Answer on Question #50677-Physics-Molecular Physics-Thermodynamics

What is the transport phenomenon in gases? Obtain an expression for coefficient of viscosity of a gas if the average number of molecules crossing an area is given by $\Delta n = \frac{1}{4} nv$ and molecules make their last collision before crossing an imaginary surface at a distance of $\frac{2}{3}\lambda$ above or below it.

Answer

We have been able to relate quite a few macroscopic properties of gasses such as P, V, T to molecular behavior 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.

At a height $\frac{2}{3}\lambda$ above the surface, the flow velocity of the gas molecules will be $u + \frac{2}{3}\lambda\frac{du}{dy}$, where u is flow velocity at the surface. The momentum transported by a molecule moving with this velocity will be $m\left(u + \frac{2}{3}\lambda\frac{du}{dy}\right)$. So, the total momentum in direction of the flow carried across the surface per unit area per unit time by all the molecules crossing the surface from above will be

$$G^+ = \frac{1}{4} nvm\left(u + \frac{2}{3}\lambda\frac{du}{dy}\right).$$

Similarly, the total momentum flow carried across the surface per unit area per unit time by the molecules crossing it in upward direction from below will be

$$G^- = \frac{1}{4} nvm\left(u - \frac{2}{3}\lambda\frac{du}{dy}\right).$$

Hence, the net transport of momentum across the surface from below in the direction of mass motion per unit area per unit time, which is equal to the viscous force per unit area, is given by

$$G = G^- - G^+ = -\frac{1}{3} mnv\lambda\frac{du}{dy}.$$

The coefficient of viscosity of a gas is given by

$$\eta = \frac{1}{3} mnv\lambda = \frac{1}{3}\rho v\lambda.$$