

MODULE 10: SOLVED PROBLEMS

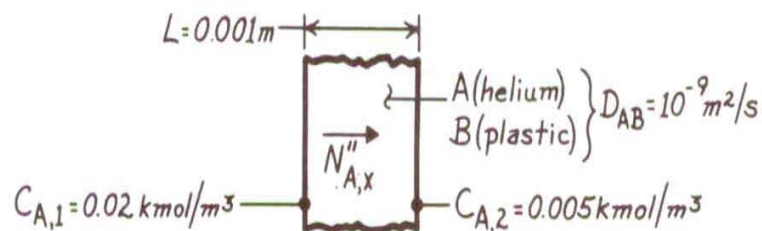
Problem 1: A thin plastic membrane is used to separate Helium from a gas stream. Under steady conditions, the concentration of helium in the membrane is known to be 0.02 and 0.005 kmol/m³ at the inner and outer surfaces, respectively. If the membrane is 1 mm thick and the binary diffusion coefficient of helium with respect to the plastic is 10⁻⁹ m²/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

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

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

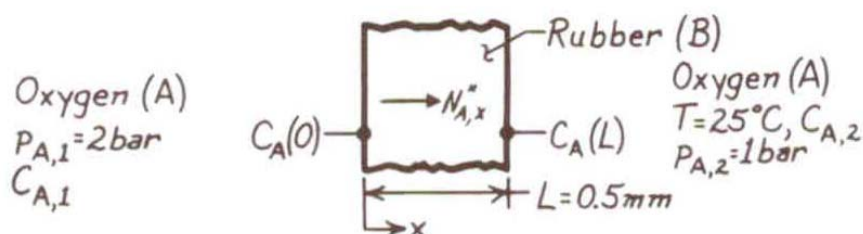
Problem 2: Oxygen is maintained at pressures of 2 bars and 1 bar on opposite sides of a rubber membrane that is 0.5 mm thick, and the entire system is at 25 C. What is the molar diffusion flux of O₂ through the membrane? What are the molar concentrations of O₂ on both sides of the membrane (outside the 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): $D_{AB} = 0.21 \times 10^{-9} \text{ m}^2/\text{s}$; $S = 3.12 \times 10^{-3} \text{ kmol/m}^3 \cdot \text{bar}$.

Analysis:

(a) For the assumed conditions

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

$$C_A(0) = Sp_{A,1} = 6.24 \times 10^{-3} \text{ kmol/m}^3$$

$$C_A(L) = Sp_{A,2} = 3.12 \times 10^{-3} \text{ kmol/m}^3$$

Hence:

$$N''_{A,x} = 0.21 \times 10^{-9} \text{ m}^2/\text{s} \frac{(6.24 \times 10^{-3} - 3.12 \times 10^{-3}) \text{ kmol/m}^3}{0.0005 \text{ m}}$$

$$N''_{A,x} = 1.31 \times 10^{-9} \text{ kmol/s} \cdot \text{m}^2$$

(b) From the perfect gas law:

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

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