For the following, refer to O'Hanlon

Maxwell-Boltzmann velocity distribution

$$\frac{dN}{dv} = \frac{4N}{\pi^{1/2}} \left(\frac{m}{2kT}\right)^{3/2} v^2 e^{-mv^2/2kT}$$

The mean velocity can be determined to be:

$$v = \left(\frac{8kT}{\pi m}\right)^{1/2}$$

Mean free path:

$$\lambda = \frac{1}{\sqrt{2}\,\pi n d_0^2}$$

Air at room T:

$$\lambda(\text{mm}) = \frac{6.6}{P(\text{Pa})}$$

$$\boxed{\lambda(\text{mm}) = \frac{.05}{P(\text{torr})}}$$

Ex: at 1 atm:

$$\lambda = 6.6 \times 10^{-5}\ \text{mm} = \underline{66\ \text{nm}}$$

at 10^{-3} torr

$$\lambda = 50\ \text{mm} = \underline{5\ \text{cm}}$$

at 10^{-11} torr

$$\lambda = 5 \times 10^{9}\ \text{mm} = \underline{5000\ \text{km}}\ !$$

Kinetic Theory

Particle Flux

$$\Gamma \left(\frac{\text{particles}}{m^2 - s} \right) = \frac{n v}{4}$$

v = average velocity

$$\Rightarrow \Gamma = n \left(\frac{kT}{2\pi m} \right)^{1/2}$$

n = particle density

m = particle mass

Question:

How much time does it take to cover a surface with 1 monolayer of molecules (or atoms)?

$$t_{ml} = \frac{1}{\Gamma d_o^2} = \frac{4}{n v d_o^2}$$

$$PV = NkT$$

$$\frac{N}{V} = \frac{P}{kT}$$

Pressure $= 1\ \text{atm} = 10^5\ \text{Pa}$

$$kT = .025\ \text{eV} = 4.1 \times 10^{-21}\ \text{J}$$

$$\boxed{n = 2 \times 10^{25} / m^3}$$

$$\Gamma = n \left(\frac{4.1 \times 10^{-21}\ \text{J}}{2\pi \times 28 \times 1.7 \times 10^{-27}\ \text{kg}} \right)^{1/2}$$

$$\Gamma = \left(2 \times 10^{25} / m^3\right) \left(1.2 \times 10^{2}\ \text{m/s}\right)$$

$$\Gamma = 2.3 \times 10^{27} / m^2 s$$

$$d_o^2 = \left(.37 \times 10^{-9}\ \text{m}\right)^2$$

$$t_{mf} = 3.1 \times 10^{-9}\ \text{s}$$

1 atm $\simeq 10^{3}$ torr $\longrightarrow$ $\tau_{ml} = 3 \times 10^{-9}$ s $= 3$ ns

1 torr $\longrightarrow$ $\tau_{ml} =$ 3 μs

10^{-3} torr $\longrightarrow$ $\tau_{ml} =$ 3 ms

10^{-6} torr $\longrightarrow$ $\tau_{ml} =$ 3 s $\sim$ 1 s

10^{-9} torr $\longrightarrow$ $\tau_{ml} =$ 3000 s $\sim$ 1 hour

5×10^{-11} torr $\longrightarrow$ $\tau_{ml} = 6 \times 10^{4}$ s $\sim$ 17 hours