which of the following is a correct description of the particles in a liquid?

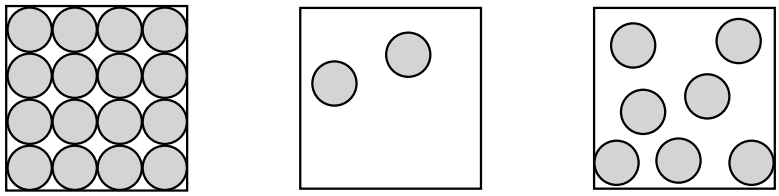
(A) Particles are arranged in a regular arrangement.

(B) Particles can move past one another due to the weak attractive forces.

(C) Particles vibrate in fixed in positions.

(D) Particles can move around freely in all directions and can be compressed. ( )

3. The following diagrams show some particles in different arrangements.



I **II** **III**

Which of the following is a correct description of the above diagrams?

	I	II	III
(A)	Solid	Liquid	Gas
(B)	Gas	Solid	Liquid
(C)	Gas	Liquid	Solid
(D)	Solid	Gas	Liquid

( )

4. In a sample of air at 25 °C, the molecules of oxygen, nitrogen and carbon dioxide move at different average speeds. Which of the following lists the molecules in order of decreasing average speed?

Fastest ⟶ Slowest

(A)	Carbon dioxide	Oxygen	Nitrogen
(B)	Nitrogen	Carbon dioxide	Oxygen
(C)	Nitrogen	Oxygen	Carbon dioxide
(D)	Oxygen	Carbon dioxide	Nitrogen

( )