Transport phenomena of gases

The transport of momentum, energy and mass by the molecule represent viscosity, Conduction and diffusion respectively. These are Called transport phenomena. The transport phenomena are irreversible. These phenomena occur due to the thermal agitation of the molecules. The transport phenomena occur only in the non-equilibrium state of gas. In non-equilibrium state, there are three cases —

(i) The different parts of the gas may have different velocities. If so, there will be a relative motion of the layers of the gas with respect to one another. In such a case the layers moving faster impart momentum to slower moving layers to bring the equilibrium state. This gives rise to the phenomenon of Viscosity.

(ii) The different parts of the gas may have different temperatures. If so, the molecules of the gas will carry kinetic energy from regions of higher temperature to the regions of lower temperature to bring the equilibrium state. This gives rise to the phenomenon of Conduction.

(iii) The different parts of the gas may have different molecular Concentrations i.e the no. of molecules per unit volume. If so, the molecules of the gas will carry the mass from the regions of higher concentrations to those of lower concentrations to bring the equilibrium state. This gives rise to the phenomenon of diffusion.

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The transport phenomena are basically governed by the mean free path (λ) of a molecule. The molecule moving through a free path λ is actually transferring momentum, energy and mass through a distance λ.

According to Maxwell's law of distribution of velocity,

$$dN = 4\pi N A^3 e^{-bc^2} c^2 dc \quad \text{—— (i)}$$

But $4\pi c^2 dc = du\, dv\, dw$

$$dN = N A^3 e^{-bc^2} du\, dv\, dw \quad \text{—— (ii)}$$

where dN represents the no. of molecules in the volume element.

N — represents the number of molecules per c.c.

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

$$dN = N A^3 e^{-b(u^2+v^2+w^2)} du\, dv\, dw \quad \text{—— (iii)}$$

Let u_0, v_0 and w_0 be the components of the mass velocity. Therefore, the actual velocity of a molecule consists of two parts

(i) the mass velocity components u_0, v_0 and w_0.

(ii) the random thermal velocity components

$u - u_0$, $v - v_0$ and $w - w_0$.

Corresponding to thermal motion without mass motion, similar quantities with mass motion are

$$U = u - u_0$$
$$V = v - v_0$$
$$W = w - w_0$$

From (iii), Maxwell's law of distribution of velocity can be written as —

$$dN = N A^3 e^{-b(U^2+V^2+W^2)} dU\, dV\, dW \quad \text{—— (iv)}$$

Equation (iv) holds good only if u_0, v_0, w_0, T and N are constants throughout the gas.

If the gas is not in an equilibrium state, there are three possibilities occurring simultaneously [illegible] allowed to suffer Joule's free expansion, [illegible] jointly.

(1) The components of velocity u_0, v_0 and w_0 may not have the same value in all parts of the gas. This will result in relative motion of the gas layers with respect to one another.

There is relative velocity between different layers of the gas. This gives rise to the phenomena of Viscosity.

(2) The temperature of the gas may not be the same throughout. This results in the transference of thermal energy from regions ~~to~~ of higher to lower temperature. This gives rise to the phenomenon of Conduction.

(3) The No. of molecules per c.c i.e N, may not be the same throughout the volume of the gas. This results in the movement of molecules from regions of higher value of N to lower value of N. This gives rise to the phenomenon of diffusion.