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19/4/21

class \Rightarrow B.Sc. (Hons) Part-1

Subject \Rightarrow Chemistry

Chapter \Rightarrow Gaseous state (Group-A)

Topic \Rightarrow Deduction of gas laws

Paper \Rightarrow IA (Physical Chemistry)

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Deduction of gas laws from the kinetic gas equation

1. Boyle's Law

According to the kinetic theory, there is a direct proportionality between absolute temp. and average kinetic energy of the molecules.

$$\text{i.e. } \frac{1}{2} m N u^2 \propto T$$

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

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

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

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

We get

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

The product PV , therefore, will have a constant value at constant temperature. This is Boyle's Law.

2. Charles's law

We know that,

$$PV = \frac{2}{3} K T$$

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

At constant pressure,

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

$$\text{or, } V \propto T \quad \text{ie.}$$

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

3. Avogadro's Law

If equal volume of two gases is considered at the same pressure,

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

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

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

When the temperature T of both the gases is same, their mean kinetic energy per

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molecule will also be the same.

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

Dividing eqⁿ. (1) by eqⁿ. (2) we get,

$$N_1 = N_2$$

Under the same conditions of temperature and pressure, equal volume of the two gases contain the same no. of molecules.

This is Avogadro's law.

4. Graham's Law of diffusion

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

$$N_1 = N_2$$

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

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

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

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

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

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

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

This is Graham's law of diffusion.

$$\frac{r_1}{r_2} = \sqrt{\frac{M_2}{M_1}}$$