CHE318 L18

Recitation + Dimensionless Numbers

Topic 1: Steady State mass transfer

Gov. Eq.

$\frac{dC}{dt} = 0$

Mass Balance

In - Out + Gen = 0 (always true)

Flux Equation

In & Out are fluxes

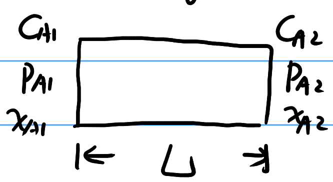
$N_A = J_{Az}^* + x_A(N_A + N_B)$

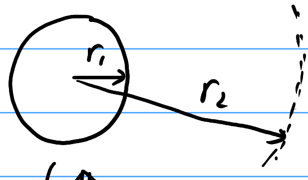
J_{Az}^* = diffusive in z

$= -D_{AB}\frac{dC_A}{dz}$

N_A & N_B ratio ⇒ { EMCD; Diff thru Stagnant B; $N_A = kN_B$ }

Geometry





(↑ use $\bar{N}_A = N_A \cdot 4\pi r^2$)

Applications

1. EMCD diffusion of gases
2. Thin membrane diffusion
3. Water evaporation to stagnant air
4. Evaporation / Sublimation of spheres
5. Absorption of gas bubble
6. Gas leakage in tube walls

No Vol. Gen Term + 1D

⇓

$$N_A = \frac{D_{AB} C_T}{L} S \ln\left(\frac{S - x_{A2}}{S - x_{A1}}\right)$$

$$S = \frac{N_A}{N_A + N_B}$$

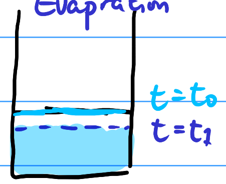
- EMCD $N_A = -N_B$ $\quad N_A = \frac{D_{AB} C_T}{L}(x_{A1} - x_{A2})$
- Stagnant B $N_B = 0$ $\quad N_A = \frac{D_{AB} C_T}{L}\ln\left(\frac{1 - x_{A2}}{1 - x_{A1}}\right)$

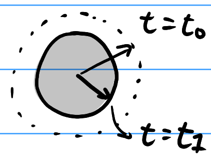
$$= \frac{D_{AB} C_T}{L} \cdot \frac{1}{x_{BM}}(x_{A1} - x_{A2})$$

Pseudo Steady State

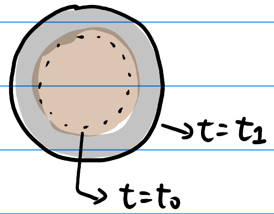
- A simplified version to solve changing $N_A(t)$.
- Each t, assume steady state
- Usually involving moving boundary

Evaporation





Growth of particle



Topic 2 Unsteady State Mass Transfer

Govern. Eq.

$$\frac{\partial c}{\partial t} \neq 0$$

M.B.

In − Out + Gen = Acc

$$-\nabla \cdot \vec{N}_A + r_A = \frac{\partial C_A}{\partial t}$$

Flux Eq. (3D)

$$\vec{N}_A = \vec{J}_A^* + C_A \cdot v_m$$

$$= -D_{AB} \nabla C_A + C_A \cdot v_m$$

$$\nabla \cdot \vec{N}_A = \nabla \cdot (-D_{AB} \nabla C_A + C_A \cdot \vec{v}_m)$$

$$= -D_{AB} \nabla^2 C_A + \nabla (C_A \vec{v}_m)$$

Usually we simplify to

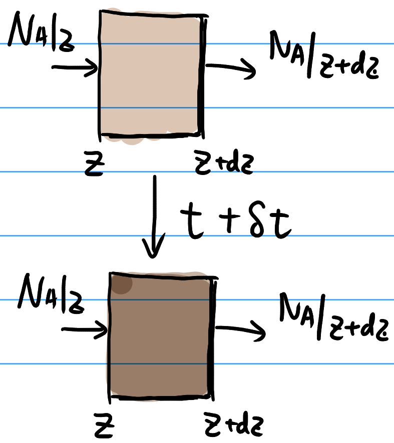
Convection >> diffusion

$$\nabla \cdot \vec{N}_A \approx \vec{v}_m \cdot \nabla C_A$$

1D Case

$$\frac{\partial N_A}{\partial x} \Rightarrow v_m \cdot \frac{\partial C_A}{\partial x}$$

Reaction / Generation r_A



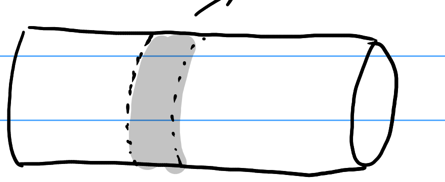
(r_A does NOT have a direction)

Geometry

The same as in S.S.

Special attention:

Tube Case



r_A in this case?

① If reaction on tube end

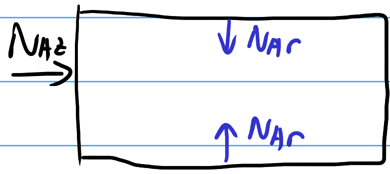
$r_A = 0$

② If reaction on tube wall

$r_A \neq 0$

usually

$r_A \propto k_c (C_{A,wall} - C_{A,bulk})$



Applications

The same as S.S.

Special case

time dependent

Penetration length

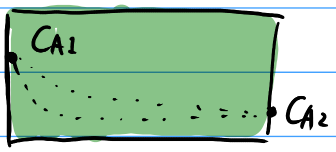
pure diffusion

$$L_D \simeq \sqrt{4 D_{AB} \cdot t}$$

Topic 3 Convective Mass Transfer + Coefficients

Gov. Eq

$$N_A = k_c' \cdot \frac{1}{x_{BM}} \cdot (C_{A1} - C_{A2})$$



Motivation:

- Don't need to solve exact $N_A = J_A^* + x_A(N_A + N_B) \ldots$
- Convection makes solving complex
- Just need to use

$$[\text{Flux}] = \frac{[\text{Driving Force}]}{[\text{Resistance}]}$$

$$k_c \propto \frac{1}{[\text{Resistance}]}$$

Multiple forms of k

k_c (overall conc. coeff) } m/s

k_c' (EMCD coeff) } m/s

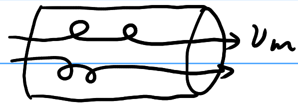
k_x k_y } $\frac{\text{kg mol}}{m^2 \cdot s}$

k_G } $\frac{\text{kg mol}}{m^2 \cdot s \cdot Pa}$

Geometry

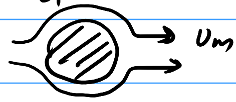
varied

tube

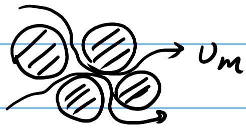


plate

sphere



packed bed



Applications

- industrial convective transport
- Anything you're not sure how to solve the Flux Eq.
- If know k_c in case 1

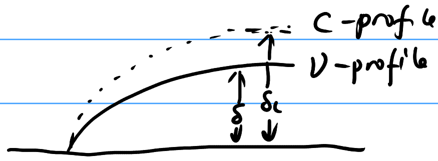
  N_{Re} N_{Sc} ⇓

  k_c in case 2

Meaning of N_{Re} & N_{Sc}

N_{Re} = Laminar or Turbulent ?

N_{Sc} = Boundary Layer of velocity vs concentration



Physically $N_{Sc} = \left(\frac{\delta}{\delta_c}\right)^3$

$N_{Sc} >> 1 \Rightarrow (\mu/\rho) >> D_{AB}$ momentum diffuses much faster than mass