

Subject  $\Rightarrow$  chemistry  
Chapter  $\Rightarrow$  Gaseous state (Group-A)  
Topic  $\Rightarrow$  Deduction of gas laws.

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## Deduction of gas laws from the kinetic gas equation

(1) Boyle's Law  $\Rightarrow$  According to the kinetic theory, there is a direct proportionality between absolute temperature and average kinetic energy of the molecules.

i.e.

$$\frac{1}{2} m N u^2 \propto T$$

$$\text{or } \frac{1}{2} m N u^2 = K T$$

$$\text{or, } \frac{3}{2} \times \frac{1}{3} m N u^2 = K T$$

$$\text{or } \frac{1}{3} m N u^2 = \frac{2}{3} K T$$

Substituting the above value in the kinetic gas equation,  $P V = \frac{1}{3} m N u^2$ , we get

$$P V = \frac{2}{3} K T$$

The product  $P V$ , therefore, will have a constant value at constant temp. This is Boyle's law.

(2.) Charles's law  $\Rightarrow$  We know that

$$PV = \frac{2}{3} NKT$$

$$\text{or } V = \frac{2}{3} \times \frac{N}{P} \times K T$$

At constant pressure,

$$V = K' T \quad \left( \text{where } K' = \frac{2}{3} \times \frac{N}{P} \times K \right)$$

~~$$V = K' T$$~~

$$\text{or } V \propto T$$

At constant pressure, volume of a gas is proportional to kelvin temperature and this is Charles' Law.

(3.) Avogadro's Law  $\Rightarrow$  If equal volume of two gases is considered at the same pressure

$$PV = \frac{1}{3} m_1 N_1 u_1^2 \quad \text{Kinetic eqn for 1st gas}$$

$$PV = \frac{1}{3} m_2 N_2 u_2^2 \quad \text{Kinetic eqn for 2nd gas}$$

$$\therefore \frac{1}{3} m_1 N_1 u_1^2 = \frac{1}{3} m_2 N_2 u_2^2 \quad \text{--- (1)}$$

When the temperature  $T$  of both the gases is same, their mean kinetic energy per molecule will also be the same.

$$\text{i.e. } \frac{1}{3} m_1 u_1^2 = \frac{1}{3} m_2 u_2^2 \quad \text{--- (2)}$$

Dividing eqn (1) by (2) we get.

under the same conditions of temperature and pressure, equal volumes of the two gases contain the same number of molecules. This is Avogadro's law.

#### (4.) Graham's Law of diffusion $\Rightarrow$

If  $m_1$  and  $m_2$  are the masses and  $u_1$  and  $u_2$  are the velocities of the molecules of gases 1 and 2, then at the same pressure and volume

$$\frac{1}{3} m_1 N_1 u_1^2 = \frac{1}{3} m_2 N_2 u_2^2$$

By Avogadro's law

$$N_1 = N_2$$

$$\therefore m_1 u_1^2 = m_2 u_2^2$$

$$\text{or } \left(\frac{u_1}{u_2}\right)^2 = \frac{m_2}{m_1}$$

If  $M_1$  and  $M_2$  represent the molecular masses of gases 1 and 2 then

$$\left(\frac{u_1}{u_2}\right)^2 = \frac{M_2}{M_1}$$

$$\text{or } \frac{u_1}{u_2} = \sqrt{M_2/M_1}$$

The rate of diffusion  $r$  is proportional to the velocity of molecules  $u$ .

$$\therefore \frac{\text{Rate of diffusion of gas 1}}{\text{Rate of diffusion of gas 2}} = \frac{r_1}{r_2} = \sqrt{\frac{M_2}{M_1}}$$

classmate This is Graham's Law of diffusion

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diffusion