BPC-403 Thermal Physics

Unit 1- Lecture 1

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The Gaseous state

Gas, Solids and liquids are considered as the three states of matter. The chemical constitution of a substance remains the same in all three states. All these states are inter convertible. State change is also known as a phase change.

All these states are inter convertible. State change is also known as a phase change. Every phase change is accompanied by free energy change ΔG.

$$\mathbf{\Delta G = \Delta H - T\Delta S}$$

ΔH is the enthalpy change associated with making/breaking of bonds and ΔS is the entropy change. Entropy is the degree of disorderliness. As compared to liquids, gases are more disordered and have more entropy.

By the process of Sublimation, solid can directly change into a gas. By condensation, the gaseous state changes into a liquid state. By solidification, liquid changes into a solid-state.

The Gaseous state

This is the simplest state of matter. Throughout our life we remain immersed in the ocean of air which is a mixture of gases. We spend our life in the lowermost layer of the atmosphere called troposphere which is held to the surface of the earth by gravitational force. The thin layer of atmosphere is vital to our life. It shields us from harmful radiations and contains substances like dioxygen, dinitrogen, carbon dioxide, water vapour, etc

The atmosphere is comprised of layers based on temperature. These layers are the **troposphere, stratosphere, mesosphere and thermosphere**. A further region at about 500 km above the Earth's surface is called the exosphere.

Characteristics of the Gaseous State of Matter

- The volume and the shape of gases are not fixed. These assume volume and shape of the container.

- Gases are highly compressible.

- Gases have much lower density than the solids and liquids.

- Large empty spaces between the particles of gases are present

- Gases exert pressure equally in all directions.

- Gases mix evenly and completely in all proportions without any mechanical aid

Characteristics of the Gaseous State of Matter

- Simplicity of gases is due to the fact that the forces of interaction between their molecules are negligible. Their behaviour is governed by same general laws, which were discovered as a result of their experimental studies.

- These laws are relationships between measurable properties of gases. Some of these properties like pressure, volume, temperature and mass are very important because relationships between these variables describe state of the gas. Interdependence of these variables leads to the formulation of gas laws.

Gas Laws

Boyle's Law

- The law states that "Gas volume is inversely proportional to gas pressure, at a constant temperature.“

- This is true for fixed amounts of gas.

- According to this law, pressure increases when the volume decreases.

- P is inversely proportional to V.

- PV is constant

• => $P_1V_1 = P_2V_2$ or $PV = K$

It means that at constant temperature, product of pressure and volume of a fixed amount of gas is constant

Gas Laws

Charles's Law

- This law states that Volume is directly proportional to the temperature at constant pressure and for a fixed mass of a gas.

- Charles performed several experiments on gases independently and their investigations showed that for a fixed mass of a gas at constant pressure, volume of a gas increases on increasing temperature and decreases on cooling.

$$\mathbf{V/T = K}$$

Gas Laws

Gay - Lussac's Law

- According to this law, at constant volume, Pressure is directly proportional to the temperature.

PT = K

$$\mathbf{P_1/T_1 = P_2/T_2}$$

Gas Laws

Avogadro's Law

- Two gases that have equal volumes also have the same number of molecules. This is true at the same temperature and pressure.

- The gas' volume is proportional to the moles.
- $V_1/n_1 = V_2 / n_2$

It states that equal volumes of all gases under the same conditions of temperature and pressure contain equal number of molecules.

The Ideal Gas Equation

All the variables can be related according to the gas laws in a single equation known as the Ideal Gas Equation.

$$PV = nRT$$

This is the ideal gas equation and R is the ideal gas constant.
R is expressed in the unit of work or energy per mole per Kelvin.

At constant T and n; $V \propto 1/p$ Boyle's Law
At constant p and n; $V \propto T$ Charles' Law At
constant p and T ; $V \propto n$ Avogadro Law

$$V \infty\ nT/P \text{ or } PV=nRT$$

Real and Ideal Gas

➢The three states of matter that are recognized by their characteristics are solids, liquids and gases.

➢Solids have definite mass and shape due to the strong molecular attraction.

➢In liquids, the molecules are moving so they result in taking the shape of the container.

➢In gases, the molecules are free to move anywhere in the container. Two types of gases exist. Real gas and Ideal gas.

➢As the particle size of an ideal gas is extremely small and the mass is almost zero and no volume Ideal gas is also considered as a point mass.

➢The molecules of real gas occupy space though they are small particles and also have volume.

Ideal Gas

- An ideal gas is defined as a gas that obeys gas laws at all condition of pressure and temperature.

- Ideal gases have velocity and mass. They do not have volume. When compared to the total volume of the gas the volume occupied by the gas is negligible.

- It does not condense and does not have triple point.

- An ideal gas is a theoretical gas composed of many randomly moving point particles that are not subject to interparticle interactions.

Ideal Gas

Ideal gas molecules do not attract or repel each other. The only interaction between ideal gas molecules would be an elastic collision upon impact with each other or an elastic collision with the walls of the container.

The phrase **elastic collision** refers to a collision wherein no kinetic energy is converted to other forms of energy during the collision. In other words, kinetic energy can be exchanged between the colliding objects (e.g. molecules), but the **total kinetic energy before the collision is equal to the total kinetic energy after the collision**.

Ideal gas molecules themselves take up no volume. The gas takes up volume since the molecules expand into a large region of space, but the Ideal gas molecules are approximated as point particles that have no volume in and of themselves.

Ideal Gas

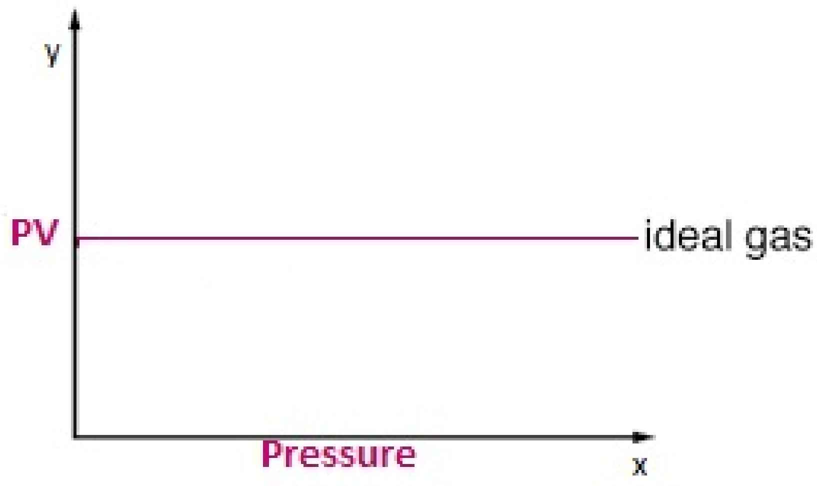
The pressure, P, volume V, and temperature T of an ideal gas are related by a simple formula called the **ideal gas law**. The simplicity of this relationship is a big reason.

$$PV=nRT$$

Where P is the pressure of the gas, V is the volume taken up by the gas, T is the temperature of the gas, R is the gas constant, and n is the number of moles of the gas.

Ideal Gas

Robert Boyle's law, showed that the quantities of pressure times volume are a constant for a sample at equilibrium. The straight horizontal line in the P V versus P graph is for an ideal gas.



At constant temperature the process is called as isothermal. Subsequently if temperature is kept constant the RHS of the equation (nRT) is also constant. If we are going to draw a graph, PV against P, it will be a **straight line parallel to** the P axis.

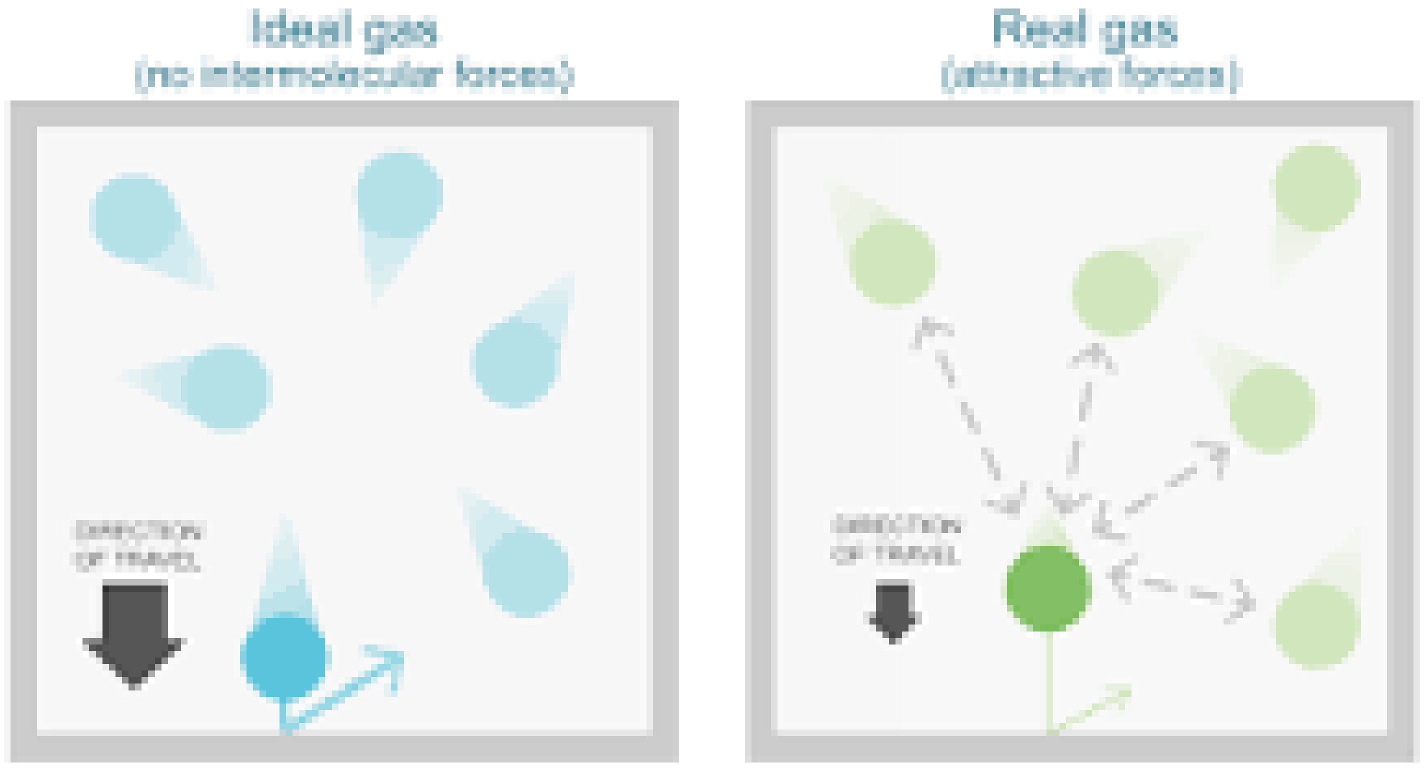
Ideal Gas

Why are gases ideal at high temperature and low pressure?

Gases behave very ideally at high temperature and low pressure. High temperature means the molecules are moving around faster and have **less chance of sticking together**. Lower pressure means that the molecules are far apart from each other and won't interact as much.

Why are gases non ideal at low temperatures?

The pressure we measure comes from the force of the gas molecules hitting the walls of the container. ... The effect of intermolecular forces is much more prominent at low temperatures because the molecules have **less kinetic energy to** overcome the intermolecular attractions.



Real Gas

- A real gas is defined as a gas that does not obey gas laws at all standard pressure and temperature conditions.
- When the gas becomes massive and voluminous it deviates from its ideal behavior.

- Real gases have velocity, volume and mass. When they are cooled to their boiling point, they liquefy.

- When compared to the total volume of the gas the volume occupied by the gas is not negligible.

Difference between Ideal gas and Real gas

IDEAL GAS	REAL GAS
No definite volume	Definite volume
Elastic collision of particles	Non-elastic collisions between particles
No intermolecular attraction force	Intermolecular attraction force
Does not really exists in the environment and is a hypothetical gas	It really exists in the environment
High pressure	The pressure is less when compared to Ideal gas
Independent	Interacts with others
Obeys $PV = nRT$	Obeys $p + ((n^2 a)/V^2)(V - n b) = nRT$

Real Gas

Systems with either very low pressures or high temperatures enable real gases to be estimated as “ideal.” The low pressure of a **system allows the gas particles to experience less intermolecular forces with other gas particles**. This allows for the previous ideal gas equation to be re-written:

$$\mathbf{PV = nRT}$$