IDEAL GAS EQUATION

An ideal gas is characterized as a system devoid of intermolecular or interatomic forces, existing exclusively in the gaseous state. In reality, a system approaches ideal gas behavior when the pressure is exceedingly low, and the temperature is sufficiently high to overcome attractive intermolecular forces.

An ideal gas is one for which the laws of Boyle and Charles are strictly valid under all temperature and pressure conditions.

From Boyle's law we get, $V \propto \frac{1}{P}$ (at constant n and T)

From charles law we get, $V \propto T$ (at constant n and P)

From Avogadro's law we get, $V \propto n$ (at constant T and P)

Combining the above three equations we get

$$V \propto \frac{nT}{P}$$

or $$V = R\frac{nT}{p}$$ [Where R = ideal gas constant]

or $$PV = nRT$$

Ideal gas equation is a relation between four variables and it describes the state of any gas. For this reason, it is also called Equation of State.

Dimension of R

$$R = \frac{PV}{nT} = \frac{\text{Pressure} \times \text{Volume}}{\text{Mole} \times \text{Temperature}}$$

$$= \frac{(\text{Force / Area}) \times (\text{Area} \times \text{Length})}{\text{Mole} \times \text{Degree (K)}}$$

$$= \frac{\text{Force} \times \text{Length}}{\text{Mole} \times \text{Degree (K)}} = \frac{\text{Work or energy}}{\text{Mole} \times \text{Degree (K)}}$$

Physical Significance of R

The dimensions of R are energy per mole per Kelvin, indicating the quantity of work (or energy) that can be derived from one mole of a gas when its temperature is increased by 1 Kelvin.

Key Points Units of R

(i) In lit-atm $R = \frac{1\ \text{atm} \times 22.4\text{lit}}{273\ \text{K}} = 0.0821$ lit-atm $\text{mol}^{-1}\text{K}^{-1}$

(ii) In C.G.S system $R = \frac{1 \times 76 \times 13.6 \times 980\ \text{dyne cm}^{-2} \times 22400\ \text{cm}^3}{273\ \text{K}}$

$= 8.314 \times 10^7$ erg $\text{mole}^{-1}\text{K}^{-1}$.

(iii) In M.K.S. system $R = 8.314$ Joule $\text{mole}^{-1}\text{K}^{-1}$. [$10^7$ erg = 1 joule]

(iv) In calories $R = \frac{8.314 \times 10^7 \text{ergmole}^{-1}\ \text{K}^{-1}}{4.184 \times 10^7 \text{erg}}$

$= 1.987\ 2$ calorie $\text{mol}^{-1}\text{K}^{-1}$.

Ex. Some spherical balloons each of volume 2 liter are to be filled with hydrogen gas at one atm & 27°C from a cylinder of volume 4 liters. The pressure of the H_2 gas inside the cylinder is 20 atm at 127°C. Find number of balloons which can be filled using this cylinder. Assume that temperature of the cylinder is 27°C.

Sol. No. of moles of gas taken initially $=\frac{20\times4}{R\times400}$ = 2.43 L

No. of moles of gas left in cylinder $=\frac{1\times4}{R\times300}$ = 0.162L

No. of moles of gas to be filled in balloons = 2.43 – 0.162 = 2.268
Let we have 'n' balloons that we can fill

No. of moles of gas that can be filled in 1 balloon = $\frac{1\times2}{0.082\times300}$ = 0.081

$\therefore$ $0.081 \times n = 2.268$

$n = 28$ balloons.