MODULE 10: SOLVED PROBLEMS

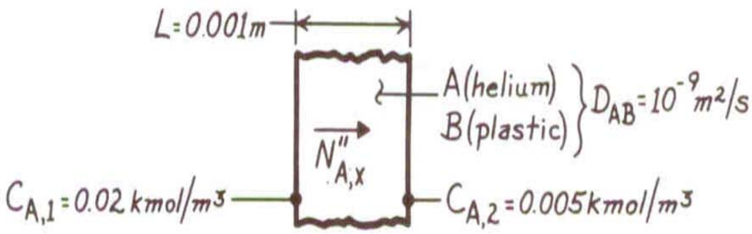
Problem 1: A thin plastic membrane is used to separate Helium from a gas stream. Under state conditions, the concentration of helium in the membrane is known to be 0.02 and 0.005 kmol/m^3 at the inner and outer surfaces, respectively. If the membrane is 1 mm thick and the binary diffusion coefficient of helium with respect to the plastic is 10^{-9} m^3/s, what is the diffusion flux?

Solution:

Known: Molar concentrations of He at the inner and outer surfaces of a plastic membrane; diffusion coefficient and membrane thickness.

To calculate: Molar diffusion flux

Schematic:



Assumptions: Steady state, 1D diffusion in a plane wall, stationary medium, uniform $C = C_A + C_B$

Analysis: The molar flux may be obtained from

$$N''_{A,x} = \frac{D_{AB}}{L}\left(C_{A,1} - C_{A,2}\right) = \frac{10^{-9}\,\mathrm{m^2/s}}{0.001\,\mathrm{m}}\left(0.02 - 0.005\right)\mathrm{kmol/m^3}$$

$$N''_{A,x} = 1.5 \times 10^{-8}\ \mathrm{kmol/s.m^2}$$

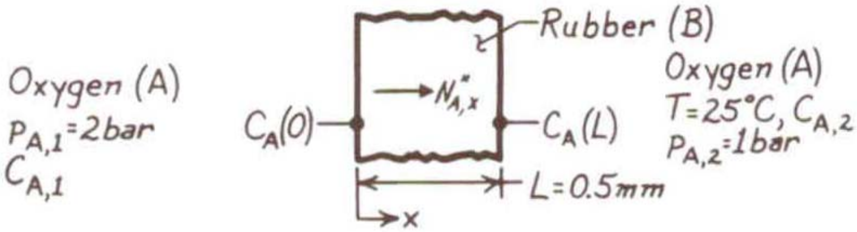
Problem 2: Oxygen is maintained at pressures of 2 bars ans 1 bar on opposite sides of a rubber membrane that is 0.5 mm thick, and the entire system is at 25 C. What is the molar diffusion flux of O2 through the membrane? What are the molar concentrations of O2 on both sides of the membrane (outside the rubber)?

Solution:

Known: Oxygen pressures on opposite sides of a rubber membrane.

To find: Molar diffusion flux of oxygen; Molar concentration of oxygen outside the rubber.

Schematic:



Assumptions: Steady state, 1D diffusion, stationary medium of uniform total molar concentrations, C = C_A + C_B; perfect gas behaviour.

Properties given: Oxygen-rubber (298 K): $D_{AB} = 0.21 \times 10^{-9}$ m^2/s; S = 3.12×10^{-3} kmol/m^3.bar.

Analysis:

(a) For the assumed conditions

$$N''_{A,x} = J''_{A,x} = -D_{AB}\frac{dC_A}{dx} = D_{AB}\frac{C_A(0) - C_A(L)}{L}$$

$$C_A(0) = Sp_{A,1} = 6.24\times10^{-3}\ \text{kmol/m}^{-3}$$

$$C_A(L) = Sp_{A,2} = 3.12\times10^{-3}\ \text{kmol/m}^3$$

Hence:

$$N''_{A,x} = 0.21\times10^{-9}\ \text{m}^2\text{/s}\,\frac{(6.24\times10^{-3} - 3.12\times10^{-3})\ \text{kmol/m}^3}{0.0005\,\text{m}}$$

$$N''_{A,x} = 1.31\times10^{-9}\ \text{kmol/s.m}^2$$

(b) From the perfect gas law:

$$C_{A,1} = \frac{P_{A,1}}{RT} = \frac{2\ \text{bar}}{(0.08314\,\text{m}^3\text{.bar/kmol.K}} = 0.087\,\text{kmol/m}^3$$

$$C_{A,2} = 0.5C_{A,1} = 0.0404\,\text{kmol/m}^3$$