Quiz 16.1 – Transport in Gases

Name: Key

The Diffusion Coefficient

Find the diffusion coefficients for both He gas and N_2 at $25°C$ and $0.82\ atm$ (Typical values for Cedar City) $\rightarrow$ 83,087 Pa

$$D = \frac{1}{3}\left(\frac{k_B T}{\sigma p}\right)\left(\frac{8RT}{\pi M}\right)^{1/2}$$

He: $\sigma = 0.21\ nm^2$, $M = 0.00400\ kg/mol$

$$D_{He} = \frac{1}{3}\left(\frac{1.38\cdot10^{-23}\ \frac{J}{K}\cdot 298K}{0.21\cdot10^{-18} m^2 \cdot 83{,}087 Pa}\right)\left(\frac{8\cdot 8.314\ J/mol{\cdot}K \cdot 298K}{\pi \cdot 0.00400\ kg/mol}\right)^{1/2} = 9.87\cdot10^{-5}\ m^2/s$$

N_2: $\sigma = 0.43\ nm^2$ $M = 28.01\ g/mol = 0.02801\ kg/mol$

$$D_{N_2} = \frac{1}{3}\left(\frac{1.38\cdot10^{-23}\ \frac{J}{K}\cdot 298K}{0.43\cdot10^{-18} m^2 \cdot 83{,}087 Pa}\right)\left(\frac{8\cdot 8.314\ \frac{J}{mol{\cdot}K} \cdot 298K}{\pi \cdot 0.02801\ kg/mol}\right)^{1/2} = 1.82\cdot10^{-5}\ m^2/s$$

The Earth's atmosphere grows thinner at higher altitudes with a concentration gradient of approximately $\frac{d[N_2]}{dz} \approx -8\times10^{-7}\frac{M}{m}$. This gradient can be used in Fick's first law just like $\frac{dN}{dz}$, and will just give a flux in units of molar concentration rather than units of number density. The atmosphere (thankfully) doesn't diffuse away into space because of the pull of gravity. If gravity suddenly stopped functioning, what flux (J_{Matter}) we would expect as the atmosphere begins its escape from Cedar City into space?

$$J = -D\frac{d[N_2]}{dz} = -1.82\cdot10^{-5}\ m^2/s \cdot -8\cdot10^{-7}\ \frac{M}{m} = 1.46\cdot10^{-11}\ \frac{M\,m}{s}$$

–or–

$$= 1.46\cdot10^{-8}\ \frac{mol}{m^2\cdot s}$$

The Other Transport Coefficients

Consider a gas with $D = 1.5 \times 10^{-5}\frac{m^2}{s}$ at $15°C$ (288 K) and $1.2\ atm$ (121,590 Pa)

Find the coefficient of thermal conductivity (κ) for this gas if it is: $\kappa = \frac{\nu p D}{T}$

- A noble gas: $\nu = 3$

$$\kappa = \frac{3 \cdot 121{,}590\ Pa \cdot 1.5 \cdot 10^{-5}\frac{m^2}{s}}{288\ K} = 0.0190\ \frac{Pa\ m^2}{K\ s} = 0.0190\ \frac{W}{m \cdot K}$$

- A non-linear polyatomic gas: $\nu = 6$

$$\kappa = \frac{6 \cdot 121{,}590\ Pa \cdot 1.5 \cdot 10^{-5}\frac{m^2}{s}}{288\ K} = 0.0380\ \frac{W}{m \cdot K}$$

In each case, find the flux of energy if the gas has a temperature gradient of $\frac{dT}{dz} = 5\frac{K}{m}$

$J = -\kappa \frac{dT}{dz}$ Noble: $J = -0.0190\ \frac{W}{m \cdot K} \cdot 5\ \frac{K}{m} = -0.0950\ \frac{J}{s \cdot m^2}$

Non-Linear: $J = -0.380\ \frac{W}{m \cdot K} \cdot 5\ \frac{K}{m} = -0.190\ \frac{J}{s\,m^2}$

Find the coefficient of viscosity for the gas if has a molar mass of: $\eta = \frac{pMD}{RT}$

- $37\frac{g}{mol}$ → $0.037\ kg/mol$

$$\eta = \frac{121{,}590\ Pa \cdot 0.037\ kg/mol \cdot 1.5 \cdot 10^{-5}\ \frac{m^2}{s}}{8.314\ J/mol \cdot K \cdot 288\ K} = 2.82 \cdot 10^{-5}\ Pa \cdot s = 2.82 \cdot 10^{-5}\ P$$

- $115\frac{g}{mol}$

$0.115\ \frac{kg}{mol}$

$$\eta = \frac{121{,}590\ Pa \cdot 0.115\ \frac{kg}{mol} \cdot 1.5 \cdot 10^{-5}\ \frac{m^2}{s}}{8.314\ J/mol \cdot K \cdot 288\ K} = 8.76 \cdot 10^{-5}\ Pa \cdot s = 8.76 \cdot 10^{-5}\ P$$