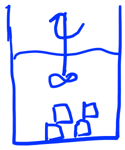
Convective Mass Transfer & Mass Transfer Coefficient

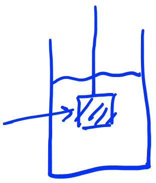


Convective mass transfer

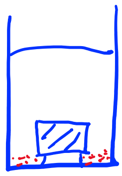
1) Forced convection : An external agent induces fluid motion
2) Free convection (Natural Convection) : Fluid motion is caused by the density difference.

Example :

Sugar cube suspended



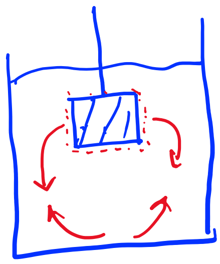
(a)



(b)

→ Q: Does the placement of sugar cube (top vs bottom of the glass) affect mass transfer?
↳ In which case does the sugar cube dissolve faster?

Case (b) : - No forced convection
- Sugar dissolution occur due to molecular diffusion

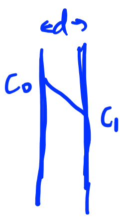


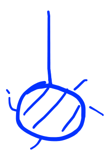
- C_s ↑ in water that is in the vicinity of sugar cube.
- The density of water (w/ dissolved sugar) also ↑.

Case (a) : - No forced convection
- Sugar dissolution is due to (a) Molecular diffusion (b) Natural / free convection.

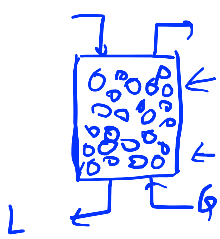
Mass Transfer coefficient : Include the effect of fluid motion & molecular diffusion on mass transfer.

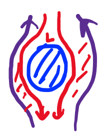
$$\cancel{N_A} \quad J_A = -D_{AB}\frac{dC_A}{dz}$$





Absorption :



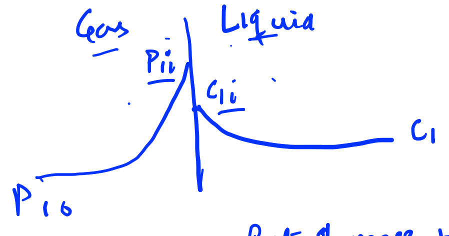


1) Molecular diffusion
2) Convective mass transfer
3) Interfacial area between gas/liquid changes w/ time & distance

$$N_A = x_A(N_A + N_B) - D_{AB}\frac{dc_A}{dz}$$

$$N_A = \underset{\substack{\uparrow \\ \text{Mass transfer coefficient}}}{K}\;(\text{Driving force})$$

<u>Consider mass transfer between gas & liquid</u>



Rate of mass transfer:

$$(\text{Rate of mass transfer}) = k\,(\text{Interfacial area})\,(\text{concentration difference})$$

$$\Rightarrow \text{Flux} = \frac{\text{Rate of mass transfer}}{\text{Interfacial area}} = k\,(\text{Concentration difference})$$

$$N_A = k_c(C_{1i} - C_1) \leftarrow (\text{Liquid side})$$

$$N_A = k_G(P_{1o} - P_{1i}) \leftarrow \text{Gas side}$$

N_A : $mol/m^2.s$

C : mol/m^3 $\Rightarrow K_c$: $\dfrac{mol/m^2.s}{mol/m^3} = m/s$

<u>Physical meaning of mass transfer coefficient</u>: A rate constant for moving a species from the interface into the bulk.

<u>Note</u>: (1) K includes mass transfer due to diffusion & convection

(2) For interphase mass transfer, we assume that equilibrium exist at the interface.

$$P_{1i} = H x_{1i}$$

Definitions of mass transfer coefficient

Flux	Units of mass transfer coefficient
1) $N_A = K_c \, \Delta C_A$ (concentration difference)	m/s or cm/s (L/T)
2) $N_A = K_G \, \Delta P_A$ (partial pressure)	mol / cm^2.s . Pa
3) $N_A = k_x \, \Delta x_1$ (mole fraction)	mol / cm^2. s

mole fraction of component A in the gas phase

Gas: $N_A = K_G (P_{A_1} - P_{A_2}) = k_y (y_{A_1} - y_{A_2}) = k_c (C_{A1} - C_{A2})$

Liquids: $N_A = k_x (x_{A_1} - x_{A_2}) = K_L (C_{A1} - C_{A2})$

x represents mole fraction of species A in the liquid phase

Ex: Recall, the flux obtained for diffusion of A through non-diffusing B, in the previous chapter, was given by

$$N_A = \frac{D_{AB} P}{RT\ell} \cdot \frac{P_{A_0} - P_{A\ell}}{P_{BM}} \quad \text{—(i)}$$

; P_{BM} = Log mean partial pressure of B

Using mass transfer coefficient approach:

$$N_A = K_G (P_{A_0} - P_{A\ell}) \quad \text{—(ii)}$$

Comparing (i) & (ii):

$$K_G = \frac{D_{AB} P}{RT\ell P_{Bm}}$$

; ℓ : Thickness of the film

$$k_y = \frac{D_{AB} P^2}{RTl \, P_{Bm}} \quad ; \quad k_c = \frac{D_{AB} P}{P_{Bm} \, l}$$

HW.

Ex: Equimolar counter diffusion of A & B:

$$N_A = \frac{D_{AB} (P_{A0} - P_{Al})}{RTl}$$

$$K_G' = \frac{D_{AB}}{RTl} \quad ; \quad K_y' = \frac{D_{AB} P}{RTl} \quad ; \quad k_c' = \frac{D_{AB}}{l}$$

HW

- For complex practical problems, we rely on empirical correlations to obtain mass transfer coefficient.