Chapter 5

1. In gas separation by membrane, why gas film resistance is negligible?
   Ans: High diffusivity of gaseous components.

2. In gas separation which resistance is dominating?
   Ans: membrane resistance.

3. For complete mixing model in case of gas separation, find maximum composition of reject stream if, \( \alpha^* = 10; \frac{P_l}{P_h} = \frac{1}{60}; \ x_f = 0.3; \)

   \[
   x_{om} = \frac{x_f \left[ 1 + (\alpha^*-1) \left( \frac{P_l}{P_h} \right) (1-x_f) \right]}{\alpha^* (1-x_f) + x_f}
   \]

   Ans:

   \[
   \alpha^* = 10; \quad \frac{P_l}{P_h} = \frac{1}{60}; \quad x_f = 0.3
   \]

   \[
   x_{om} = \frac{0.3 \left[ 1 + 9 \times \frac{1}{60} \times 0.7 \right]}{10 \times 0.7 + 0.3}
   \]

   \[
   = 0.045
   \]

4. Counter current model in gas separation is like

   (a) CSTR        (b) PFR        (c) CSTR+PFR

   Ans: (b)
5. Find membrane area to separate air using a membrane 0.002 cm thick with oxygen permeability \( P_A = 400 \times 10^{-10} \text{ cm}^3 \text{(STP)} \text{ cm} / \text{s cm}^2 \text{ cmHg} \) and \( \alpha^* = 8 \) for permeability ratio of oxygen and nitrogen. Feed rate, \( q_f = 10^6 \text{ cm}^3 / \text{s} \) and \( \theta = 0.3 \); \( P_h = 150 \text{ cm Hg} \) and \( P_l = 10 \text{ cm Hg} \). Assume complete mixing model, calculate permeate composition, reject composition and membrane area.

Ans:

\[
t = 0.002 \text{ cm}; \quad \alpha^* = 8; \quad P_A = 400 \times 10^{-10}; \quad q_f = 10^6 \text{ cm}^3 / \text{s}; \quad \theta = 0.3
\]

\[
P_h = 150 \text{ cm Hg}; \quad P_l = 10 \text{ cm Hg}; \quad x_f = 0.21
\]

\[
a_1 = \theta + \frac{P_l}{P_h} (1 - \theta) - \alpha^* \theta - \alpha^* \frac{P_l}{P_h} (1 - \theta)
\]

\[
= 0.3 + \frac{1}{15} \times 0.3 - 8 \times 0.3 - 8 \times \frac{1}{15} \times 0.7
\]

\[
= -2.45
\]

\[
b_1 = 1 - \theta - x_f - \frac{P_l}{P_h} (1 - \theta) + \alpha^* \theta + \alpha^* \frac{P_l}{P_h} (1 - \theta) + \alpha^* x_f
\]

\[
= 1 - 0.3 - 0.21 - \frac{1}{15} \times 0.7 + 8 \times 0.3 + 8 \times \frac{1}{15} \times 0.7 + 8 \times 0.21
\]

\[
= 4.897
\]

\[
c_1 = -\alpha^* x_f = -8 \times 0.21 = -1.68
\]
\[ y_p = \frac{-b_1 + \sqrt{b_1^2 - 4a_1c_1}}{2a_1} \]

\[ = \frac{-4.897 + \sqrt{4.897^2 - 4\times(-2.45)\times(-1.68)}}{2\times(-2.45)} \]

\[ = 0.44 \]

\[ x_0 = \frac{x_f - \theta y_f}{1 - \theta} \]

\[ = \frac{0.21 - 0.3\times0.44}{1 - 0.3} \]

\[ = 0.11 \]

\[ A_m = \frac{\theta q_f y_p}{\left( -\frac{p_A}{t} \right) \left( p_h x_0 - p_l y_p \right)} \]

\[ = \frac{0.3\times10^6\times0.44}{\left( -\frac{400\times10^{-10}}{0.002} \right) \left( 150\times0.11 - 10\times0.44 \right)} \]

\[ = \frac{132000}{2\times10^5 \times 12.1} \]

\[ = 5.45\times10^8 \text{ cm}^2 \]