Sheet No. 1

~~molecular~~ diffusion for Gas and liquids ~~Tutorial~~

Q1 A small diameter tube closed at one end, was filled with acetone to within 18 mm of the top and maintained at 298 K and 99.75 KN/m^2 with a gentel stream of air blowing across the top. After about 15 Ksec the liquid level had fallen to 27.5 mm. Calculate the diffusivity of acetone in air? $\rho_{acetone} = 790\ Kg/m^3$ m.wt = 58 and P_A° (acetone) = 21.95 KN/m^2.

Q2 Ammonia gas is diffusing at a constant rate through a layer of stagnant air 1 mm thick. Conditions are fixed so that the gas contains 50% by volume of ammonia at oute boundary as a stagnant layer. The ammonia diffusing to the other boundary is quickly absorbed and the concentration is negligible at that plane. The temp. is 295 K and pressure atmospheric, under these conditions the diffusivity of NH_3 in air is 0.18 cm^2/sec. Calculate the rate of diffusion of ammonia through the layer?
R = 8.314 $m^3.$Pa/Kmol.K

Q3 Calculate the diffusivity of ethanol (C_2H_5OH) in air at 20°C and atmospheric pressure in m^2/sec. Given that the atomic volumes

for Carbon = 0.014 $m^3/Kgmol$
for Oxygen = 0.0074 "
for H_2 = 0.0037 "
for air = 0.0299 "

Q4 Nickel Carbonyl (A) is produced by passing Carbon monoxide (B) at 323 K and 1 atm over a nickel slab. The following reaction takes place at the solid surface :-

$$Ni_{(s)} + 4\,CO_{(g)} \rightarrow Ni(CO)_4\ _{(g)}$$

The reaction is very rapid, so that the partial pressure of CO at the metal surface is essentially zero. The gases diffuse through a film 0.625 mm thick. At steady state, estimate the rate of production of Nickel carbonyl in mol/m².sec. The composition of the bulk gas phase is 50% mol Co.

$D_{AB} = 20.0$ mm²/sec.

Q5 By what percentage would the rate of mass transfer be increased or decreased by increasing the total pressure from [200 – 400] KN/m² in the following cases:-

1- The absorption of SO_2 from SO_2 air mixture containing 15 % by volume SO_2 using pure water as absorbing solvent.

2- The same as case (1), but the absorbing solvent contains amount of SO_2 which exerts 10 KN/m² partial pressure of SO_2.

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Q1 $Z_1 = 18\ mm = 0.018\ m$ $Z_2 = 0.0275\ m$

$T = 298\ K$ $P_T = 99.75\ KN/m^2$ $M.wt = 58$

$t = 15\ Ksec$ $\rho_A = 790\ kg/m^3$ $P_A^\circ = 21.95\ KN/m^2$

Find D_{AB} ?

$$\frac{-D_{AB}}{R.T} \cdot \frac{P_T}{P_{BM}} (P_{A2} - P_{A1}) \cdot \int dt = \frac{\rho_A}{M_A} \int dz \cdot z$$

$$\frac{-D_{AB}}{R.T} \cdot \frac{P_T}{P_{BM}} (P_{A2} - P_{A1}) \cdot t = \frac{\rho_A}{M_A} \cdot \left(\frac{Z_2^2}{2} - \frac{Z_1^2}{2} \right)$$

$P_{A1} = P_A^\circ = 21.95\ KN/m^2$ $P_{A2} = 0$

$P_{B1} = P_T - P_{A1}$

$= 99.75 - 21.95 = 77.8\ KN/m^2$ $P_{B2} = 99.75\ KN/m^2$

$$\therefore P_{BM} = \frac{P_{B2} - P_{B1}}{\ln \frac{P_{B2}}{P_{B1}}} = \frac{99.75 - 77.8}{\ln \frac{99.75}{77.8}} = 88.33\ KN/m^2$$

$$\therefore \frac{-D_{AB}}{(8.314)(298)} \cdot \frac{99.75}{88.33} (0 - 21.95)(15 \times 1000) = \frac{790}{58} \left(\frac{0.075^2 - 0.015^2}{2} \right)$$

$\therefore D_{AB} = 1.9 \times 10^{-5}\ m^2/sec$.

$$\frac{Kmol \cdot K \cdot \frac{m^2}{sec} \cdot \frac{KN}{m^2} \cdot \frac{KN}{m^2} \cdot sec}{m^3 \cdot KN \cdot K \cdot \frac{KN}{m^2}} = \frac{Kg}{m^3} \cdot \frac{Kmol}{kg} \cdot m^2$$

$$\frac{Kmol}{m} = \frac{Kmol}{m}$$

Q2 $Z = 1\ mm = 0.01\ cm$

$y_{A1} = 0.5 \qquad T = 295\ K \qquad P_T = 1\ atm$

$D_{AB} = 0.18\ cm^2/s. \qquad$ find N_A ?

For stagnant Layer :-

$$N_A = \frac{-D_{AB}}{R.T} \cdot \frac{1}{Z} \cdot \frac{P_T}{P_{BM}} \cdot (P_{A2} - P_{A1})$$

$$\frac{-0.18 \times 10^{-4}}{(8.314)(295)} \cdot \frac{1}{0.001} \cdot \frac{101.3}{P_{BM}} (P_{A2} - P_{A1})$$

$P_{A1} = y_{A1} * P_T = 0.5 \times 101.3 = 50.65\ KN/m^2$

$P_{A2} = y_{A2} * P_T = \text{zero}$ (quickly absorbed)

$$\left.\begin{array}{l} P_{B1} = 101.3 - 50.65 = 50.65\ KN/m^2 \\ P_{B2} = 101.3 - \text{zero} = 101.3\ KN/m^2 \end{array}\right\} P_{BM} = \frac{P_{B2} - P_{B1}}{\ln \frac{P_{B2}}{P_{B1}}}$$

$\therefore P_{BM} = 73.07\ KN/m^2$

$$\therefore -7.43 \times 10^{-4} \cdot \frac{(0 - 50.65)}{73.07} = N_A$$

$N_A = 5.153 \times 10^{-4}\ kmol/m^2.s$

Q3 C_2H_5OH find D_{AB} ?

$$D_{AB} = \frac{b \cdot T^{3/2}}{P_T (V_A^{1/3} + V_B^{1/3})^2} \cdot \left(\frac{1}{M_A} + \frac{1}{M_B}\right)^{0.5}$$

To find V_A, V_B :-

$V_A = \sum V_i$

$= V_{O_2} + V_H + V_C$

$V_C = 2 * 0.0148 = 0.0296$ $m^3/kmol$

$V_H = 6 * 0.0037 = 0.022$ "

$V_{O_2} = 0.0074 / 2 = 3.7 \times 10^{-3}$ " (atomic)

$\therefore V_A = 0.029 + 0.022 + 3.7 \times 10^{-3}$

$V_A = 0.055$ m / kgmol.

$$\therefore D_{AB} = \frac{(0.004)(293)}{101.3 \times (0.055^{1/3} + 0.0299^{1/3})^2} \cdot \left(\frac{1}{46} + \frac{1}{29}\right)^{0.5}$$

$$D_{AB} = \frac{1.172}{49.35} (0.237)$$

$D_{AB} = 5.63 \times 10^{-3}$ kmol/m^2.s

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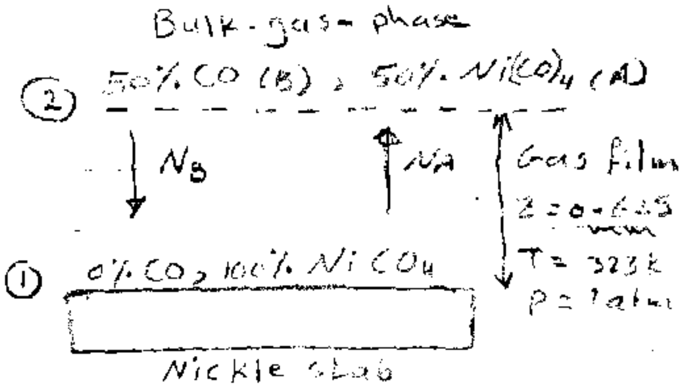
Q4



$$Ni\,(s) + 4\,CO\,(g) \longrightarrow Ni(CO)_4\,(g)$$
$$\qquad\quad (B) \qquad\qquad\quad (A)$$

From stoichiometry :-

$N_B = -4\,N_A \qquad N_T = N_A + N_B = N_A - 4N_A = -3N_A$

$$N_A = -D_{AB}\cdot C_T\,\frac{dy_A}{dz} + y_A\,(N_A + N_B)$$

$$\therefore\ N_A = \frac{N_A}{(N_A+N_B)}\cdot\frac{D_{AB}\cdot C_T}{Z}\,\ln\left[\frac{\left(\frac{N_A}{N_A+N_B}\right) - y_{A2}}{\left(\frac{N_A}{N_A+N_B}\right) - y_{A1}}\right]$$

$$\because\ \frac{N_A}{N_A+N_B} = -\frac{1}{3}$$

$$\therefore\ N_A = \frac{-1}{3}\,\frac{D_{AB}}{R\cdot T}\cdot\frac{\overset{C_T}{P_T}}{Z}\,\ln\left[\frac{-\frac{1}{3} - y_{A2}}{-\frac{1}{3} - y_{A1}}\right]$$

$y_{A1} = 1.0 \qquad y_{A2} = 0.5$

$$\therefore\ N_A = \frac{(2.0\times10^{-5}\ m^2/s)\,(1.013\times10^{5}\ Pa)}{3\times(8.13)(323)(0.625\times10^{-3})}\,\ln\left(\frac{1/3 + 1.0}{1/3 + 0.5}\right)$$

$N_A = 0.187\ mol/m^2.s$

seperating the variables :-

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

Q5

$\boxed{\text{Case (1)}}$ $P_T = 200\ kN/m^2$

$$N_A = -\frac{D_{AB}}{R.T.Z} \cdot \frac{P_T}{P_{BM}} (P_{A2} - P_{A1})$$

$P_{A1} = 0 \qquad P_{A2} = y_2 . P_T = 0.15 \times 200 = 30\ kN/m^2$

$$P_{BM} = \frac{P_{A1} - P_{A2}}{\ln \frac{P_T - P_{A2}}{P_T - P_{A1}}} = \frac{0 - 30}{\ln \frac{200 - 30}{200 - 0}} = 184.6\ kN/m^2$$

$$N_A = -32.5 \frac{D_{AB}}{R.T.} = -32.5\ A$$

when $P_T = 400$ then $P_{A2} = 0.15 * 400 = 60\ kN/m^2$

$P_{BM} = 369.2\ kN/m^2$

$$\frac{D_{200}}{D_{400}} = \frac{400}{200} = 2 \quad \therefore D_{AB})_{400} = \frac{1}{2} D_{AB})_{200}$$

$$\therefore N_A = -\frac{D_{AB}}{2R.T.Z} \cdot \frac{400}{369.2} \times 60 = -32.5 \frac{D_{AB}}{R.T.Z}$$

$\therefore$ No change in flux.

$\boxed{\text{Case (2)}}$ $P_T = 200\ kN/m^2$ $\quad P_{A1} = 10\ kN/m^2 \quad P_{A2} = 30\ kN/m^2$

$$\therefore P_{BM} = \frac{10 - 30}{\ln \frac{170}{190}} = 179.8\ kN/m^2$$

$$\therefore N_A = -\frac{D_{AB}}{R.T.Z} \frac{200}{179.8} (30 - 10) \Rightarrow = \boxed{-22.25 \frac{D_{AB}}{R.T.Z}}$$

increasing (P) to be (400 kN/m²).

$P_T = 400\ kN/m^2 \qquad P_{A1} = 10\ kN/m^2 \qquad P_{A2} = 60\ kN/m^2$

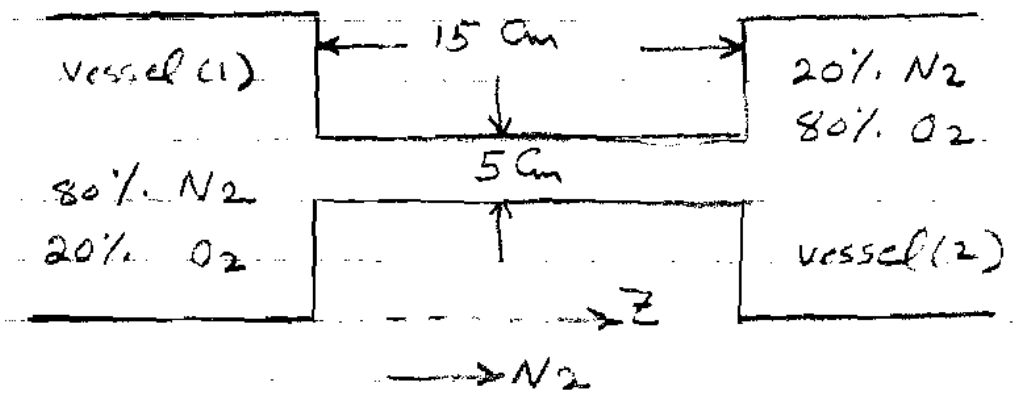
$P_{BM} = 364.4\ kN/m^2$

$$N_A = -\frac{D_{AB}}{RTZ} \cdot \frac{400}{364.4} (60 - 10) = -27.44 \frac{D_{AB}}{RTZ}$$

Q6 Two Large vessels are connected as in figure.
Vessel (1) Contains 80% N_2 (A) and 20% O_2 (B).
vessel (2) contains 20% N_2 and 80% O_2.
The temp. 20°C and total pressure (2 atm). Calculate:-

1. The flux and rate of transport of (N_2) from vessel (1) to vessel (2), and same for (O_2).
2. The partial pressure of (N_2) and its gradient in the tube (0.05 m) from vessel (1).
3. The net mass-flux (n_T).

Given that $D_{AB} = 1.01 \times 10^{-5}$ m²/sec.



For EMD :-

a) $N_A = \frac{-D_{AB}}{R \cdot T} \cdot \frac{1}{z_2 - z_1} (P_{A1} - P_{A2})$

$P_{A1} = y_{A1} \cdot P_T$
$= 0.8 * 2$
$= 1.6$ atm

$P_{A2} = y_{A2} * P_T$
$= 0.2 \times 2$
$= 0.4$ atm

$z_2 - z_1 = 0.15$ m

$\therefore N_A = 3.36 \times 10^{-6}$ kmol / m^2. s
$N_B = -N_A = -3.3 \times 10^{-6}$ Kmol/ m^2. s

$n_A = N_A * \text{Area} = 3.36 \times 10^{-6} * \frac{\pi}{4} (0.05)^2$
$n_A = 6.6 \times 10^{-9}$ Kmol/sec.

(b) $\frac{dP}{dz} = \frac{P_{A2} - P_{A1}}{z} = \frac{.4 - 1.6}{0.15} = -8$ atm / m

at point 0.05
$P_A = P_{A1} + \frac{dP}{dz} \cdot \Delta z$

$= 1.6 + (-8)\ 0.05$
$= 1.2$ atm

(c) $N_T = N_A \cdot Mwt_A + N_B\ Mwt_B$

$= (3.36 \times 10^{-6} \times 28) - (3.36 \times 10^{-6} * 32)$

$= -1.344 \times 10^{-5}$ km / m^2. s

multiply by (N_A)

$$N_A = \frac{N_A}{N_A + N_B} \cdot \frac{C \cdot D_{AB}}{Z} \ln\left[\frac{\frac{N_A}{N_A+N_B} - y_{A2}}{\frac{N_A}{N_A+N_B} - y_{A1}}\right]$$