Marwari college Darbhanga

Subject---physics

Class--- B.Sc. part 1

Paper---02 ; group----A

Topic--- Equipartition of Energy (Thermal physics)

Lacture series---11

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Maxwell's Law of Equipartition of Energy

Degree of Freedom :-

The total number of independent variables required to describe completely the state of motion of a body are called its degree of freedom.

An ant moving along a straight line i.e a wire, it has only one degree of freedom (x). If it moves on a plane, then it has two degrees of freedom (x, y).
A flying insect in air, say a mosquito has 3 degrees of freedom (x, y, z). A rigid body, however, not only moves but also rotates about any axis passing through itself. Hence, it has 3 degree of freedom due to rotational motion. Thus it has in all 6 degree of freedom.

Monoatomic molecules

A monoatomic molecule, eg:- Neon (Ne), Helium (He) etc; has 3 degree of freedom. (all are translational)

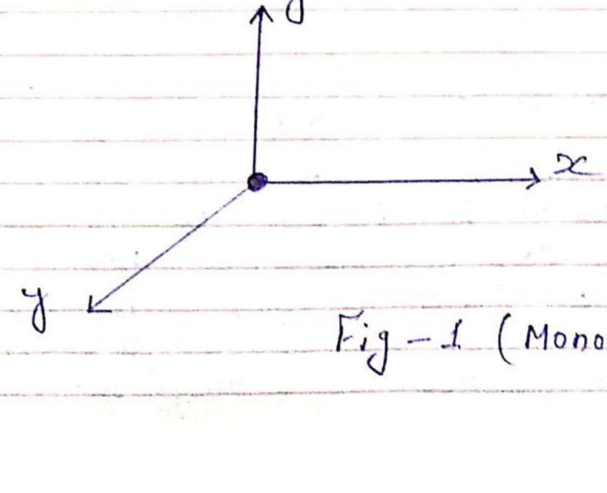

Fig - 1 (Monoatomic molecules)

Diatomic Molecule

A diatomic molecule having a dumb-bell shape.
Eg – HCL, Cl_2, O_2, CO etc. has 5 degree of freedom (3 translational + 2 rotational).

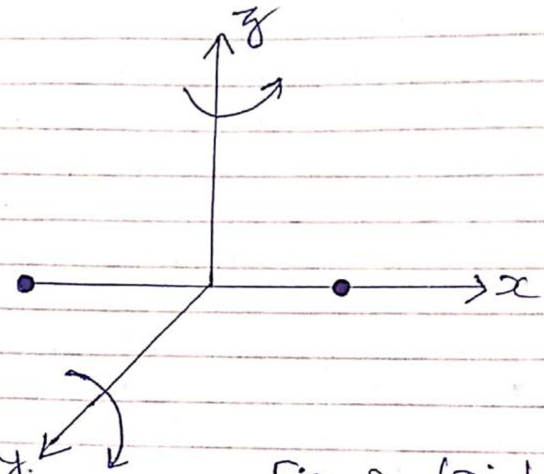

Fig.-2 (Diatomic molecule)

NOTE → At high temperatures, in addition to the translational and rotational degree of freedom. The vibrational degree of freedom are also excited and in that case a diatomic molecule possesses 7 degree of freedom in all.

Equipartion of Energy

For any dynamical System in thermal equilibrium, the total energy is divided equally among all the degrees of freedom and the energy associated per molecule per degree of freedom is $1/2\, KT$; where K is Boltzmann's constant and T is absolute temperature of the gas.

According to kinetic theory of gases, the mean kinetic energy of a gas molecule at a temperature T is given by

$$\frac{1}{2}mc^2 = \frac{3}{2}KT$$

But $\quad c^2 = u^2 + v^2 + w^2$

As x, y and z are all equivalent, mean square velocities along three axes are equal.

$\therefore \quad u^2 = v^2 = w^2$

Hence, $\quad u^2 = v^2 = w^2 = \frac{1}{3}c^2$

or,

$$\frac{1}{2}mu^2 = \frac{1}{2}mv^2 = \frac{1}{2}mw^2$$

$$\frac{1}{2}mc^2 = 3\left[\frac{1}{2}mu^2\right] = 3\left[\frac{1}{2}mv^2\right] = 3\left[\frac{1}{2}mw^2\right]$$

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

$\therefore \quad \frac{1}{2}mu^2 = \frac{1}{2}KT$

$\frac{1}{2}mv^2 = \frac{1}{2}KT$

$\frac{1}{2}mw^2 = \frac{1}{2}KT$

Therefore, the average kinetic energy associated with each degree of freedom $= \frac{1}{2}KT$.

Thus, the energy associated with each degree of freedom (whether translatory or rotatory) is $\frac{1}{2}KT$.