Ideal gas equation.

(1) The simple gas laws relating gas volume to pressure, temperature and amount of gas, respectively, are stated below :

Boyle's law: $P \propto \frac{1}{V}$ or $V \propto \frac{1}{P}$ (n and T constant)

Charle's law: $V \propto \mathrm{T}$ (n and P constant)

Avogadro's law: $V \propto n$ (T and P constant)

If all the above law's combines, then

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

or $$V = \frac{nRT}{P}$$

or $$\boxed{PV = nRT}$$

This is called **ideal gas equation**. R is called **ideal gas constant**. This equation is obeyed by isothermal and adiabatic processes.

(2) **Nature and values of R :** From the ideal gas equation, $R = \frac{PV}{nT} = \frac{\text{Pressure} \times \text{Volume}}{\text{mole} \times \text{Temperatur e}}$

$$= \frac{\frac{\text{Force}}{\text{Area}} \times \text{Volume}}{\text{mole} \times \text{Temperatur e}} = \frac{\text{Force} \times \text{Length}}{\text{mole} \times \text{Temperatur e}} = \frac{\text{Work or energy}}{\text{mole} \times \text{Temperatur e}}.$$

So, R is expressed in the unit of work or energy $mol^{-1}\ K^{-1}$.

Different values of R are summarizedbelow:

$R = 0.0821\ L\,atm\,mol^{-1}\ K^{-1}$

$= 8.3143 \times 10^{7}\ erg\,mol^{-1}\ K^{-1}$

$= 8.3143\ joule\,mol^{-1}\ K^{-1}$ (S.I. unit)

$= 8.3143\ Nm\ mol^{-1}\ K^{-1}$

$= 8.3143\ KPa\,dm^{3}\ mol^{-1}\ K^{-1}$

$= 8.3143\ MPa\,cm^{3}\ mol^{-1}\ K^{-1}$

$= 8.3143 \times 10^{-3}\ kJ\,mol^{-1}\ K^{-1}$

$= 5.189 \times 10^{19}\ eV\,mol^{-1}\ K^{-1}$

$= 1.99\ cal\,mol^{-1}\ K^{-1}$

$$= 1.987 \times 10^{-3}\ K\,cal\,mol^{-1}\ K^{-1}$$

Note: Although R can be expressed in different units, but for pressure-volume calculations, R must be taken in the same units of pressure and volume.

(3) Gas constant, R for a single molecule is called Boltzmann constant (k)

$$k = \frac{R}{N} = \frac{8.314 \times 10^{7}}{6.023 \times 10^{23}}\, ergs\ mole^{-1}\ degree^{-1}$$

$$= 1.38 \times 10^{-16}\ ergs\ mol^{-1}\ degree^{-1} \text{ or } 1.38 \times 10^{-23}\ joule\ mol^{-1}\ degree^{-1}$$

(4) Calculation of mass, molecular weight and density of the gas by gas equation

$$PV = nRT = \frac{m}{M}RT \qquad \left(\because n = \frac{\text{mass of the gas } (m)}{\text{Molecular weight of the gas } (M)}\right)$$

$$\therefore \boxed{M = \frac{mRT}{PV}}$$

$$\boxed{d = \frac{PM}{RT}} \qquad \left(\because d = \frac{m}{V}\right)$$

$$\text{or } \frac{dT}{P} = \frac{M}{R}$$

Since M and R are constant for a particular gas,

Thus, $\frac{dT}{P} = \text{constant}$

Thus, at two different temperature and pressure

$$\boxed{\frac{d_1 T_1}{P_1} = \frac{d_2 T_2}{P_2}}$$

(5) Gas densities differ from those of solids and liquids as,

(i) Gas densities are generally stated in g/L instead of g/cm^3.

(ii) Gas densities are strongly dependent on pressure and temperature as,

$$d \propto P$$

$$d \propto \frac{1}{T}$$

Densities of liquids and solids, do depend somewhat on temperature, but they are far less dependent on pressure.

(iii) The density of a gas is directly proportional to its molar mass. No simple relationship exists between the density and molar mass for liquid and solids.

(iv) Density of a gas at STP $= \frac{\text{molar mass}}{22.4}$

$d(N_2)$ At STP $= \frac{28}{22.4} = 1.25\ g\,L^{-1}$

$d(O_2)$ At STP $= \frac{32}{22.4} = 1.43\ g\,L^{-1}$