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Reg. no. :- 20232073

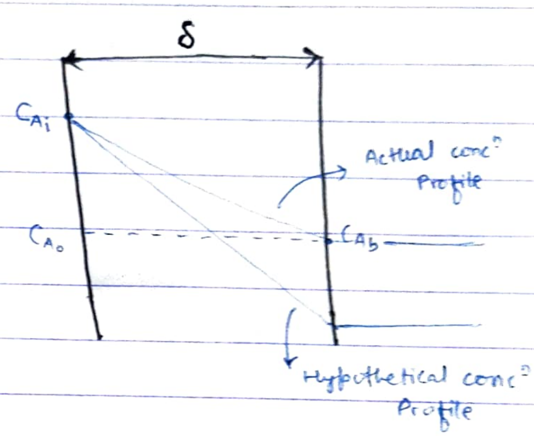
Sub. :- MTO Assignment

→ Theories of Mass transfer :-

(i.) Film Theory :-

When 2 phases come in contact, mass transfer due to diffusion occur in film not in bulk, as in bulk, mass transfer due to convection take place.

Mass transfer due to diffusion occur only in film because driving force $C_{Ai} - C_{Ab}$ exists in film theory.



Assumptions :-

(i) Steady State

(ii) Linear Profile

(iii) Mass transfer occur in film only.

$$N_A = \cancel{N_T X_A}^{\,0} + J_A \quad \text{(No bulk transfer)}$$

$$N_A = J_A$$

↳ ~~dilute sol^n~~ $-D_{AB}\dfrac{dC_A}{dz}$

$$\therefore \lim_{\Delta z \to 0} \frac{N_A|_z - N_A|_{z+\Delta z}}{\Delta z} = 0$$

$$\frac{dN_A}{dz} = 0$$

$$\Rightarrow -\frac{d}{dz}\left(D_{AB}\frac{dC_A}{dz}\right) = 0 \Rightarrow \frac{d^2C_A}{dz^2} = 0 \Rightarrow \frac{dC_A}{dz} = C_1$$

$$C_A = C_1 z + C_2$$

Now, $z = 0$, $C_A = C_{Ai}$

$z = \delta$, $C_A = C_{Ab}$

$C_{Ai} = 0 + C_2$

$C_{Ab} = C_1\delta + C_{Ai}$

$$C_1 = \frac{C_{Ab} - C_{Ai}}{\delta}$$

$$N_A = D_{AB}\left[\frac{C_{Ai} - C_{Ab}}{\delta}\right] \Rightarrow \boxed{k_c = \frac{D_{AB}}{\delta}}$$

② Penetration Theory :-

Assumptions :-

1.) Unsteady state, M.T

fick's 2^{nd} law

$$\frac{\partial C_A}{\partial z} = -D_{AB} \frac{\partial C_A^2}{\partial z^2}$$

θ = time spent by element at surface

2.) Time spent by every element are same.

3.) Equilibrium exists at gas-liquid interface.

4.) Time spent by each element is very less.

boundary conditions :-

at $t=0$, $C_A = C_{Ab}$

at $t>0$, $C_A = C_{Ai}$ $Z = 0$ (Interface)

at $t<0$, $C_A = C_{Ab}$ $Z \to \infty$ (bulk)

$$\frac{\partial C_A}{\partial t} = -D_{AB} \frac{\partial C_A^2}{\partial z^2}$$

Solve to get solution $\quad K_c = \sqrt{\frac{D_{AB}}{\pi t_c}}$ t_c = contact time

$$(K_c)_{avg} = 2\sqrt{\frac{D_{AB}}{\pi t_c}}$$

K_c = mass transfer coefficient

$\therefore K_c \propto \sqrt{D_{AB}}$ & $K_c \propto \frac{1}{\sqrt{t_c}}$

③ Surface Renewal theory :-

All are same as peneteration theory except θ, time spent by all elements are not same.

$K_c = \sqrt{D_{AB} S}$ $S \to$ surface renewal rate.

$K_c \propto \sqrt{D_{AB}}$

→ Mass Transfer Coefficients :-

Molecular M.T → flux = concⁿ × Diffusion velocity

Convective M.T → flux = M.T.C × Driving force (M.T.C ↑ M.T ↑)

- → Pressure difference (ΔP_A) $N_A = M.T.C \times \Delta P_A$
- → Concⁿ diff. (ΔC_A) $N_A = M.T.C \times \Delta C_A$
- → liquid mole fraction diff. (Δx_A) $N_A = M.T.C \times \Delta x_A$
- → Gas mole fraction diff. (Δy_A) $N_A = M.T.C \times \Delta y_A$

Heat Transfer coefficient is unique has one driving force i.e temperature different for different driving force.

→ Types of M.T.C :-

Case - I :- A diffusing through non-diffusing B

Part - A :- for gases

(i) $N_A = K_c \times \Delta C_A$

(ii) $N_A = k_g \times \Delta P_A$

(iii) $N_A = k_y \times \Delta y_A$

Part - B :- for liquid

(i) $N_A = K_L \times \Delta C_A$

(ii) $N_A = k_x \times \Delta x_A$

Unit of M.T.C :-

$N_A = k_c \times \Delta C_A$

$\frac{mol}{m^2 sec} = \frac{m}{sec} \times \frac{mol}{m^3}$

Now, $k_c \Delta C_A = k_g \Delta P_A = k_y \Delta y_A$

$k_c \Delta C = k_g RT \Delta C = k_y \frac{\Delta C}{RT}$

$$\boxed{\frac{k_c}{RT} = k_g = \frac{k_y}{P_T}}$$

Relationship between k_L and k_x

$$N_A = k_L \Delta C_A = k_x \Delta X_A$$

$$k_L \Delta C_A = k_x \frac{\Delta C_A}{C_T} \Rightarrow \boxed{k_L = \frac{k_x}{C_T}}$$

→ Expression for mass transfer coefficient

Part - A :- Gases

(i) for k_c

$$N_A = \frac{D_{AB} C_T}{Z} \ln\left[\frac{1-y_{A2}}{1-y_{A1}}\right] \quad ; \quad C_{Blm} = \frac{\Delta C_A}{\ln\left[\frac{1-y_{A2}}{1-y_{A1}}\right]}$$

(ii) for k_g

$$N_A = \frac{D_{AB} P_T}{RTZ} \frac{\Delta P_A}{P_{Blm}} = k_g \Delta P_A$$

$$k_g = \frac{D_{AB} P_T}{ZRT P_{Blm}}$$

(iii) $$k_y = \frac{D_{AB} C_T}{Z y_{Blm}} = \frac{D_{AB} P_T^2}{RTZ P_{Blm}}$$

Part B :- liquids

(i) for k_x: $$N_A = \frac{D_{AB} C_T}{Z} \frac{\Delta X_A}{X_{Blm}} = k_x \Delta C_A$$

$$k_x = \frac{D_{AB} C_T}{Z X_{Blm}}$$

(ii) for k_L :- $$k_L = \frac{D_{AB} C_T}{Z C_{Blm}}$$

Case-2:- for Equimolal counter diffusion :-

Part A :- gas

$$N_A = k_g' \Delta P_A$$

$$N_A = k_y' \Delta y_A$$

$$N_A = k_c' \Delta C_A$$

Part B :- liquid

$$N_A = k_x' \Delta X_A$$

$$N_A = k_L' \Delta C_A$$

$$k_g' \Delta P_A = k_y' \Delta y_A = k_c' \Delta C_A$$

$$\therefore k_g' = \frac{k_y'}{P_T} = \frac{k_c'}{RT}$$

→ M.T.C in equimolal counter diffusion :-

for k_g', $N_A = \frac{D_{AB} \Delta P_A}{ZRT} = k_g' \Delta P_A$

$$\boxed{k_g' = \frac{D_{AB}}{ZRT}}$$

for k_c' $N_A = \frac{D_{AB} \Delta C_A}{Z} = k_c' \Delta C_A$

$$\therefore \boxed{k_c' = \frac{D_{AB}}{Z}}$$

k_y' - $N_A = \frac{D_{AB} C_T \Delta y_A}{Z} = k_y \Delta y$

$$\therefore \boxed{k_y' = \frac{D_{AB} C_T}{Z}}$$

Now, $\frac{k_g}{k_g'} = \frac{P_T}{P_{B\,lm}}$, $\frac{k_c}{k_c'} = \frac{C_T}{C_{B\,lm}}$, $\frac{k_y}{k_y'} = \frac{1}{y_{B\,lm}}$

Part B:- for liquid

for k_x'; $N_A = \frac{D_{AB} C_T \Delta x_A}{Z} = k_x' \Delta x$

$$\boxed{k_x' = \frac{D_{AB} C_T}{Z}}$$

for k_L', $N_A = \frac{D_{AB} \Delta C_A}{Z} = k_L' \Delta C_A$

$$\boxed{k_L' = \frac{D_{AB}}{Z}}$$

$$\therefore \frac{k_x}{k_x'} = \frac{1}{(x_B)_{lm}} \qquad \frac{k_L}{k_L'} = \frac{C_T}{(C_B)_{lm}}$$

CRYSTALLIZATION

A crystal is a solid body with plane faces in which the atoms are arranged in an orderly repetitive array.

The process of formation or production of crystals from a solution or a melt is called crystallization.

Crystallization process :-

(i.) Saturation of solution → increasing solution concentration to get it saturated.
when concentration of solution is more than the solubility of solid at a particular temperature it is called supersaturated.

(ii.) Spontaneous formation and growth of tiny crystals called nuclei take place in saturated solution.
Super saturation in a solution is the driving force for transport of solute from bulk solution to crystal surface.

(iii.) If a nucleus or seed crystal is added to supersaturated solution it gradually grows to larger size.

(iv.) On reaching the surface, solute molecules get oriented and integrated into crystals.

(v.) The suspension with crystals and solution is called magma.
Solution remaining after removal of crystals is called mother-liquor.

→ Batch v/s Continuous Crystallization :-

In batch crystallization, the process occurs in a closed vessel for a specific time. The entire process feeding, nucleation, crystal growth and product withdrawal is done in distinct time intervals.

In continuous crystallization, the solution continuously flows through the crystallizer, allowing for constant nucleation and growth while product is continuously withdrawn.

Ex :- Mixed suspension mixed - product removal crystallizer.

↳ Based on how super saturation is achieved crystallizers can be classified into :-

1. Evaporative :- solvent is removed increasing the solute concentration and causing crystals to form.

2. Cooling :- Solution is cooled to reduce solute solubility leading to crystal formation.

3. Reactive Crystallization :- chemical reaction leads to crystal formation.

→ Based on Crystal suspension :-

1. Bulk solution crystallizer :- crystals are suspended in the solution for a significant time, allowing nucleation and growth to occur.

2. Precipitation Vessels :- Rapidly forming large no. of small crystals due to high supersaturation.

→ forced - circulation crystallizer:- circulate the solution within crystallizer to promote nucleation and growth.

Crystallizers

- Cooling Crystallizer
  - Swenson Walker
  - Cerny direct contact
  - O'slo - krystal
- Evaporative Crystallizers
  - APV kestner
  - Swenson Evaporative
  - O'slo - krystal evaporative
- Vaceum Crystallizers
  - Swenson Draft tube buffled
  - Standard Messo
  - Batch vaccum.