Marwari college Darbhanga

Subject---physics (Hons)

Class--- B. Sc. Part 1

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

Topic--- Transport phenomenon (Thermal physics)

Lacture series---12

By:- Dr Sony Kumari, Assistant professor

Marwari college Darbhanga

Transport phenomenon

Molecular collision

According to kinetic theory of gas, the molecules are of finite size. During the random motion of gas molecules in all possible directions and with all possible Velocities, they collide with each other. Between two successive collisions ,a molecule moves with a constant speed, along a straight line. These collisions are know as molecular collisions.

Perfect Gases – Transport Phenomena

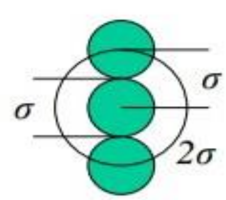
We have been able to relate quite a few macroscopic properties of gasses such as *P, V, T* to molecular behaviour on microscale. We saw how macroscopic pressure is related to the molecular motion in case of perfect gasses. Is there anything else interesting one can learn from the *kinetic theory* of perfect gasses? Indeed there is. So far we only considered macroscopic properties that can be termed as static. We shell now look at some properties that are not. Collectively they are termed *transport phenomena* and can be further subdivided in:

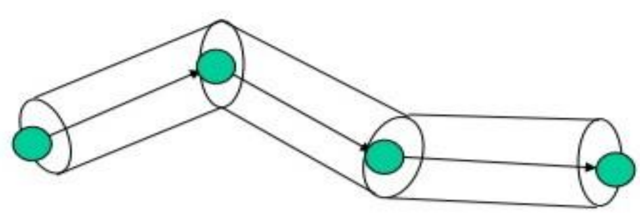
- *Diffusion* – molecular transport due to *concentration gradients*
- *Thermal* conduction – transport of *energy*
- *Viscosity* – transport of *momentum*

These are described by their corresponding coefficients: *D* for diffusion, *K* for thermal conduction and η for viscosity.

Mean free path

In order to consider the diffusion we must first look in details at molecular collision. We again suppose that all molecules are the same and collide elastically and also suppose σ to be an effective molecular diameter. We will follow the progress of a single molecule as it collides with others moving through the gas. For simplicity we assume that the rest of the molecules are frozen in their positions. Thus if our lonely molecule travels distance l it will sweep an element of volume $\pi\sigma^2 l$ and if there are n molecules per m^3 then our molecule will collide with $\pi\sigma^2 l\, n$ of them.





We can now define the mean distance between collisions or *mean free path* as (distance travelled)/(number of collisions):

$$\lambda = \frac{l}{\pi\sigma^2 nl} = \frac{1}{\pi\sigma^2 n} = \frac{k_B T}{P\pi\sigma^2}$$

Mean free path cntd.

We only considered the simplest approach, in reality other molecules will move too and if the speed distribution will be describe by that of Maxwell

$$P_M(v) = 4\pi\left[\frac{m}{2\pi k_B T}\right]^{3/2} v^2 e^{-mv^2/2k_B T} \Rightarrow \lambda = \frac{1}{\sqrt{2}\pi\sigma^2 n}$$

what a change!

We see that $\lambda \sim 1/n \sim 1/P$. For air ($\sigma$=0.3nm) at STP (standard temperature and pressure) $\lambda \approx$100nm, whilst mean distance between the molecules is of order $(1/n^3) \approx$3nm.

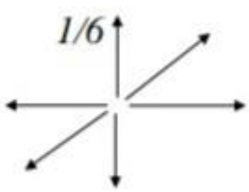
Number of collisions per unit area per second (*flux*)

Consider a volume of gas with concentration n and mean velocity v and lets see how many molecules will pass through an area A per unit time. We further split our velocity in three components one of which is perpendicular to area A (we done this before in kinetic theory). Then in time t about 1/6 of the molecules in the volume vtA will pass through A and hence flux j:

$$l = \bar{v}t$$

$$V = lA = \bar{v}tA$$

$$j = \frac{1}{6}\frac{n\bar{v}At}{At} = \frac{1}{6}n\bar{v}$$



Transport of moment

The different layers of the gas may have different Velocities. In such a case there will be a relative motion of the layers of the gas with respect to each other and to bring a steady state the layers moving faster will transfer momentum to the layers moving slower. This is the phenomenon of viscosity and arises due to transport of momentum.

Transport of Energy

The different layers of the gas may be at different temperatures. The molecules at a higher temperature will have greater energy. To bring about a steady state the molecules will transfer energy from regions of higher temperature to regions of lower temperature.

This energy is in the form of heat and gives rise to phenomenon of thermal conductivity. Thus the phenomenon of thermal conductivity is due to transport of Energy.

Transport of Mass

The different layers of the gas may have different concentrations. In such a case the molecules of the gas will move from regions of higher concentration to regions of lower concentration to come to a steady state, thereby transferring Mass from regions of higher concentration to regions of lower concentration. This is the phenomenon of diffusion and arises due to transport of Mass.