States of Matter

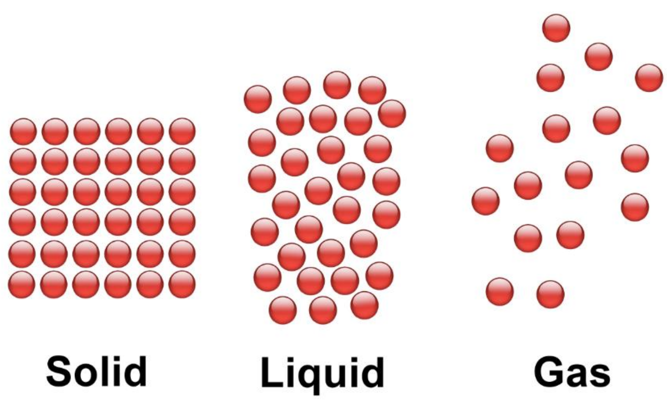
The Three States of Matter

The physical state of a substance depends on its structure and bonding.

● **Solids:** Particles are **touching** and usually in a **regular arrangement** (lattice). They cannot change positions and can only **vibrate** around fixed points, giving solids a fixed shape and volume.

● **Liquids:** Particles are **close together** and mostly **randomly arranged**. They have limited movement and can slide over one another, allowing liquids to take the shape of their container while maintaining a fixed volume.

● **Gases:** Particles are **far apart**, **randomly arranged**, and move **freely** in all directions. Because of the large space between particles, gases have no fixed shape or volume and are easily compressed.



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The Gaseous State and Kinetic Theory

Every gases is composed of very minute and tiny particles called molecules. The kinetic theory of gases are as follows

1. Gas molecules are always in rapid random motion in all direction.
2. Volume occupied by individual gas molecule is negligible in comparison to volume occupied by gas.
3. The intermolecular force of attraction between gas molecule is negligible.
4. The collision between gas molecule is perfectly elastic. During collision kinetic energy of gas molecule is conserved.

5. Pressure exerted by gaseous molecule on wall of container due to collision between gas molecule and wall of container.
6. The average kinetic energy of gas molecule is directly proportional to the absolute temperature.

- **Ideal Gases:** A theoretical gas that perfectly obeys these assumptions and follows the **ideal gas equation**: **pV = nRT**. In this equation, p is pressure (Pa), V is volume (m^3), n is the number of moles, R is the gas constant (8.31 J $K^{-1}mol^{-1}$), and T is temperature (K).

- **Real Gases:** Real gases deviate from ideal behavior, particularly at high pressures and low temperatures. But at very **high temperature** and **low pressure** they tend to exhibit the properties of ideal gas
- **At high temperatures,** kinetic energy of the molecules are low and there is negligible inter molecular force of attraction between the gaseous molecules.
- **At low pressure,** the volume of the gas increases and the molecular volume become negligible compared to total volume of the gas.

The Gas Law

- **Boyle's law**

At constant temperature, the volume of given mass of gas is inversely proportional to its pressure.

$$P \, \alpha \, \frac{1}{v}$$

$$P_1V_1 = P_2V_2$$

- **Charle's law**

The volume of given mass of gas is directly proportional to absolute temperature at constant pressure.

$$P \, \alpha \, T$$

$$\frac{P_1}{T_1} = \frac{V_2}{T_2}$$

- **Combined Gas Equation**

$$\frac{P_1V_1}{T_1}=\frac{P_2V_2}{T_2}$$

- **Ideal Gas Equation**

PV=nRT

- **Dalton's Law of Partial pressure**

Total pressure exerted by mixture of non-reacting gases is equal to sum of partial pressure of the constituent gases.

If P_1, P_2 and P_3 be the pressure exerted by gases A, B and C and P_T be the total pressure exerted by mixture of A, B and C then,

$P_T=P_1 + P_2 + P_3$

In general

$P_T=P_1 + P_2 + P_3$…….

The Liquid State: Vaporisation and Vapour Pressure

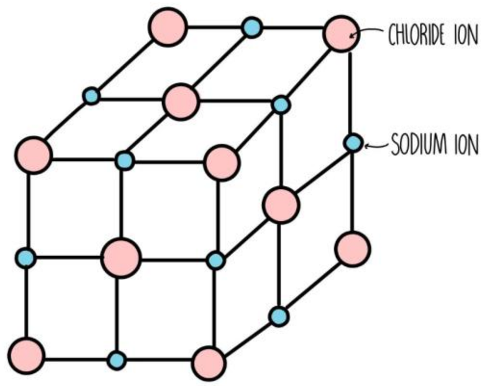
As a liquid is heated, particles gain kinetic energy and eventually overcome the attractive forces holding them together.

- **Vaporisation:** The change from liquid to gas. The energy required to change one mole of liquid to gas is the **enthalpy change of vaporisation**.
- **Vapour Pressure:** In a closed container, the pressure exerted by vapourof substance when it is in equilibrium with liquid substance is called the vapour pressure. Vapour pressure is increases as temperature rises.

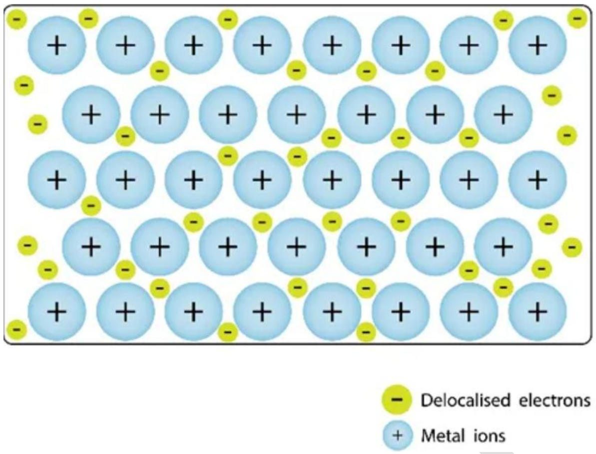
The Solid State: Crystal Lattices

Solids are characterized by a **crystal lattice**, a regularly repeating arrangement of particles. The sources identify four main types of solid structures:

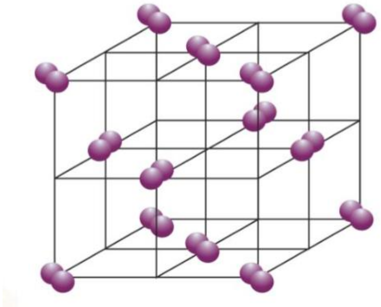
- **Giant Ionic Lattices:** (e.g., NaCl, MgO) These consist of alternating positive and negative ions. They are **hard**, **brittle** (splitting along cleavage planes), and have **high melting points** due to strong electrostatic attractions between oppositely charged ions.



- **Giant Metallic Lattices:** (e.g., Copper) Positive ions are surrounded by a **"sea" of delocalised electrons**. This structure makes metals **malleable** and **ductile**, as layers can slide over each other while the delocalised electrons maintain the bonds.



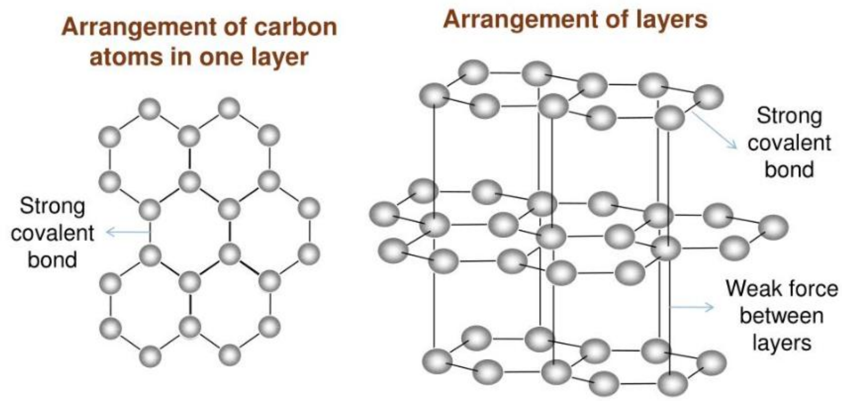
- **Simple Molecular Lattices:** (e.g., Iodine, Ice) Molecules are held in a regular pattern by **weak intermolecular forces** (van der Waals' or hydrogen bonds). These solids have **low melting points** because the forces between molecules are easily broken.



- **Giant Molecular (Covalent) Structures:** (e.g., Diamond, Graphite, SiO_2) These feature a three-dimensional network of strong covalent bonds. They have **extremely high melting points**.

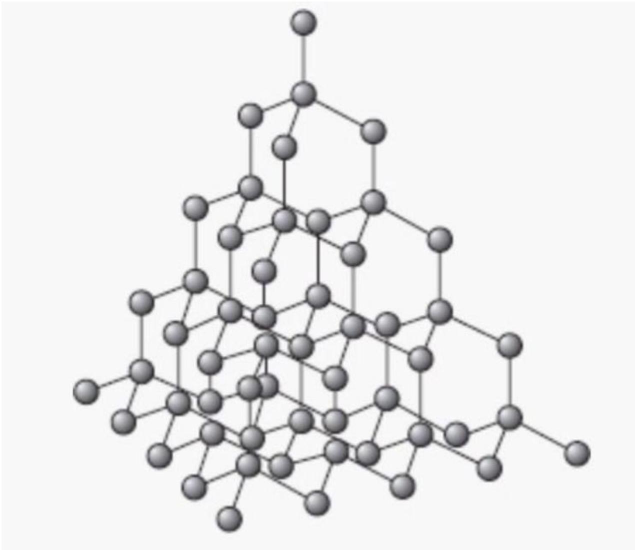
Graphite

Graphite is arranged in planar layers held by weak forces, with delocalised electrons between layers allowing it to conduct electricity. In graphite each carbon atom is sp^2 hybridised and bond angle is 120˚.



Diamond

Diamond is exceptionally hard because every carbon atom forms four covalent bonds in a tetrahedral arrangement. Each carbon atoms are sp^3 hybridised and bond angle is 109.5˚.

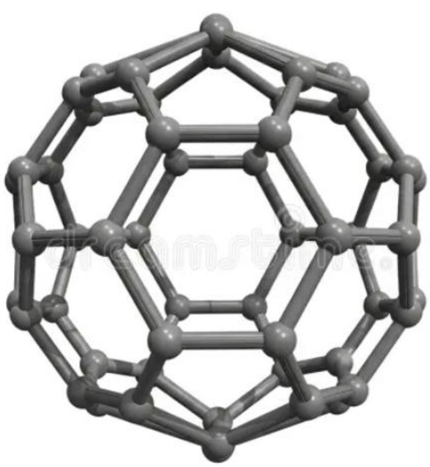


Silicon
Silicon(IV)oxide

Fullerenes and Graphene

These are modern allotropes of carbon with unique properties:

- **Buckminsterfullerene (C_{60}):** A simple molecular structure with football-shaped molecules.



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- **Graphene:** A single isolated layer of graphite that is incredibly strong and an excellent conductor of heat and electricity.