Matter

Physical nature of matter

Matter is anything that has mass and occupies space. It is made up of tiny particles called atoms, which vary in size, shape, and nature. These particles are too small to be seen with a simple microscope.

Matter exists in three states: solid, liquid, and gas.

Characteristics of particles

- A large number of particles constitute matter.
- Particles are very small in size.
- Particles have spaces between them.
- Particles are continuously in motion.
- Particles attract each other through interparticle forces of attraction.
- The strength of attraction decreases in the order: Solid > Liquid > Gas.

States of matter

Solid state: Solids have a definite shape and volume with negligible compressibility. They are rigid and maintain their shape under external forces.

Liquid state: Liquids have a definite volume but no fixed shape. They take the shape of their container and can flow, hence called fluids. The particles are loosely packed and move freely.

Gaseous state: Gases have neither definite shape nor volume. They expand to fill their container and are highly compressible. Gas particles move randomly at high speeds, exerting pressure on container walls.

Interconversion of states

Matter can change from one state to another by altering temperature or pressure. This process is called interconversion of states of matter.

Water is an example that exists in all three states: solid (ice), liquid (water), and gas (water vapour).

Change of state processes

- **Melting:** Solid to liquid by absorbing heat (e.g., ice to water).
- **Freezing:** Liquid to solid by releasing heat (e.g., water to ice).
- **Evaporation:** Liquid to gas at the surface by absorbing heat.
- **Boiling:** Liquid to gas throughout the liquid at boiling point.
- **Condensation:** Gas to liquid by releasing heat (e.g., steam to water).
- **Sublimation:** Solid to gas without becoming liquid (e.g., dry ice).

Temperature and heat

The SI unit of temperature is Kelvin (K), related to Celsius by $T(K) = t(^{o}C) + 273$.

Melting point: Temperature at which a solid melts to liquid at atmospheric pressure (e.g., ice melts at 273.16 K or 0°C).

Boiling point: Temperature at which a liquid boils at atmospheric pressure (e.g., water boils at 373 K or 100°C).

Latent heat of fusion: Heat required to change 1 kg of solid into liquid at melting point without temperature change.

Latent heat of vaporisation: Heat required to change 1 kg of liquid into gas at boiling point without temperature change.

Evaporation details

Evaporation occurs only at the surface of a liquid and causes cooling. It is affected by surface area, temperature, humidity, and wind speed:

- Increases with surface area and temperature.
- Decreases with humidity.
- Increases with wind speed.

Solved Examples

Example 1: Explain why gases are highly compressible compared to solids and liquids.

Solution: Gas particles are far apart with large spaces between them and move randomly at high speeds. This large space allows gases to be compressed easily by reducing the volume. In contrast, solids and liquids have particles closely packed with little space, making them less compressible.

Example 2: Calculate the temperature in Kelvin if the temperature in Celsius is 25°C.

Solution: Using the formula T(K) = t(°C) + 273,

T = 25 + 273 = 298 K.

Example 3: Describe the process of sublimation with an example.

Solution: Sublimation is the change of a solid directly into gas without passing through the liquid state. For example, dry ice (solid carbon dioxide) sublimates at room temperature, turning directly into carbon dioxide gas.

Practice Set

- **Level 1 (Easy):** Define matter and list its three states.
- **Level 2 (Moderate):** Explain why liquids have a fixed volume but no fixed shape.
- **Level 3 (Challenging):** A solid melts at 0°C and boils at 100°C. Identify the substance and explain the significance of these temperatures.

Answer Key

Level 1: Matter is anything that has mass and occupies space. Its three states are solid, liquid, and gas.

Level 2: Liquids have a fixed volume because their particles are close together, but no fixed shape because particles can move and flow, taking the shape of the container.

Level 3: The substance is water. 0°C is its melting point where solid ice changes to liquid water. 100°C is its boiling point where liquid water changes to gas (steam).

Quick Reference Table

- **Matter:** Anything that has mass and occupies space.
- **States of Matter:** Solid (definite shape and volume), Liquid (definite volume, no fixed shape), Gas (no definite shape or volume).
- **Melting Point:** Temperature at which solid changes to liquid.
- **Boiling Point:** Temperature at which liquid changes to gas.
- **Latent Heat of Fusion:** Heat required to change solid to liquid at melting point.
- **Latent Heat of Vaporisation:** Heat required to change liquid to gas at boiling point.
- **Evaporation:** Surface phenomenon where liquid changes to gas.
- **Sublimation:** Solid changes directly to gas without liquid state.

Common Mistakes and Misconceptions

- Confusing evaporation with boiling: Evaporation occurs only at the surface and at all temperatures, while boiling occurs throughout the liquid at boiling point.
- Assuming gases have fixed volume: Gases have neither fixed shape nor volume and expand to fill their container.
- Believing solids can be compressed easily: Solids are rigid and have negligible compressibility.
- Thinking sublimation involves liquid state: Sublimation skips the liquid state entirely.

Glossary

- **Atom:** The smallest particle of matter that retains its chemical properties.
- **Interparticle Force:** The force of attraction between particles of matter.
- **Density:** Mass per unit volume of a substance.
- **Humidity:** The amount of water vapour present in the air.
- **Fusion:** The process of melting from solid to liquid.
- **Diffusion:** Movement of particles from higher to lower concentration.
- **Condensation:** Change of gas to liquid by releasing heat.
- **Latent Heat:** Heat absorbed or released during a change of state without temperature change.
- **Plasma:** Ionised gas with super energetic particles, found in stars and neon signs.