Gaseous State

Kinetic Theory Of Gases

In order to explain behaviour of gases Maxwell, Boltzmann, clausius, etc suggested a theoretical model which is known as Kinetic theory of gases.

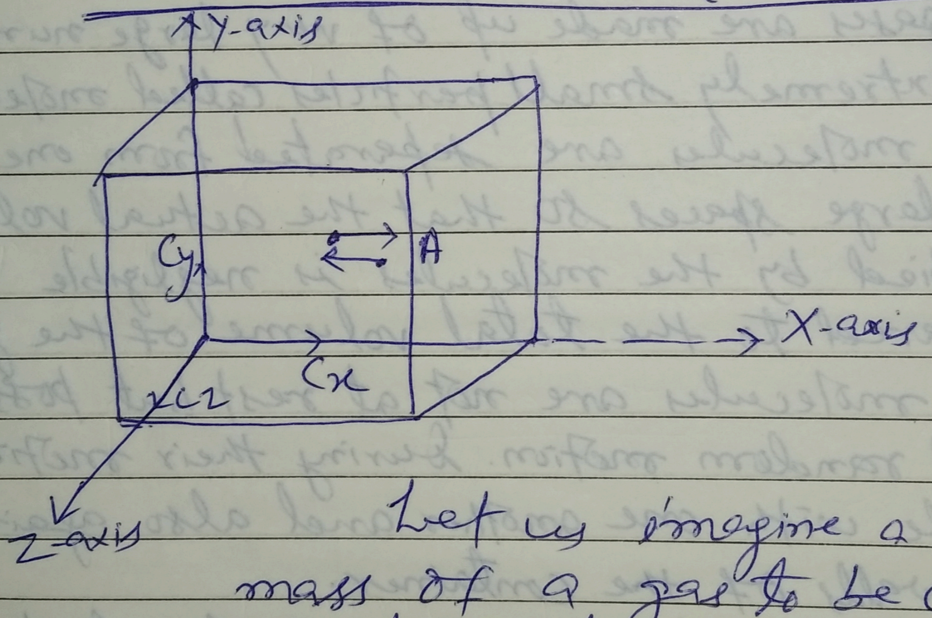
The main assumptions of the kinetic theory of gases are —

(i) All gases are made up of very large number of extremely small particles called molecules.
(ii) The molecules are separated from one another by large spaces so that the actual volume occupied by the molecules is negligible as compared to the total volume of the gas.
(iii) The molecules are not at rest but possess rapid random motion. During their motion, they collide with one another and also against the walls of the container.
(iv) The pressure of the gas is due to bombardment of the gas molecules against the walls of the container.
(v) The collisions of the molecules with each other and with the walls of the container are perfectly elastic, i.e There is no loss or gain of kinetic energy. However, there may be redistribution of energy during such collisions.

(vi) There are no attractive or repulsive forces between the molecules of gas. They are completely independent of each other.

(vii) At any instant, different molecules possess different velocities and hence, different energies. However, the average kinetic energy of the molecules is directly proportional to the absolute temperature.

Derivation of kinetic Equation of gases



Let us imagine a given mass of a gas to be confined in a cubical vessel.

Let, l = length of the edge of the cube

n = Total no of molecules enclosed

m = mass of each molecule

C = root mean square velocity

C_x, C_y, C_z are three components related to C as –

$$C^2 = C_x^2 + C_y^2 + C_z^2$$

Let us consider only one molecule moving between two opposite faces.
The velocity of the molecule before striking the face A is x and since it is perfectly elastic, it rebounds with the same velocity $(-x)$.

Momentum of the molecule before it strikes $= mC_x$
" " " after impact $= -mC_x$
change of momentum after each impact

$$= m \cdot C_x - (-m \cdot C_x) = 2m \cdot C_x$$

Now the molecule strikes the same face after travelling a distance $2l$ cms with a velocity C_x cms per second.

$\therefore$ Number of impacts per second on the same face $= \frac{C_x}{2l}$

$\therefore$ Number of impacts per second on the two opposite faces along the X-axis $= 2 \times \frac{C_x}{2l} = \frac{C_x}{l}$

Hence, the total change of momentum per second due to the impact of one molecule on two opposite walls of the cube along X-axis $= 2mC_x \times \frac{C_x}{l} = \frac{2mC_x^2}{l}$

Similarly ~~total change of momentum per second due to the impact of one molecule~~ on the two opposite faces along Y-axis is $\frac{2mC_y^2}{l}$ and along Z axis is $\frac{2mC_z^2}{l}$

Hence the total change of momentum on on all the six faces of the cube per second per molecule —

$$= \frac{2mC_x^2}{l} + \frac{2mC_y^2}{l} + \frac{2mC_z^2}{l}$$

$$= \frac{2m}{l}(C_x^2 + C_y^2 + C_z^2) = \frac{2mC^2}{l}$$

where C is called root mean square velocity.

∴ Total change of momentum due to n molecules —

$$= \frac{2mC^2}{l} \times n = \frac{2mnC^2}{l}$$

But the change of momentum per second is force and force per unit area is pressure.

$$\therefore P = \frac{Force}{Area} = \frac{2mnC^2}{l \times 6l^2}$$ (Since cube has six faces)

$$= \frac{1}{3}\frac{mnC^2}{l^3} = \frac{1}{3}\frac{mnC^2}{V}$$ (∵ volume of cube = l^3)

$$\therefore \boxed{PV = \frac{1}{3}mnC^2}$$ This equation is called kinetic equation of gas.