IGCSE CHEMISTRY STUDY NOTES
UNIT 1 THE PARTICULATE NATURE OF MATTER
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1.1 The particulate nature of matter

State the distinguishing properties of solids, liquids and gases

<table>
<thead>
<tr>
<th>Solids</th>
<th>Liquids</th>
<th>Gases</th>
</tr>
</thead>
<tbody>
<tr>
<td>definite shape</td>
<td>assume the shape of the</td>
<td>no definite shape</td>
</tr>
<tr>
<td></td>
<td>container</td>
<td></td>
</tr>
<tr>
<td>definite volume</td>
<td>definite volume</td>
<td>occupy as much space as</td>
</tr>
<tr>
<td></td>
<td></td>
<td>possible</td>
</tr>
<tr>
<td>not compressible</td>
<td>slightly more compressible</td>
<td>highly compressible</td>
</tr>
<tr>
<td></td>
<td>than solids</td>
<td></td>
</tr>
<tr>
<td>high density</td>
<td>moderate to high density</td>
<td>low density</td>
</tr>
<tr>
<td>cannot flow</td>
<td>can flow</td>
<td>can flow</td>
</tr>
</tbody>
</table>

Basic assumptions of the Kinetic Particle Theory of matter:

- All matter is made up of particles.
- All particles are constantly moving (KINETIC).
- The average kinetic energy of particles is dependent on temperature; higher the temperature, greater the average kinetic energy of particles and vice-versa.
Describe the structure of solids, liquids and gases in terms of particle separation, arrangement and types of motion

<table>
<thead>
<tr>
<th>Solids</th>
<th>Liquids</th>
<th>Gases</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Energy</strong></td>
<td>low</td>
<td>higher than solids</td>
</tr>
<tr>
<td><strong>Movement</strong></td>
<td>particles can vibrate about fixed positions</td>
<td>particles can slide over each other / move over each other; collide often</td>
</tr>
<tr>
<td><strong>Arrangement</strong></td>
<td>particles are closely packed and have a regular, ordered arrangement often in the form of a lattice (crystalline)</td>
<td>particles are loosely arranged in comparison to solids; the arrangement is disordered</td>
</tr>
</tbody>
</table>

*Random movement: no fixed velocity

**Arrangement of particles in solid, liquid and gas**

- SOLID
- LIQUID
- GAS
Describe changes of state in terms of melting, boiling, evaporation, freezing, condensation and sublimation

The three common physical states of matter are:

- **SOLID**
- **LIQUID**
- **GAS**

Changes of state:

![Diagram showing changes of state](image)

<table>
<thead>
<tr>
<th>Solid</th>
<th>Change of state from liquid to gas can be termed as boiling or evaporation.</th>
</tr>
</thead>
<tbody>
<tr>
<td>LIQUID</td>
<td>Boiling takes place at a fixed temperature called the boiling point.</td>
</tr>
<tr>
<td>Gas</td>
<td>Evaporation takes place over a range of temperatures.</td>
</tr>
</tbody>
</table>

**NOTE:**

For IGCSE 0620 exams, change of state from gas to solid can also be termed as **SUBLIMATION**.
Heating and cooling curves

A heating / cooling curve is a graph of temperature against time which depicts the changes of state as a substance is heated or cooled.

The sloping regions of the curves depict changes in temperature but not in state. The flat regions of the curves depict changes in state but not in temperature.

Heating curve depicting the change from ice at −15°C to water to steam above 100°C

The cooling curve for a substance
QUESTION

The graph shows how the temperature of a substance changes as it is cooled over a period of 30 minutes. The substance is a gas at the start.

Each letter on the graph may be used once, more than once or not at all.

(a) Which letter, S, T, V, W, X, Y or Z, shows when

(i) the particles in the substance have the most kinetic energy,
(ii) the particles in the substance are furthest apart,
(iii) the substance exists as both a gas and a liquid?

SOLUTION:

(i) S
(ii) S
(iii) V

Explanation:
Order of energy:
gas > liquid > solid

Point S represents gas particles with the highest energy. The gas particles can move randomly and are furthest apart.

*energy ∝ temperature
Higher the temperature, greater the energy
The flat regions of the curves depict changes in state but not in temperature. The substance exists in a gas-liquid state along V.

(b) Use the graph to estimate the freezing point of the substance.

**SOLUTION:**

140°C (as can be seen from the graph above)

(c) Name the change of state directly from a solid to a gas.

**SOLUTION:**

Sublimation
Melting

- When a solid is heated, the particles gain energy and start vibrating faster.
- They push against each other. The compact structure loosens up and the arrangement starts changing from ordered to disordered.
- Once the melting point is reached, the particles change over to a liquid and start moving over each other.

Freezing (reverse of melting)

- When a liquid is cooled, the particles lose energy. Their movement slows down.
- They collide less frequently and come closer. The arrangement starts changing from disordered to ordered.
- Once the freezing point is reached, the particles change over to a solid and start vibrating about their fixed positions.

NOTE:

Melting point of a pure substance is the same as its freezing point.
**Boiling**

- When a liquid is heated, the particles gain energy and start moving faster.
- They collide more frequently and push away from each other.
- As heating is continued, the forces of attraction between the particles weaken further and the distance between the particles increases.
- At the boiling point, the particles start changing over to the gas phase. They move randomly and their arrangement becomes highly disordered.

**Condensation (reverse of boiling)**

- When a gas is cooled, the particles lose energy and start moving slower.
- They collide less frequently and come closer.
- As cooling is continued, the forces of attraction between the particles get stronger and the distance between the particles decreases.
- As the boiling point is reached, the particles start changing over to the liquid phase. They start moving over each other and their arrangement becomes ordered.

**ASSESSMENT: STATES OF MATTER**
Describe qualitatively the pressure and temperature of a gas in terms of the motion of its particles

- In a gas the particles are relatively far apart.
- They are free to move anywhere within the container in which they are held. They move randomly at very high velocities.
- They collide with each other.
- They also collide with the walls of the container, thereby creating pressure on the walls. (MUST KNOW!)
- At a higher temperature, the average kinetic energy of the gas particles increases. They move faster and collide with the walls of the container more often. This increases the pressure exerted on the container by the gas. The reverse is applicable at lower temperatures.
Show an understanding of the random motion of particles in a suspension (sometimes known as Brownian motion) as evidence for the kinetic particle (atoms, molecules or ions) model of matter.

The BROWNIAN MOTION was discovered by botanist Robert Brown while studying the movement of pollen grains on the surface of water under a microscope.

The random (zig-zag) motion of visible particles (pollen grains) caused by much smaller, invisible ones (water particles) is called Brownian motion – AN EVIDENCE FOR THE KINETIC PARTICLE THEORY.
Describe and explain Brownian motion in terms of random molecular bombardment

As per Robert Brown, the pollen grains were moving because the much smaller and faster-moving water particles were constantly colliding with them (bombardment).

**Bombardment of Pollen particle by water molecules**

**QUESTION**

Dust particles in the air move around in a random way.

(i) What term describes the random movement of the dust particles?

**SOLUTION:**

The random zig-zag movement of dust particles is known as **BROWNIAN MOTION**.

(ii) Explain why the dust particles move in this way.

**SOLUTION:**

The dust particles (much larger than air particles) frequently collide with the surrounding air particles and thereby move randomly.
State evidence for Brownian motion

1. Smoke (as seen in a smoke cell)

2. Diffusion of matter through liquids and gases

CLICK TO VIEW ANIMATED DEMONSTRATION OF BROWNIAN MOTION
Describe and explain diffusion

Diffusion is the movement of particles from an area of high concentration to an area of low concentration. (MUST LEARN!)

It results in the spreading out of particles of a substance through other substances.

Example: diffusion of smoke through air

It is the process by which different substances mix as a result of the random motions of their particles.

The particles of the diffusing substance collide with the surrounding particles and drift apart (Brownian motion).

Diffusion occurs readily through liquids and gases, but not through solids due to the compact arrangement of particles in solids.

When a (soluble) solid is added to a liquid, it first dissolves, then diffuses. (MUST KNOW!)
Describe and explain dependence of rate of diffusion on molecular mass

The rate of diffusion of a gas depends upon its relative molecular mass, \( M_r \).
Lower the \( M_r \), lighter the molecules, higher the rate of diffusion.

**QUESTION**

When chlorine gas, \( \text{Cl}_2 \), is put into a gas jar, it spreads out to fill the gas jar.
When bromine gas, \( \text{Br}_2 \), is put into a gas jar, it also spreads out to fill the gas jar.

The process takes longer for bromine gas than for chlorine gas.

(i) What term describes the way that the gas particles spread out?

**SOLUTION:**

<table>
<thead>
<tr>
<th>Diffusion</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Explanation:</strong></td>
</tr>
</tbody>
</table>

The gas particles move from an area of high concentration to an area of low concentration. This phenomenon is called **DIFFUSION**.
(ii) Use data from the Periodic Table to explain why bromine gas takes longer to fill a gas jar than chlorine gas.

**SOLUTION:**

<table>
<thead>
<tr>
<th>Br₂ has an Mᵣ of 160 AND Cl₂ has an Mᵣ of 71.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heavier Bromine molecules diffuse more slowly.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Data from the Periodic Table</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cl</strong></td>
</tr>
<tr>
<td>17</td>
</tr>
<tr>
<td>chlorine</td>
</tr>
<tr>
<td>35.5</td>
</tr>
<tr>
<td><strong>Br</strong></td>
</tr>
<tr>
<td>35</td>
</tr>
<tr>
<td>bromine</td>
</tr>
<tr>
<td>80</td>
</tr>
</tbody>
</table>

**Mᵣ** of Cl₂ = 35.5 × 2 = 71  
**Mᵣ** of Br₂ = 80 × 2 = 160  

Rate of diffusion depends upon relative molecular mass, **Mᵣ**.  
Higher the **Mᵣ**, slower the diffusion.  
Bromine molecules are heavier than Chlorine molecules, hence diffuse slower and take longer to fill the gas jar.

(iii) Explain why increasing the temperature increases the rate at which the gas particles spread out.

**SOLUTION:**

At a higher temperature, the average kinetic energy of the particles increases and they diffuse at a faster rate (move with a greater speed). **(MUST KNOW!)**
ASSESSMENT: DIFFUSION

QUESTION-BANK