12. KINETIC THEORY OF GASES

Speeds of Gas Molecules

Root Mean square speed:
Square root of mean of square of speed of different molecules.

$$V_{rms} = \sqrt{\frac{V_1^2 + V_2^2 + \dots\dots\dots\dots + V_n^2}{n}}$$

$$V_{rms} = \sqrt{\frac{3RT}{M}}$$

Average Speed:
Arithmatic mean of speed of molecules of gas at given temperature.

$$V_{avg} = \sqrt{\frac{|\vec{v}_1| + |\vec{v}_2| + \dots\dots + |\vec{v}_n|}{n}}$$

$$V_{avg} = \sqrt{\frac{8RT}{\pi M}}$$

Most probable speed:

- Speed possessed by maximum number of molecules of gas.

$$V_{mp} = \sqrt{\frac{2RT}{M_o}}$$

Assumptions in Kinetic Theory of Gases

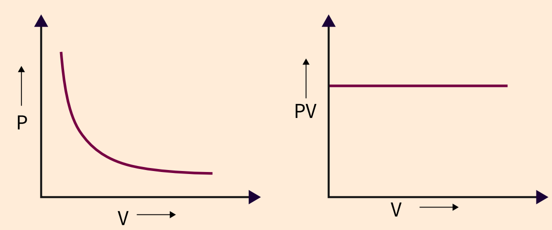
- Gas consists of small particles known as Molecules.
- Molecules of Gas are identical rigid sphere and elastic points mass.
- Molecules of Gas moves randomly in all directions with possible velocity.

IDEAL GAS LAWS

- Pressure, Temperature and volume of Gas are related to each other by following equation, PV = nRT.
- P – pressure, V – volume, n – no. of moles , R = Universal Gas Constant = 8.314 J/mol.k, T – Temperature.

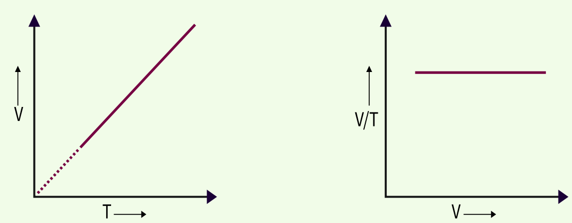
$$PV = \frac{m}{M_A}RT \, ; \left[\because n = \frac{m}{M}\right]$$

Boyle's Law



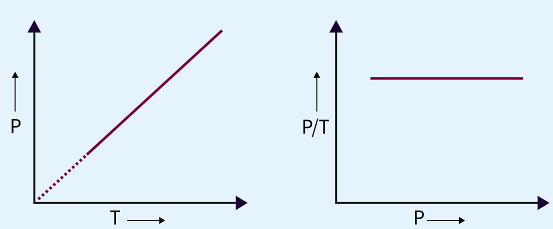
- At constant temperature, pressure of given mass of gas is inversely proportional to its volume.
- PV = constant, if T = Constant
- $P_1V_1 = P_2V_2$,When gas changes it's state under constant temperature.

Charle's Law



- At constant pressure, volume of given mass of a gas is directly proportional to its absolute temperature.
- $V \propto T : \frac{V}{T}$ = constant; P = constant.
- $\frac{V_1}{T_1} = \frac{V_2}{T_2}$,When gas change its state under constant pressure.

Gay Lussac's Law



- At constant volume, pressure of given mass of a gas is directly proportional to its absolute temperature.
- $P \propto T : \frac{P}{T}$ = constant; V = constant.
- $\frac{P_1}{T_1} = \frac{P_2}{T_2}$,When gas change its state under constant volume.

Law of Equipartition of Energy

The total Kinetic energy of a gas molecule is equally distributed among it's all degrees of freedom.

$$U = \frac{f}{2} k_B T$$

f = degrees of freedom.
k_B = Boltzmann Constant.

- For monoatomic gas, $U = \frac{3}{2} k_B T$
- For diatomic gas, $U = \frac{5}{2} k_B T$

Relation between Kinetic Energy and Temperature

Kinetic Energy of gas molecule.

- $K.E = \frac{1}{2} m v_{rms}^2 = \frac{3}{2} K_B T$

Kinetic energy of one mole of gas molecule.

- $K.E = \frac{3}{2} N K_B T$

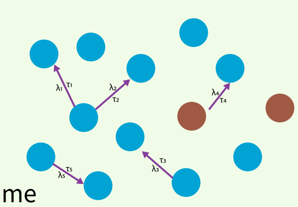
Kinetic energy of one gram of gas molecule.

Mean Free Path

Average distance travelled by molecules between two successive collision.

$$\lambda_{mean} = \frac{1}{\sqrt{2}\,\pi d^2 n}$$

d = diameter of molecules.
n = no. of molecules per unit volume



SPECIAL RELATIONS

- Pressure exerted by a gas,

$$P = \frac{1}{3} \rho v_{rms}^2$$

- Relation between pressure and Kinetic Energy.

$$\frac{E}{N} = \frac{3}{2} K_B T$$

Degrees of Freedom

- **For monoatomic gas,** f = 3
- **For diatomic gas,**
  (a) at room temperature, f = 5
  (b) at high temperature, f = 7
- **For polyatomic gas,**
  (a) at room temperature , f = 6
  (b) at high temperature, f = 8,
  f $\longrightarrow$ degree of freedom.

Specific Heat Capacity

Specific heat capacity for an ideal gas, $\mathbf{C_P - C_V = R}$

- For monoatomic gas, $\frac{C_P}{C_V} = \gamma = \frac{5}{3}$
- For diatomic gas, $\frac{C_P}{C_V} = \gamma = \frac{7}{5}$
- For polyatomic gas, $\frac{C_P}{C_V} = \gamma = \frac{4}{3}$

and f is degrees of freedom.

$$C_P = \left(1 + \frac{f}{2}\right)R\ ,\ C_V = f\,\frac{R}{2}$$

$$\gamma = \frac{C_P}{C_V} = 1 + \frac{2}{f}$$