Statistical Physics

March 13, 2025

11-17 Diffusion can be regarded as a random walk problem in which the successive displacements of a gas molecule are statistically independent. In this model, the distance L traveled by a molecule after N displacements is related to the mean free path ℓ by the expression $L^2 = N\ell^2$, and the time t required to move a distance L is given by $t = N\ell/\bar{v}$. Using these relations, estimate how long it would take a molecule in a room of macroscopically "still" air with uniform temperature and pressure to move a distance of 5 meters.

11-18 The experimental value of the viscosity of argon gas is found to be $22.0 \times 10^{-6}\,\mathrm{Pa\,s}$ at $15\,^{\circ}\mathrm{C}$ and atmospheric pressure. The atomic weight is 39.94. Estimate the diameter of an argon atom.

11-19 The radius of an air molecule is approximately $1.8 \times 10^{-10}\,\mathrm{m}$, its mass is about $4.8 \times 10^{-26}\,\mathrm{kg}$, and it has 5 degrees of freedom. The molecular weight of air is 29 and its density is $1.29\,\mathrm{kg/m^3}$ under standard conditions.

(a) Estimate the values of the coefficient of viscosity η, the thermal conductivity λ, and the diffusion constant D under these conditions.

(b) Check that for air,

$$\frac{\lambda M}{\eta c_v} \approx 1 \quad \text{and} \quad \frac{D\rho}{\eta} \approx 1.$$

Also, check that these quantities are indeed dimensionless.