ملخصات مدار

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انتقال المادة

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* Molecular transport process of (Momentum, heat, mass) ⇒ (Rate of transfer = $\frac{\text{driving force}}{\text{resistance}}$)

* different conc. ⇒ component transfer from phase to phase or same phase ⇒ Mass transfer ⇒ May occur in gas mixture or liquid solution or solid

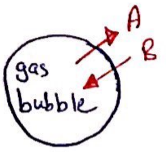
(region of high conc. → lower conc.) ⇒ direction of decreasing conc.

⇓

Fick's law (Diffusion) ⇒ flux $\frac{N}{A} = -D \frac{dc}{dx}$ → gradient : concentration

* Mass transfer (within fluid mixture or across phase boundry) ⇒ play major role in industrial process

⇓ examples



① Dispersion of gases from stacks.

② Distillation columns in Petroleum refinery ⇒ exchange btw gas and liquid around trays ⇒ mass transfer enriches species A in liquid, B in gas.

③ Removal Pollutents from plant discharge streams by absorption in example absorption of CO_2 by water

④ stripping of gasses from waste water.

③, ④ ⇒ gas – liquid interface

⑤ Adsorption of liquid or gas to solid surface. ⇒ liquid - solid interface. ⇒ reactents or product diffuse in or out of porous catalysts pelts

⑥ Neutron diffusion within nucler reactors ⇒ control rod → made of material usually Boron or cadmium; absorb excess neutrons → by controlling the number of neutrons ⇒ control the rate of fissions

①

⑦ Breathing ⇒ exchange btw lungs and blood capillaries ⇒ Air → blood (diffusion O_2); Air ← blood (diffusion CO_2)

No Net movment at equilibrium

⇑

* examples of Mass transfer process ⇒ ① Diffusion → lump of sugar in coffe → make concentration uniform

② water evaporate → increase humidity of passing air steam or seperate solid substance that has dissolved in water

③ wood, perfumes

* we need (Pure substance) so mass transfer important.

* mass transfer operations are charcterized by transfer of substance through another on molecular scale..

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* 3 ways to Mass transfer occures :

① Diffusion ② Advection ③ convection.

- Diffusion : net transport of substances in
  ① stationary solid
  ② stagnant fluids
  ③ fluids moving in laminer flow
  ④ may present in highly developed turbulet flow but near solid surface. (viscous sublayer)

  ⇒ due to concentration gradient

⇓

① Caused by random molecular motion. (Molecular diffusion) or (random walk process)

random → random path

② take place in mixtures (≥ 2 components) but heat, momentum need one component phases

* in Molecular diffusion with time at the end you achieve uniform conc..

* $\boxed{\text{flux} = \dfrac{(\text{mass or moles of species})}{(\text{cross sectional Area})(\text{time})}}$ ⇒ Unit : $\dfrac{\text{Kg/moles A}}{m^2 \cdot s}$

* flux defined with Refernce to coordinates
  ① fixed in space
  ② moving with mass averge velocity
  ③ moving with molar 〃 〃

*Fick's law for Molecular Diffusion :

$$\boxed{J^*_{AZ} = -C_T D_{AB} \frac{dx_A}{dz}}$$ ⇒ for : isothermal, isobaric, binary mixture of A, B in stagnant media or laminer flow

J^*_A : molar flux, z direction, molar Avg. velocity cordinates ⇒ Unit : $\dfrac{\text{Kmol of A}}{m^2 \cdot s}$

D_{AB} : molecular diffusivity of Molecule A in B ⇒ $\dfrac{m^2}{s}$

C_T : total concentration ⇒ $\dfrac{\text{Kmol of (A+B)}}{m^3}$

Z : distance of diffusion ⇒ m

X_A : mole fraction of A in mixture of A and B

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* $\boxed{J^*_{Az} = \frac{\bar{J}_{Az}}{A_m}}$

$\bar{J}_{Az}$: rate of molecular diffusion $\Rightarrow$ $\frac{Kmol \text{ of } A}{s}$

A_m : mass transfer Area which is normal to transfer direction $\Rightarrow$ m^2

* negative sign $\Rightarrow$ diffusion occures in the direction of drop in conc.
* mass transfer rate proportional to area $\Rightarrow$ rate can expressed as flux
* Net transfer stops when $\rightarrow$ conc. uniform
* fick's low $\Rightarrow$ flux due diffusion (J_{Az}) but not due bulk flow (N_{Az})

* $\boxed{C_A = C_T \, X_A} \xrightarrow[\text{C constant}]{\text{if}}$ $c\,dx_A = d(cX_A) = dC_A$ $\Rightarrow$ $\boxed{J^*_{Az} = -D_{AB}\frac{dC_A}{dz}}$

* $\boxed{C = \frac{P}{RT} = \frac{n}{V}}$

* $\boxed{J^*_{Az} = \frac{D_{AB}(P_{A_1} - P_{A_2})}{RT(Z_2 - Z_1)}}$ $\Rightarrow$ steady state, Constant total pressure

* Equimolar Counter diffusion $\Rightarrow$ $\boxed{J^*_{Az} = -J^*_{Bz}}$

$P = P_{A_1} + P_B = \text{constant} \Rightarrow C = C_A + C_B = \text{constant}$

$\Downarrow$

$D_{AB} = D_{BA} \Leftarrow dC_A = -dC_B$

* $\boxed{P_B = P - P_A}$

* $R = 8314.3 \ \frac{m^3 . Pa}{Kg.mol.K}$

$= 82.057 \ \frac{cm^3 . atm}{g.mol.K}$

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* Advection : ① net transport of substances by the moving fluid
② not include transport by diffusion
③ can't happen in solid.

* Convection : net transport caused by both { advection, diffusive }

⇓ depends on

① transport prop. ② dynamic charc. of moving fluid.

$$\boxed{N_{Az} = K_c \, \Delta C_A}$$

similar to Newton law of cooling.

N_{Az} ⇓ molar mass transfer; K_c ⇓ convective mass transfer cofficient

* Summary slide 40 important.

* General flux equation ⇒

total mass transported	=	mass transport by diffusion	+	mass transport by bulk fluid

Stefan and Maxwell using Kinetic theory.

$$V_{A,\,diffusion}\,(m/s) = \frac{J_A^*\,(mol/m^2.s)}{C_A\,(mol/m^3)}$$

$$V_{bulk,avg} = \frac{\sum_{i=1}^{n} C_i V_i}{C}$$

⇒ $\boxed{V_i\,(total) = V_{bulk} + V_{diff}}$

* $N_A = C_A V_A$
* $N_B = C_B V_B$

] $\boxed{V_{Bulk} = \frac{(N_A + N_B)}{C_T}}$

$\boxed{N_i = \frac{W_i\,(mol/s)}{A\,(m^2)}}$ total Molar flux by convection.

$$\Rightarrow \boxed{N_A = - D_{AB}\frac{dc_A}{dz} + \frac{C_A}{C_T}(N_A + N_B)}$$ general flux equation ④

N_A ⇓ total; $- D_{AB}\frac{dc_A}{dz}$ ⇓ diffusion; $\frac{C_A}{C_T}(N_A + N_B)$ ⇓ Bulk flow

Note : if C_A too small (mixture dilute in A), bulk flow term ignored ⇒ $N_A = - D_{AB}\frac{dc_A}{dz}$

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* $\boxed{N_A = -\frac{D_{AB}}{RT}\frac{dp_A}{dz} + \frac{p_A}{P}(N_A + N_B)}$

* $C_A = \frac{n_A}{V} = \frac{P_A}{RT}$ → Partial pressure.

* $C_T = \frac{n_T}{V} = \frac{P}{RT}$

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

* $x_A = \frac{P_A}{P} = \frac{N_A}{N_A + N_B} = \frac{C_A}{C_T}$

* Diffusivity ⇒

* $D_{AB} = \frac{-J_{Az}}{dC_A/dz} = \left(\frac{m^2}{s}\right)$ → L^2, → t

depends on: pressure, Temp., composition

* gases at low density: $D_{AB}\uparrow$ with Temp
$D_{AB}\downarrow$ with Pressure
indp. with composition

* liquid and solids: $D_{AB}\uparrow$ with Temp.
depended with composition

* Diffusivity in gases:

$$\boxed{D_{AB}(T_2, P_2) = D_{AB}(T_1, P_1)\left(\frac{P_1}{P_2}\right)\left(\frac{T_2}{T_1}\right)^{3/2}}$$

Hirschfelder extrapolation (below 25 atm). ⇒ * $D_{AB} \propto \frac{1}{P}$, $D_{AB} \propto T^{3/2}$

$$D_{1\text{-mixture}} = \frac{1}{\frac{X_2'}{D_{1-2}} + \frac{X_3'}{D_{1-3}} + \dots + \frac{X_n'}{D_{1-n}}}$$

$$X_n' = \frac{X_2}{X_2 + X_3 + \dots + X_n}$$

$$\boxed{D_{AB} = \frac{10^{-3}\, T^{1.75}\left[\frac{1}{M_A} + \frac{1}{M_B}\right]^{\frac{1}{2}}}{P\left[(\Sigma V_A)^{\frac{1}{3}} + (\Sigma V_B)^{\frac{1}{3}}\right]^2}}$$

Fuller method.
Diff. for binary system.

* $D_{AB} \propto \frac{1}{P}$, $D_{AB} \propto T^{1.75}$

D_{AB}: in cm^2/s
P: in atm
M: molecular weight
T: in K
V: volume diffusion (من الجدول)

(5)

* Diff. in liquid ten thousand time slower than dilute gas

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* Diff. in liquid $\Rightarrow$ nearer to 10^{-5} cm^2/s.

$$\boxed{\underset{(cm^2/s)}{D_{AB}} = \frac{9.96\times10^{-12}\,T}{\mu\, V_A^{1/3}}}$$

T → K

μ → Viscosity of solution (Kg/ms)

V_A → Solute Molar volume at Normal boiling point (نقطة الغليان) ($m^3/Kmol$)

$\Rightarrow$ very large spherical dilute solute A of 1000 M.weight or greater diffusing in liq. solvent B of small molecules $\Rightarrow$ Proportional to $\frac{1}{\mu}$ and T

$$\left(\frac{D_{AB}\,\mu}{T}\right)_{T_2} = \left(\frac{D_{AB}\,\mu}{T}\right)_{T_1}$$

$$\boxed{\underset{(cm^2/s)}{D_{AB}} = \frac{7.4\times10^{-8}\,(\phi M_B)^{1/2}\,T}{\mu_B\, V_A^{0.6}}}$$

ϕ → parmeter for solvent

M_B → M.weight

T → K

μ_B → viscosity of B in cp

$\Rightarrow$ Smaller molecules A diff. in dilute liq. solution of solvent B $\Rightarrow$ Proportional to $\frac{1}{\mu_B}$ and T

* if V_A not available in Tables $\Rightarrow$ Tyn and clus correlation.

$$\boxed{V_A = 0.285\, V_c^{1.048}}$$

V_c → critical volume of solute A ($cm^3/g\,mol$)

$$\boxed{\underset{(cm^2/s)}{D^{0}_{AB}} = \frac{8.928\times10^{-10}\,T\,(1/n_+ + 1/n_-)}{\underbrace{(1/\lambda_+ + 1/\lambda_-)}_{\text{limiting ionic conductance in very dilute solution.}}}}$$

T → 298.2 (25°C)

n_+ → valence of cation

n_- → Valence anion

$\Rightarrow$ Electrolytes in liquid (dilute liquid) of solvent B $\Rightarrow$ Proportional to T

* Diff. in solids $\Rightarrow$ btw $5\times10^{-14} - 1\times10^{-10}$

$\Rightarrow$ less than liquid, liquid less than gas

$\Rightarrow$ important in catalysis.

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* $\underbrace{\frac{\partial N_{Az}}{\partial z} + \frac{\partial C_A}{\partial t}}_{\text{1D, no chemical Rxn.}} = 0 \xrightarrow[\text{state}]{\text{steady}} \frac{\partial N_{Az}}{\partial z} = 0 \Rightarrow N_{Az} = \text{constant}$

$$\boxed{N_A = -C_T D_{AB} \frac{dx_A}{dz} + x_A (N_A + N_B)} \Rightarrow \text{general flux equation}$$

after Integrate

$$\Rightarrow * N_A = \frac{N_A}{(N_A+N_B)} \frac{C_T D_{AB}}{z} \ln \left(\frac{\frac{N_A}{N_A+N_B} - \frac{C_{A2}}{C_T}}{\frac{N_A}{N_A+N_B} - \frac{C_{A1}}{C_T}} \right) \Rightarrow$$

difficult to find by solving in trial and error

⇓

cases to simplify it

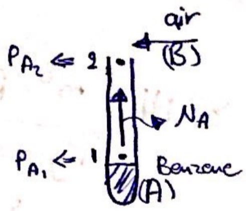
① Diffusing of A through stagnant, non-diffusing B:

⇓

B is moving but Not diffusing in the path.

impermeable to component B ⇒ can't pass through ⇒ $N_B = 0$

* evaporation of pure liquid A (benzene), large amount of air passed over the top(B)



A diffuse through B

B insoluble in A ⇒ B can't diffuse ⇒ $N_B = 0$

at point 2 ⇒ $P_{A_2} = 0$ (large volume of air is passing through)

* NH_3 vapor(A), Air(B) by water.

7

air ⇒ source, no sink ⇒ not soluble in water ⇒ not diffusing → $N_B = 0$

NH_3 ⇒ source, sink

$$* \boxed{N_A = \frac{-C_T D_{AB}}{1 - x_A} \frac{dx_A}{dz}} \xrightarrow{\text{Integrate}} \boxed{N_A = \frac{C_T D_{AB}}{z_2 - z_1} \ln \left(\frac{1 - x_{A2}}{1 - x_{A1}} \right) = \frac{C_T D_{AB}}{z_2 - z_1} \ln \left(\frac{C_T - C_{A2}}{C_T - C_{A1}} \right)}$$

$$\boxed{x_A = \frac{C_A}{C_T}}$$

$$\boxed{P_A = C_A RT \quad P = C_T RT \quad x = \frac{P_A}{P}}$$

$$\boxed{x_A = 1 - (1 - x_{A_1}) \exp \left(\frac{N_A (z - z_1)}{C_T D_{AB}} \right)} \Leftarrow$$

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(* $\boxed{N_A = \frac{P D_{AB}}{RT(z_2-z_1)} \ln\left(\frac{P-P_{A2}}{P-P_{A1}}\right)}$

* $\boxed{N_A = \frac{C_T D_{AB}}{z_2-z_1} \frac{(x_{A1}-x_{A2})}{x_{B,lm}}}$

$\boxed{N_A = \frac{P D_{AB}}{RT(z_2-z_1)} \frac{(P_{A1}-P_{A2})}{P_{B,lm}}}$

$\boxed{x_B = 1 - x_A} \Rightarrow$ * $\boxed{x_{B,lm} = \frac{x_{A1}-x_{A2}}{\ln\left(\frac{1-x_{A2}}{1-x_{A1}}\right)} = \frac{x_{B2}-x_{B1}}{\ln\left(\frac{x_{B2}}{x_{B1}}\right)}}$

$\boxed{P_B = P - P_A} \Rightarrow$ * $\boxed{P_{B,lm} = \frac{P_{B2}-P_{B1}}{\ln\left(\frac{P_{B2}}{P_{B1}}\right)} = \frac{(P-P_{A2})-(P-P_{A1})}{\ln\left(\frac{P-P_{A2}}{P-P_{A1}}\right)}}$

* C_A low, diluted $\Rightarrow$ $\boxed{\begin{array}{l} x_{B,lm} = 1 \\ P_{B,lm} = P \end{array}}$

* N_A depend on deriving force, distance.

* 1 Atm = 1.01325×10^5 pa.

* D_{AB} from $m^2/s \rightarrow ft^2/h \Rightarrow$ conversion = 3.875×10^4

* $R = 8314 \frac{m^3 \cdot Pa}{Kg \cdot mol \cdot K}$

$= 82.057 \frac{cm^3 \cdot atm}{g \cdot mol \cdot K}$

$= 0.7302 \frac{ft^3 \cdot atm}{R\ lb\text{-}mol}$

8

* Note: ① N_A constant mean flux along diffusion path constant but conc. is different.

② $-r_A$ term $\Rightarrow$ Rxn within Diffusion path + Homogeneous.

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② Equimolar Counter Diffusion :

* $N_A = -N_B$

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

$$\Rightarrow \boxed{N_A = -D_{AB}\frac{dC_A}{dz}} \xrightarrow{\text{Integrate}} \boxed{N_A = \frac{D_{AB}}{z_2 - z_1}(C_{A_1} - C_{A_2})}$$

$$\Downarrow \ * C_A = \frac{n_A}{V} = \frac{P_A}{RT}$$

$$\boxed{N_A = \frac{D_{AB}}{RT(z_2 - z_1)}(P_{A_1} - P_{A_2})}$$

* Conc. A at any location along diffusion path $\Rightarrow$

① $$N_A = \frac{D_{AB}}{(z_2 - z_1)RT}(P_{A_1} - P_{A_2})$$

$$N_A = \frac{D_{AB}}{(z' - z_1)RT}(P_{A_1} - P_{z'})$$

بنقسمهم على بعض $\Rightarrow$ $P_{z'}$ or $C_{z'}$

or

② $$\frac{C_A - C_{A_1}}{C_{A_1} - C_{A_2}} = \frac{z - z_1}{z_1 - z_2}$$

③ Relation btw N_A, N_B fixed by reaction stoichiometry

$mA \rightarrow nB$

$$\boxed{\frac{N_A}{m} = -\frac{N_B}{n}} \Rightarrow \boxed{N_B = -\left(\frac{n}{m}\right)N_A}$$

$$\boxed{N_B = -\left(\frac{\lambda_A}{\lambda_B}\right)N_A}$$ by latent heat of vaporization $\Rightarrow$ more volatile comp. transfer from liq $\rightarrow$ vap

less " " " " vap $\rightarrow$ liq.

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* Pseudo steady state diffusion ⇒ length diff. path changes a small amount over along period time.

⇓

1 molar flux : stagnant

$$\boxed{N_A = \frac{C_T D_{AB}}{Z} \frac{(x_{A_1} - x_{A_2})}{x_{B,lm}}}$$

$Z_2 - Z_1$ (length path)

2 $N_A A = \frac{dN}{dt}$

$= \frac{mass}{M.w} \sim \rho V$ A2

$$\Rightarrow \boxed{N_A = -\frac{\rho}{M_A}\frac{dz}{dt}}$$

$$\Rightarrow \boxed{\frac{\rho_{A,L}}{M_A}\frac{dz}{dt} = \frac{C_T D_{AB}}{Z}\frac{(x_{A_1} - x_{A_2})}{x_{B,lm}}}$$

Molar density

$$\boxed{t = \frac{\rho_{A,L} \; x_{B,lm} / M_A}{C_T D_{AB} (x_{A_1} - x_{A_2})}\left[\frac{Z_t^2 - Z_{t_0}^2}{2}\right]}$$

$$\boxed{D_{AB} = \frac{\rho_{A,L} \; x_{B,lm}}{M_A C_T (x_{A_1} - x_{A_2}) \, t}\left[\frac{Z_t^2 - Z_{t_0}^2}{2}\right]}$$

* Diffusion into infinite standered Media ⇒ W_A constant, N_A not constant because r changes.

large media ($N_B = 0$)

$$\boxed{N_A = \frac{-C_T D_{AB}}{1 - x_A}\frac{dx_A}{dr}}$$

$$\boxed{A = 4\pi r^2}$$

$$\boxed{W_A = 4\pi r^2 N_A = 4\pi r_0^2 N_{A_0}}$$

$$\boxed{C_T = \frac{P}{RT} \quad C_A = \frac{P_{A_1}}{RT}}$$

$$\boxed{W_A = \frac{4\pi C_T D_{AB}}{1/r_0}\ln\left(\frac{1 - x_{A_2}}{1 - x_{A_1}}\right)}$$

$$\boxed{N_{A_0} = \frac{D_{AB} P}{RT r_0}\frac{(P_{A_1} - P_{A_2})}{P_{B,lm}}} \xrightarrow[P_{A_1}\text{ small}]{P_{B,lm} = P} \boxed{N_{A_0} = \frac{2 D_{AB}}{D_1}(C_{A_1} - C_{A_2})}$$

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$$\boxed{\begin{aligned} t &= \frac{\rho_A}{M_A}\frac{1}{2C_T D_{AB}}\frac{(r_i^2 - r_f^2)}{\ln\left(\frac{1-x_{A_2}}{1-x_{A_1}}\right)} \\ &= \frac{\rho_A RT (r_i^2 - r_f^2)}{2 M_A D_{AB} P}\frac{P_{B.lm}}{(P_{A_1} - P_{A_2})} \end{aligned}}$$

* Diffusion through varying Area ⟹

$$N_A = -\frac{C_T D_{AB}}{1-x_A}\frac{dx_A}{dz}$$

$$N_A = \frac{-D_{AB}}{RT\left(1-\frac{P_A}{P}\right)}\frac{dP_A}{dz}$$ (11)

$$r = \left(\frac{(r_2 - r_1)}{(z_2 - z_1)}\right) z + r_1$$

$$\bar{N}_A = \frac{\pi D_{AB} P}{RT}\frac{r_1}{z}\left[r_1 - (r_1 - r_2)\left(\frac{z}{L}\right)\right]\ln\frac{P}{P - p_A^v}$$

* Diffusion in liquid ⟹

$$N_A = \frac{D_{AB}}{z_2 - z_1}(C_{A_1} - C_{A_2}) = \frac{C_{av} D_{AB}}{z_2 - z_1}(x_{A_1} - x_{A_2})$$

$$C_{av} = \frac{\frac{\rho_1}{M_1} + \frac{\rho_2}{M_2}}{2} \Rightarrow \boxed{N_A = \frac{D_{AB}}{z}\left(\frac{\rho}{M}\right)_{av}(x_{A_1} - x_{A_2})}$$ equimolar counter

$$\boxed{N_A = \frac{D_{AB}}{(z_2 - z_1) x_{Bm}}\left(\frac{\rho}{M}\right)_{av}(x_{A_1} - x_{A_2})}$$ not diffusing B

$$x_{Bm} = \frac{x_{A_1} - x_{A_2}}{\ln(1 - x_{A_2}/1 - x_{A_1})}$$

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* Diffusity in solids ⇒

- following fick's law

$$\boxed{N_A = D_{AB} \frac{C_{A_1} - C_{A_2}}{Z_2 - Z_1}}$$ planner surface.

$$W_A = 2\pi L D_A \frac{(C_{A_i} - C_{A_o})}{\ln\left(\frac{r_o}{r_i}\right)}$$

$$C_A(r) = C_{A_i} - \frac{(C_{A_i} - C_{A_o})}{\ln\left(\frac{r_o}{r_i}\right)} \ln\left(\frac{r}{r_i}\right)$$

$$N_A = \frac{W_A}{2\pi r L}$$

cylindrical surface

Note: W_A constant

$$W_A = 4\pi r_i r_o D_A \frac{(C_{A_i} - C_{A_o})}{r_o - r_i}$$

$$N_A = \frac{W_A}{4\pi r^2}$$

spherical surface

- following Nature of solid: type, size of Pores. ملاحظة 15 (slides)

① Liquid in solids

$$D_{A_{ef}} = (\varepsilon / K_t^2) D_{AB}$$

$$N_A = \frac{\varepsilon}{K_t^2} D_{AB} \frac{C_{A_1} - C_{A_2}}{Z_2 - Z_1}$$

ε : volume void fraction

K_t : tortuousity factor

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②

* Diff. Gases in Solid: diameter Pores, mean free Path, size of pores.

$$\boxed{\lambda_A = \frac{3.2\,\mu_A}{P}\left[\frac{RT}{2\pi M_A}\right]^{0.5}} \Longrightarrow \boxed{K_n = \frac{\lambda}{d_{pore}}}$$

Knudsen number

μ → viscosity

λ_A ⇓ mean free Path

λ: m
T: K
μ: kg/m.s
P: N/m^2
R: 8314 $\frac{J}{Kmol\,K}$

⟹ $\boxed{K_n < 0.01}$: indp. of nature of solid

$$\boxed{N_A = -\frac{D_{AB}\,P}{RT}\frac{dy_A}{dz} + y_A\,(N_A + N_B)}$$

⟹ $\boxed{K_n > 10}$

$$\boxed{D_{KA} = 4850\, \underset{(cm)}{d_{pore}}\sqrt{\frac{T\,(K)}{M_A}}}$$ Knudson diffusion

$$\boxed{\begin{aligned} N_A &= -D_{KA}\frac{dC_A}{dz} = -\frac{D_{KA}}{RT}\frac{dP_A}{dz} \\ &= \frac{D_{KA}\,P}{RT\,\Delta z}\,(y_{A_1} - y_{A_2}) \end{aligned}}$$

* Knudsen diffusion significt ⟹ low pressure, small diameter

* $0.1 < K_n < 1$ ⟹ measurble but moderate role in overall diffusion

$K_n > 1$ ⟹ important

$0.01 < K_n < 10$ ⟹ $\boxed{\frac{1}{D_{Ae}} = \frac{1}{D_{AB}} + \frac{1}{D_{KA}}}$

* Pores twisted, interconnected ⟹ $\boxed{D'_{Ae} = \varepsilon^2 D_{Ae}}$

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