**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$^2$/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

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

$$N_x^m = 1.5 \times 10^{-8} \text{ kmol/s.m}^2$$
**Problem 2:** Oxygen is maintained at pressures of 2 bars 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): \( D_{AB} = 0.21 \times 10^{-9} \text{ m}^2/\text{s} \); \( S = 3.12 \times 10^{-3} \text{ kmol/m}^3\text{.bar} \).

Analysis:

(a) For the assumed conditions

\[
\begin{align*}
N''_{A,x} &= J''_{A,x} = -D_{AB} \frac{dC_A}{dx} = D_{AB} \frac{C_A(0) - C_A(L)}{L} \\
C_A(0) &= S p_{A,1} = 6.24 \times 10^{-3} \text{ kmol/m}^3 \\
C_A(L) &= S p_{A,2} = 3.12 \times 10^{-3} \text{ kmol/m}^3
\end{align*}
\]

Hence:

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

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

(b) From the perfect gas law:

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

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