Cheatsheet: Convective Mass Transfer

Q1: Interfacial equilibrium

$$K = \frac{[\text{Conc. at gas side}]}{[\text{Conc. at liquid side}]} = \frac{c_i}{c_{Li}}$$

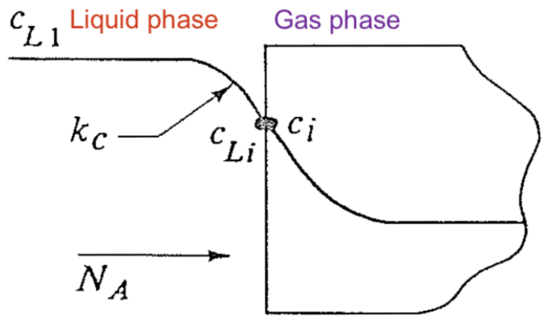
Example:

1. Henry's Law $p_A = H\, x_A$

2. Solubility (in liquid / solid)
   $c_A = S\, p_A / 22.414$ (S unit: m_3 at S.T.P)

3. Equilibrium diagram (see later topics)

Interfacial Mass Transfer



Q1:
Interfacial
concentration c_{Li}, c_i

Q2
Mass balance / Fluxes
across interface

Q2: Flux equation in convective regime

$$N_A = k_c(c_{L,b} - c_{Li})$$

Mass balance = Flux matching
- applicable to 2-phase M.T. / cooling

$$N_A|_{\text{liq}} = N_A|_{\text{gas}}$$
$$k_{c,\text{liq}}(c_{L,b} - c_{L,i}) = k_{c,\text{gas}}(c_{g,i} - c_{g,b})$$

Gas phase

$$k_c' \, c_T = k_c' \frac{p_T}{RT} = k_c \frac{p_{Bm}}{RT} = k_G' \, p_T = k_G \, p_{Bm} = k_y' = k_y \, y_{Bm} = k_c \, y_{Bm} \, c_T = k_G \, y_{Bm} \, p_T$$

- p : total pressure
- p_{Bm} : log-mean partial pressure of inert B
- y_{Bm} : log-mean mole fraction of B
- $c_T = p_T/(RT)$

Liquid phase

$$k_c' \, c = k_L' \, c = k_L \, x_{Bm} \, c = k_L' \frac{\rho}{M} = k_x' = k_x \, x_{Bm}$$

- ρ : liquid density
- M : molecular weight
- x_{Bm} : log-mean mole fraction of solvent B

Naming Convention and Units

- Superscript: EMCD $k'_{\text{driving force}}$; Convective / stagnant B $k_{\text{driving force}}$

Phase / Driving force	Concentration c_A	Partial pressure p_A	Mole fraction (gas y_A, liquid x_A)
Gas phase	k_c, k_c'	k_G, k_G'	k_y, k_y'
Liquid phase	k_c, k_c'	–	k_x, k_x'
Liquid (alt. form)	k_L, k_L'	–	–
Unit of k	$\mathrm{m \cdot s^{-1}}$	$\dfrac{\mathrm{kg\ mol}}{\mathrm{s \cdot m^2 \cdot Pa}}$	$\dfrac{\mathrm{kg\ mol}}{\mathrm{s \cdot m^2 \cdot mol\ frac}}$

Theory 1: Thin film theory

$$N_A = \boxed{\frac{D_{AB}}{\delta_f}}(c_{A,i} - c_{A,b})$$

Theory 2: Penetration theory

$$N_A = \boxed{\sqrt{\frac{4D_{AB}}{\pi t_L}}}(c_{A,s} - c_{A,b})$$

Theory 3: Boundary layer theory

$$N_A = \boxed{0.664\, D_{AB}/L\, N_{Sc}^{1/3}\, N_{Re}^{1/2}}(c_{As} - c_{A,b})$$

Practical: use cheatsheet for scaling

EMCD / Dilute

Gases: $N_A = k_c'(c_{A1} - c_{A2}) = k_G'(p_{A1} - p_{A2}) = k_y'(y_{A1} - y_{A2})$

Liquids: $N_A = k_c'(c_{A1} - c_{A2}) = k_L'(c_{A1} - c_{A2}) = k_x'(x_{A1} - x_{A2})$

Stagnant film

Gases: $N_A = k_c(c_{A1} - c_{A2}) = k_G(p_{A1} - p_{A2}) = k_y(y_{A1} - y_{A2})$

Liquids: $N_A = k_c(c_{A1} - c_{A2}) = k_L(c_{A1} - c_{A2}) = k_x(x_{A1} - x_{A2})$