Cheatsheet: Pre-midterm Mass Transfer

1D Equation. Other forms see below

Flux Equation (Solving N_A)

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

Diffusive J^*_{Az} Convective $c_A v_m$

Solutions **Gas, Steady State** (**Gen=Acc=0**)

General solution

$$N_A = \frac{c_T D_{AB}}{(z_2-z_1)}\frac{N_A}{N_A+N_B}\ln\left[\frac{N_A - x_{A2}(N_A+N_B)}{N_A - x_{A1}(N_A+N_B)}\right]$$

Suitable: boundary of heterogeneous reaction

Special case 1: EMCD

$$N_A = \frac{D_{AB}}{(z_2-z_1)}(c_{A1}-c_{A2})$$

Special case 2: Through stagnant B

$$N_A = \frac{c_T D_{AB}}{(z_2-z_1)}\ln\left(\frac{1-x_{A2}}{1-x_{A1}}\right)$$

Use log-mean format

$$N_A = \frac{D_{AB}}{RT(z_2-z_1)}\frac{p_T}{p_{Bm}}(p_{A1}-p_{A2})$$

Special case 3: reactive coupling

Use *general solution*, need N_A/N_B ratio & sign

Stoichiometry **Magnitude** ratio

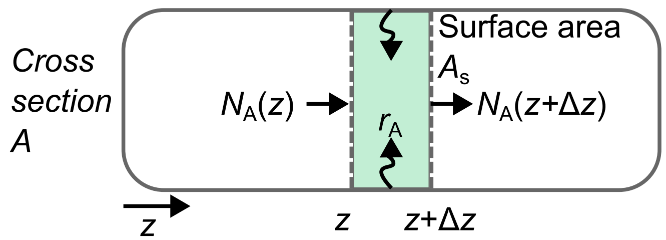
$mA \rightarrow nB$ $N_A/m = N_B/n$

sign: determined from boundary condition

Mass Balance Equation

$$[\text{In}] - [\text{Out}] + [\text{Gen}] = [\text{Acc}]$$

$$N_A(z)A(z) - N_A(z+\Delta z)A(z+\Delta z) + r_A A_s(\Delta z) = dc_A/dt$$



Diffusivity D_{AB}

Gas: Kinetic theory

$$D_{AB} = \frac{1}{3}\bar{u}\lambda_{A,B}$$

Gas: Chapman-Enskog

$$D_{AB} = \frac{1.8583\times10^{-7}T^{3/2}}{p_T\sigma_{AB}^2\Omega_{D,AB}}\left(\frac{1}{m_A}+\frac{1}{m_B}\right)^{\frac{1}{2}}$$

$$\propto \frac{T^{\frac{3}{2}}}{p_T}\left(\frac{1}{m_A}+\frac{1}{m_B}\right)^{\frac{1}{2}}$$

Gas: Fuller method

$$D_{AB} = \frac{1.0\times10^{-7}T^{1.75}}{p_T\left[(\sum\nu_A)^{1/3}+(\sum\nu_B)^{1/3}\right]^2}\left(\frac{1}{m_A}+\frac{1}{m_B}\right)^{\frac{1}{2}}$$

$$\propto \frac{T^{1.75}}{p_T}$$

Liq: Stokes-Einstein (Mw > 1000)

$$D_{AB} = \frac{9.96\times10^{-16}T}{\eta V_A^{0.333}}$$

Liq: Wilke-Change (278 K ~ 313 K)

$$D_{AB} = \frac{1.173\times10^{-16}(\phi M_B)^{1/2}T}{\eta_B V_A^{0.6}}$$

Inhom. Solid: effective

$$D_{AB,\text{eff}} = \frac{\varepsilon}{\tau}D_{AB}$$

Liquid / solid common case (like stagnant B)

$$N_A = \frac{D_{AB}c_{Aav}}{(z_2-z_1)}\frac{(x_{A1}-x_{A2})}{x_{B,m}} \quad x_{B,m} = \frac{x_{B2}-x_{B1}}{\ln(x_{B2}/x_{B1})}$$

Solid case $x_{Bm} \sim 1$

Liq. dilute case $x_{Bm} \sim (x_{B1}+x_{B2})/2$

Generation term / orthogonal M.T.

Coefficient - driving force form

Example: (details see review after mid-term)

$$r_A = k(c_{A,s} - c_A)$$

Coeff — Unit m/s

Driving force — Concentration diff

Unsteady state $dc_A/dt \neq 0$

1D uniform cross sectional area (remove Δz)

$$\frac{\partial c_A}{\partial t} = -\frac{\partial N_A(z)}{\partial z}\Big|_z + r_A$$

3D general term

$$\frac{\partial c_A}{\partial t} = r_A - \frac{\partial N_{Ax}}{\partial x} - \frac{\partial N_{Ay}}{\partial y} - \frac{\partial N_{Az}}{\partial z}$$

$$= r_A - \nabla\cdot\vec{N}_A$$

1D

$$\nabla^2 c = \frac{\partial^2 c}{\partial z^2} \qquad \nabla c = \frac{\partial c}{\partial z}$$

Most used form: incompressible liquid

$$\frac{\partial c_A}{\partial t} = D_{AB}\nabla^2 c_A - \vec{v}_m\cdot\nabla c_A + r_A$$

likely diffusion can be ignored

Varying cross section problem

N_A can vary! Steady state use $\overline{N}_A = N_A(z)A(z)$

Gen = 0. Spherical case (**stagnant B**)

$$\frac{\overline{N}_A}{4\pi}\left(\frac{1}{r_1}-\frac{1}{r_2}\right) = \frac{D_{AB}p_T}{RT}\ln\left(\frac{p_T-p_{A2}}{p_T-p_{A1}}\right)$$

Gen = 0. Spherical case (**far field stagnant B**)

$$N_{A1} = \frac{D_{AB}p_T}{RT\,p_{Bm}}(p_{A1}-p_{A2})$$