KTG Lecture – 01

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Kinetic Theory of gases

Kinetic theory of gases is an early form of statistical mechanics.

This theory was largely developed through the work of clausius , Maxwell and Boltzmann .

They were by Mayer , vander Waals and others .

In the early stage the theory has been developed entirely from a mathetical stand – point , as there was no experimental evidence of molecular motions

Now it has been verified experimentally .

Fundamental Postulates of kinetic theory of gases :

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Followings are the main assumption :

(1) A gas is composed of a large number of molecules , which are identical for a given gas .

(2) There is no force of attraction between the molecules .

(3) molecules obey Newton's law of motion .

(4)Molecules are perfectly elastic rigid solid spheres , so that there is no loss of energy in a collision .

(5) Between two collisions the molecules move with different velocity in different direction . During the collision they travel an independent path , this path is called free path and average of whole free path is called mean free path . This path is in the order of 10^{-7} meter . The time taken for this mean free path is nearly 10^{-9} sec

(6) The molecules are mere points i.e. dimensions of molecules are negligible .

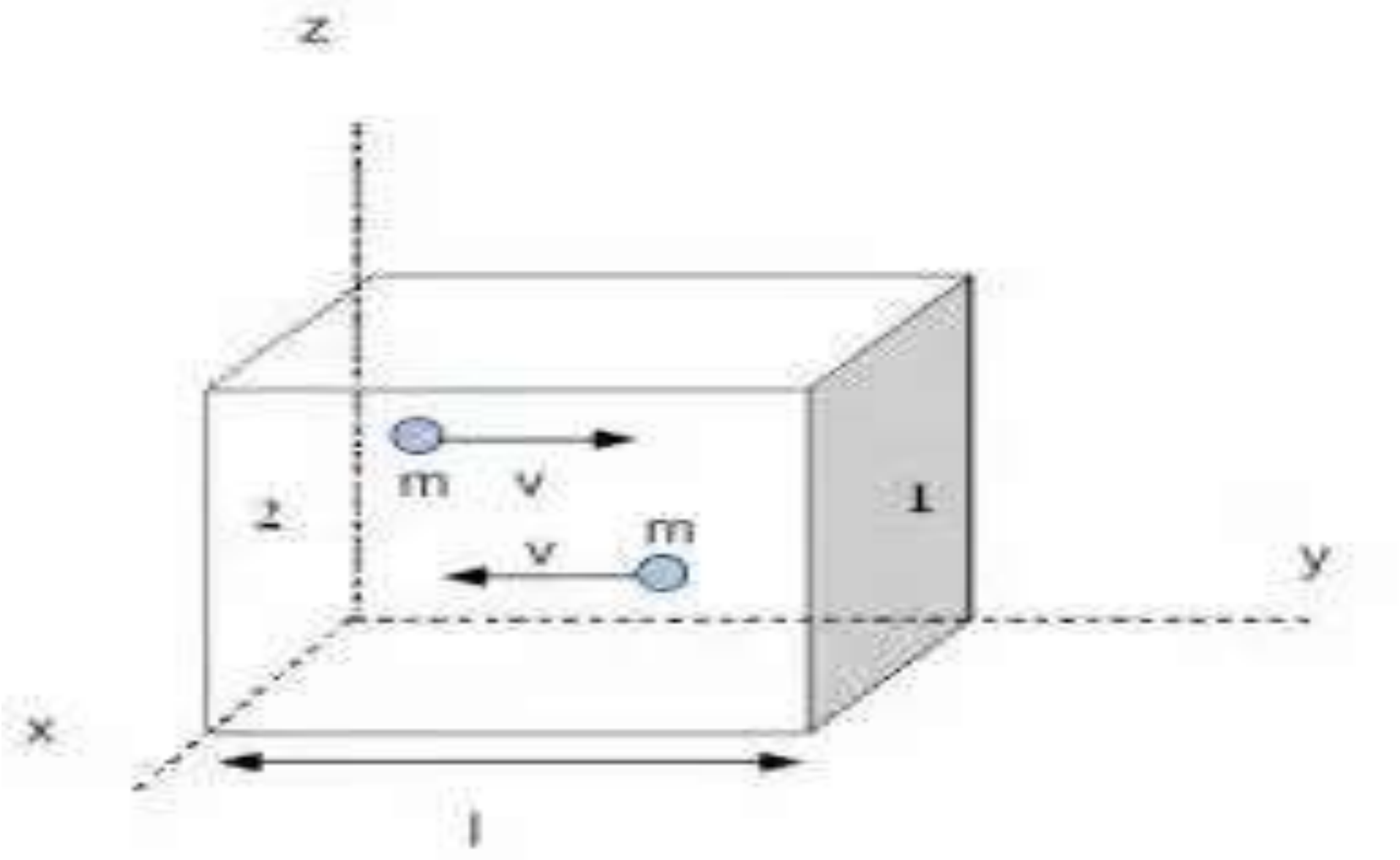
(7) The collisions between molecules and with walls are perfectly elastic so that there is no loss of energy during the collision .

(8) Since the molecules are perfectly elastic so the these molecules return back with the same momentum as it was strike upon it .

(9) The pressure of the gas in all directions is the same .

Expression of a perfect gas :

Let us consider a vessel of the shape of a cube . If this vessel be filled up with a gas and each side of the cube measures l . consider a molecule whose velocity in any direction is c their components are along X , Y and Z direction is supposed to be u ,v and w respectively , such that


z
m
v
z
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1
y
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l

$c^2 = u^2 + v^2 + w^2$

If u_1 be the velocity of the first molecule along X – direction, the molecule strike with the momentum mu_1 after collision the molecule returns back with same momentum mu_1 .

The change in momentum = $mu_1 - (-mu_1) = 2mu_1$ (1)

After this the molecule collides with the wall and returns and again collides with the wall .

Thus the molecule successively collides with the wall after travelling a distance = 2l .

The molecule takes a time $2l/ u_1$ second .

Therefore rate of change of momentum $= 2mu_1 / 2l/u_1$

$= 2mu_1 \times u_1 / 2l$

$= mu_1^2/ l$ (2)

According to Newton's second law of motion the rate of change in momentum is directly proportional to force .

$$\text{Force} = mu_1^2 / l$$

$$\text{Pressure} = mu_1^2 / l^3 \qquad (3)$$

If the cubical vessel contains n molecules then pressure exerted on the wall due to all the molecules is

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$$P_X = mu_1^2 / l^3 + m\,u_2^2 / l^3 + \ldots\ldots + mu_n^2 / l^3$$

$$= m/l^3 (u_1^2 + u_2^2 + \ldots\ldots + u_n^2)$$

$$= m/V(u_1^2 + u_2^2 + \ldots\ldots + u_n^2) \qquad (4)$$

Where $l^3 = V$ Volume of the vessel .

Similarly Pressure along Y axis

$P_Y = m/V (v_1^2 + v_2^2 + v_3^2 + ... + v_n^2)$ (5)

Along Z – axis Pressure = $P_Z = m/V(w_1^2 + w_2^2 + ... + w_n^2)$ (6)

Since the pressure of gas is the same in all directions

$P = P_X + P_y + P_z / 3$

$P = m / 3V [(u_1^2 + v_1^2 + w_1^2) + (u_2^2 + v_2^2 + w_2^2) + ...+ (u_n^2 + v_n^2 + w_n^2)]$

$$P = m / 3V (c_1^2 + c_2^2 + ...+ c_n^2) = mn/ 3V (c_1^2 + c_2^2 + ...c_n^2) /n$$

$$= MC^2/3V \qquad (7)$$

$$P = MC^2/3V \qquad (8)$$

Where M = mn (Total mass of the gas)

and $C^2 = c_1^2 + c_2^2 + c_3^2 + ... + c_n^2 / n$

C^2 is called mean square velocity and c is called root mean square velocity

Since , density of the gas $\rho = M/V$

Therefore ,Pressure $P = 1/3\ \rho\ C^2$

RMS velocity : C = $\sqrt{3P/\rho}$ (9)

For air , $P = 1.013 \times 10^5\ N/m^2$ and $\rho = 1.293\ kg/m^3$

Hence RMS velocity of air C = 484.8 m/s