

CHEN 324 HW 2

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1. Problem 19.1-9

(a) Derivation

$$\begin{aligned}
 N_B &= 0 \\
 N_A &= -cD_{AB} \frac{dx_A}{dz} + \frac{C_A}{c}(N_A + 0) \\
 N_A &= -cD_{AB} \frac{dx_A}{dz} + \frac{C_A}{c}N_A \\
 c &= \frac{P}{RT} \\
 P_A &= x_AP \\
 dx_A &= \frac{dP_A}{P} \\
 \frac{C_A}{c} &= \frac{P_A}{P} \\
 N_A &= -\frac{P}{RT}D_{AB} \frac{dP_A}{Pdz} + \frac{P_A}{P}N_A \\
 N_A &= -\frac{D_{AB}}{RT} \frac{dP_A}{dz} + \frac{P_A}{P}N_A \\
 N_A \left(1 - \frac{P_A}{P}\right) &= -\frac{D_{AB}}{RT} \frac{dP_A}{dz} \\
 N_A \int_{z_1}^{z_2} dz &= -\frac{D_{AB}}{RT} \int_{P_{A1}}^{P_{A2}} \frac{dP_A}{1 - \frac{P_A}{P}} \\
 N_A(z_2 - z_1) &= \frac{D_{AB}P}{RT} \ln \left(\frac{P - P_{A2}}{P - P_{A1}} \right) \\
 P_{BM} &= \frac{P_{A1} - P_{A2}}{\ln \left(\frac{P - P_{A2}}{P - P_{A1}} \right)} \\
 N_A(z_2 - z_1) &= \frac{D_{AB}P(P_{A1} - P_{A2})}{RTP_{BM}} \\
 N_A &= \frac{\rho_A}{M_A} \frac{dz}{dt} \\
 r_1 &= z_2 - z_1 \\
 \frac{\rho_A}{M_A} \int_{r_2}^{r_1} r_1 dr &= \frac{D_{AB}P(P_{A1} - P_{A2})}{RTP_{BM}} \int dt \\
 \frac{\rho_A}{2M_A} (r_1^2 - r_2^2) &= \frac{D_{AB}P(P_{A1} - P_{A2})}{RTP_{BM}} t_F \\
 r_2 &= 0 \\
 \frac{\rho_A}{2M_A} r_1^2 &= \frac{D_{AB}P(P_{A1} - P_{A2})}{RTP_{BM}} t_F \\
 \boxed{t_F} &= \frac{\rho_A RTP_{BM} r_1^2}{2M_A D_{AB} P(P_{A1} - P_{A2})}
 \end{aligned}$$

(b) Calculation

$$t_F = \frac{\rho_A R T P_{BM} r^2}{2 M_A D_{AB} P (P_{A1} - P_{A2})}$$

$$\rho_A = 866$$

$$R = 8.314$$

$$T = 25.9^\circ\text{C} = 299.05\text{K}$$

$$P_{A1} = 3.84$$

$$P_{A2} = 0$$

$$P_{BM} = \frac{3.82 - 0}{\ln\left(\frac{101.325 - 0}{101.325 - 3.84}\right)} = 99.39$$

$$r_1 = 0.002$$

$$M_A = 92.14$$

$$D_{AB} = 0.086 \cdot 10^{-4}$$

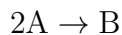
$$P = 101.325$$

$$t_F = \frac{866 \cdot 8.314 \cdot 299.05 \cdot 99.39 \cdot 0.002^2}{2 \cdot 92.14 \cdot 0.086 \cdot 10^{-4} \cdot 101.325 (3.84 - 0)}$$

$$t_F = 1388.2\text{s}$$

2. Problem 19.1-21

(a)



$$\frac{dC_A}{t} = -\nabla N_A + r_A$$

Steady state

$$-\nabla N_A + r_A = 0$$

$$N_A = -D_{AB} \frac{dC_A}{dz} + x_A N_T$$

$$\frac{1}{2} N_A = -N_B$$

$$N_T = N_A - \frac{1}{2} N_A$$

$$N_T = \frac{1}{2} N_A$$

$$N_A = -D_{AB} \frac{dC_A}{dz} + \frac{1}{2} N_A x_A$$

$$N_A = \frac{-D_{AB} C dx_A}{(1 - \frac{x_A}{2}) dz}$$

$$N_A \int dz = -D_{AB} C \int \frac{dx_A}{1 - \frac{x_A}{2}}$$

$$C = \frac{P}{RT}$$

$$N_A = \frac{2D_{AB}P}{\delta RT} \ln \left(\frac{x_{A2} - 2}{x_{A1} - 2} \right)$$

(b) Calculation

$$D_{AB} = 0.2 \cdot 10^{-4}$$

$$P = 101.32$$

$$X_{A1} = 0.97$$

$$X_{A2} = 0$$

$$\delta = 0.0013$$

$$R = 8.314$$

$$T = 298$$

$$N_A = \frac{2 \cdot 0.2 \cdot 10^{-4} \cdot 101.32}{0.0013 \cdot 8.314 \cdot 298} \ln \left(\frac{0 - 2}{0.97 - 2} \right)$$

$$N_A = 8.35 \cdot 10^{-4} \frac{\text{kgmol}}{\text{m}^2 \cdot \text{s}}$$

(c) Finite reaction rate

$$N_A A_s = k'_1 C_{A2} V_L$$

$$C_{A2} = \frac{x_{A2} P}{RT}$$

$$N_A A_s = k'_1 \frac{x_{A2} P}{RT} V_L$$

$$x_{A2} = \frac{N_A A_s RT}{k'_1 P V_L}$$

$$N_A = \frac{2 D_{AB} P}{\delta RT} \ln \left(\frac{x_{A2} - 2}{x_{A1} - 2} \right)$$

$$N_A = \frac{2 D_{AB} P}{\delta RT} \ln \left(\frac{\frac{N_A A_s RT}{k'_1 P V_L} - 2}{x_{A1} - 2} \right)$$

(d) Calculation

$$N_A = \frac{2 D_{AB} P}{\delta RT} \ln \left(\frac{\frac{N_A A_s RT}{k'_1 P V_L} - 2}{x_{A1} - 2} \right)$$

$$D_{AB} = 0.2 \cdot 10^{-4}$$

$$P = 101.32$$

$$X_{A1} = 0.97$$

$$X_{A2} = 0$$

$$\delta = 0.0013$$

$$R = 8.314$$

$$T = 298$$

$$k'_1 = 0.53 \cdot 10^{-2}$$

Solve the system

$$N_A = 1.766 \cdot 10^{-4} \frac{\text{kgmol}}{\text{m}^2 \cdot \text{s}}$$

3. Problem 19.3-1

Steady state no reaction

$$N_A = \frac{D_{AB}C}{1 - x_A} \frac{dx_A}{dz}$$

$$N_A = \frac{D_{AB}C}{\delta x_{BM}} (x_{A1} - x_{A2})$$

$$N_A = \frac{D_{AB}}{\delta x_{BM}} (C_{A1} - C_{A2})$$

$$C_A = \frac{SP_A}{22.414}$$

$$x_{BM} = 1$$

$$N_A = \frac{D_{AB}S}{t_M 22.414} (P_{A1} - P_{A2})$$

$$D_{AB} = 0.11 \cdot 10^{-9}$$

$$S = 0.90$$

$$t_M = 0.030$$

$$P_{A1} = 2$$

$$P_{A2} = 1$$

$$A_c = 4 \cdot 10^{-4}$$

$$N_A = \frac{D_{AB}S}{t_M 22.414} (P_{A1} - P_{A2})$$

$$N_A = \frac{D_{AB}S}{t_M 22.414} (P_{A1} - P_{A2}) A_c$$

$$N_A = \frac{0.11 \cdot 10^{-9} \cdot 0.90}{0.030 \cdot 22.414} (2 - 0) \cdot 4 \cdot 10^{-4}$$

$$N_A = 1.1778 \cdot 10^{-13} \frac{\text{kgmol}(\text{CO}_2)}{\text{m}^2 \cdot \text{s}}$$

4. Problem 20.10-4

Convection resistance is zero

$$\frac{k_c}{D_{AB}} \sqrt{D_{AB} t} = \infty$$

$$t = 3600$$

$$C_0 = 0.14$$

$$C_1 = 0.03$$

for $x = 0.005\text{m}$

$$\frac{x}{2\sqrt{D_{AB} t}} = \frac{0.005}{2\sqrt{1.29 \cdot 10^{-8} \cdot 3600}} = 0.367$$

From Figure 14.3-3

$$\frac{C - C_0}{C_1 - C_0} \approx 0.6$$

$$\frac{C - 0.14}{0.03 - 0.14} = 0.6$$

$$\boxed{C = 0.074}$$

for $x = 0.01\text{m}$

$$\frac{x}{2\sqrt{D_{AB} t}} = \frac{0.01}{2\sqrt{1.29 \cdot 10^{-8} \cdot 3600}} = 0.734$$

From Figure 14.3-3

$$\frac{C - C_0}{C_1 - C_0} \approx 0.28$$

$$\frac{C - 0.14}{0.03 - 0.14} = 0.28$$

$$\boxed{C = 0.109}$$

for $x = 0.02\text{m}$

$$\frac{x}{2\sqrt{D_{AB} t}} = \frac{0.02}{2\sqrt{1.29 \cdot 10^{-8} \cdot 3600}} = 1.467$$

From Figure 14.3-3

$$\frac{C - C_0}{C_1 - C_0} \approx 0.039$$

$$\frac{C - 0.14}{0.03 - 0.14} = 0.039$$

$$\boxed{C = 0.136}$$

Plot of depth v weight%:

