

Kinetic Theory of Gas

Postulates

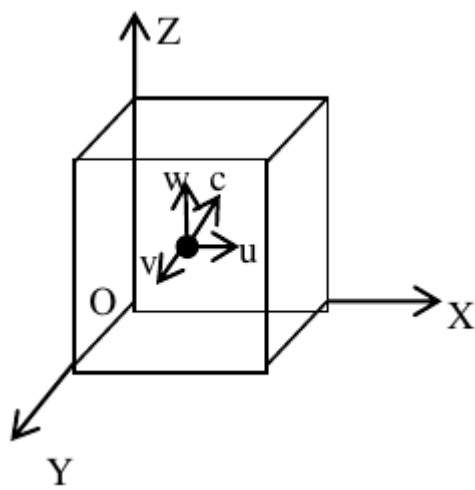
- i. Gas is made by large number of particles which are perfectly elastic in nature.
- ii. Intermolecular force of attraction is neglected
- iii. Volume of each gas molecule is negligible in comparison to volume of gas
- iv. Duration of collision is negligible in comparison to time between successive collision
- v. Effect of gravity on molecule is neglected

Pressure exerted by gas on wall of container

$$\text{Time between successive collision on wall } (t) = \frac{2l}{u}$$

$$\text{Pressure (P)} = \frac{1}{3} \frac{Nm\bar{c}^2}{V}$$

Where, N = total number of particles



m = mass of each particle

C = rms (root mean square)

$$\text{speed} = \frac{\sqrt{C_1^2 + C_2^2 + \dots + C_N^2}}{N}$$

V = volume

$$\Rightarrow \frac{N}{V} = n = \text{no. of particles per unit volume then } P = \frac{1}{3} nm\bar{c}^2$$

Nm = M = total mass of gas then

$$P = \frac{1}{3} \frac{M\bar{c}^2}{V} = \frac{1}{3} \rho \bar{c}^2$$

$$\therefore \bar{c} = \sqrt{\frac{3PV}{M}} = \sqrt{\frac{3P}{\rho}}$$

Factors affecting rms speed of gas

When 1 mole of gas is used then $PV = RT$ and $M = \text{Molar mass}$

$$\therefore \bar{c} = \sqrt{\frac{3RT}{M}} = \sqrt{\frac{3KT}{m}}$$

1. Temperature (T)

For a gas $3R/M$ is constant so

$$\bar{c} \propto \sqrt{T}$$

$$\text{or, } \frac{\bar{c}_2}{\bar{c}_1} = \sqrt{\frac{T_2}{T_1}}$$

2. Nature (M)

At constant temperature $3RT$ is constant

$$\therefore \vec{C} \propto \frac{1}{\sqrt{M}}$$

$$\text{or, } \frac{\vec{C_2}}{\vec{C_1}} = \sqrt{\frac{M_1}{M_2}}$$

When both varies

$$\frac{\vec{C_2}}{\vec{C_1}} = \sqrt{\frac{T_2}{T_1} \times \frac{M_1}{M_2}}$$

1. Average Speed (C_{av}):

The mean speed of all particles of gas molecules is called average speed.

$$\therefore C_{av} = \sqrt{\frac{8RT}{M\pi}} = \sqrt{\frac{8kT}{m\pi}}$$

2. Most probable speed (C_m):

The speed possessed by maximum number of particle is called most probable speed.

$$C_m = \sqrt{\frac{2RT}{M}} = \sqrt{\frac{2kT}{m}}$$

$$\therefore C_{rms} > C_a > C_m$$

Kinetic energy of gas

$$\text{The pressure of gas is } P = \frac{1}{3} \frac{Mc^2}{V}$$

$$\text{or, } \frac{1}{2}Mc^2 = \frac{3}{2}PV$$

$$\therefore \text{KE of gas} = \frac{3}{2}PV$$

$$\therefore P = \frac{2}{3} \frac{KE}{V}$$

For 1 mole of gas $PV = RT$

$$\therefore \text{KE of 1 mole of gas} = \frac{3}{2}RT$$

For n moles of gas,

$$PV = nRT$$

$$\therefore \text{KE} = 3/2nRT$$

For each molecule of gas

$$\text{KE} = 3/2KT$$

Vanderwaal's equation

At high temp. and low pressure the inter molecular force of attraction is negligible so the gas follow ideal gas equation. At high pressure and low temperature correction in volume of gas and pressure is needed due to finite size of gas molecule and some intermolecular force of attraction as

$$\left(P + \frac{a}{V^2}\right)(V - b) = RT$$

a & b are constants depends on nature of gas

For n moles of gas

$$\left(P + \frac{n^2a}{V^2}\right)(V - nb) = nRT$$

Critical Temperature

Temperature below which gas can be liquified by increasing pressure only. The value of critical temperature is different for different gases. It is maximum for CO_2 i.e $31^\circ C$ and least for helium i.e. $-268^\circ C$. For oxygen it is $-118^\circ C$. For hydrogen it is $-240^\circ C$ etc.

Critical pressure

The minimum pressure at critical temperature required to liquefy the gas is called critical pressure. Lower the critical temperature, critical pressure also will be less. It's value is 2.26 atm . pressure for Helium and 72.8 atm pressure for CO_2 gas

$$\therefore T_c = \frac{8a}{27Rb}, P_c = \frac{8a}{27b^2} \quad V_c = 3b$$

Boyle's temperature

The temperature below which the product pV first decreases and become least and increases with increasing pressure. Above this temperature the product PV increases on increasing pressure.

$$\therefore \text{Boyle's Temperature } (T_B) = \frac{a}{Rb}$$

$$\therefore T_B = \frac{27}{8} T_c$$

Mean free path (λ)

The average distance of molecules between two successive collision is called mean free path.

$$\therefore \text{Mean free path } (\lambda) = \frac{1}{\sqrt{2}\pi\sigma^2 n}$$

Where,

σ = molecular diameter

n = no. of molecules per unit volume

$$\therefore n = \frac{P}{KT} \text{ so}$$

$$\lambda = \frac{KT}{\sqrt{2}\pi\sigma^2 p}$$