Gas Diffusion Coefficient: Measurement & Prediction

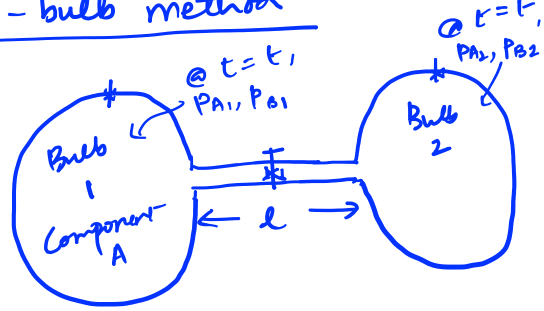
	Gas	Liquids
D_{AB}:	$0.1-1\ cm^2/s$	$(0.1-1)\times 10^{-5}\ cm^2/s$

Gases: (i) $D_{AB} \propto \dfrac{T^{1.5-1.75}}{P}$

(ii) Larger gas molecules diffuse slowly compared to the smaller molecules

Measurement of Gas Diffusion Coefficient

(i) Twin-bulb method:



Time $t=0$:

Bulb 1: $P_A = P$, $P_B = 0$

Bulb 2: $P_A = 0$, $P_B = P$

} Initial condition @ $t=0$ (Before the valve connecting the bulb is opened)

Assumptions

(i) Volume of bulbs 1 & 2 is large compared to the tube connecting them

(ii) Bulb 1 & 2 are "well mixed"

(iii) Temp. is constant

(iv) Total pressure remains same ($=P$).

(v) Steady state

- At $t>0$, we open the valve connecting the two bulbs. As a result, component A & B start to diffuse from bulb 1 & 2, respectively.
- Since the total pressure is same in both the bulbs, equimolar counter-diffusion can be assumed in the tube connecting them.
- Flux for equimolar counter-diffusion (@ steady state):

$$N_A = \frac{D_{AB}(P_{A_1} - P_{A_2})}{RTl}$$

- Cross section area of the tube = 'a'

$\Rightarrow$ Rate of mass transfer $= a N_A = -a N_B$ (cross section area of the tube)

Relating change in composition of bulbs 1 & 2 with the flux.

$$-V_1 \frac{dC_{A1}}{dt} = a N_A \Rightarrow \frac{-V_1}{RT}\frac{dP_{A1}}{dt} = a N_A \quad \text{—(i)}$$

V_1 = Volume of bulb 1

C_{A1} = Conc. of component A in bulb 1 @ $t = t$.

Similarly: $$V_2 \frac{dC_{A2}}{dt} = a N_A \Rightarrow \frac{V_2}{RT}\frac{dP_{A2}}{dt} = a N_A \quad \text{—(ii)}$$

(i) & (ii)

$$\Rightarrow -\frac{d(P_{A1} - P_{A2})}{dt} = aRT\left(\frac{1}{V_1} + \frac{1}{V_2}\right)N_A$$

$$\Rightarrow -\frac{d}{dt}(P_{A1} - P_{A2}) = \frac{a D_{AB}(P_{A1} - P_{A2})}{l}\left(\frac{1}{V_1} + \frac{1}{V_2}\right)$$

$$\Rightarrow \int \frac{-d(P_{A1} - P_{A2})}{(P_{A1} - P_{A2})} = \int_0^t \frac{a D_{AB}}{l}\left(\frac{1}{V_1} + \frac{1}{V_2}\right) dt$$

$t = 0$: $P_{A1} - P_{A2} = P - 0 = P$

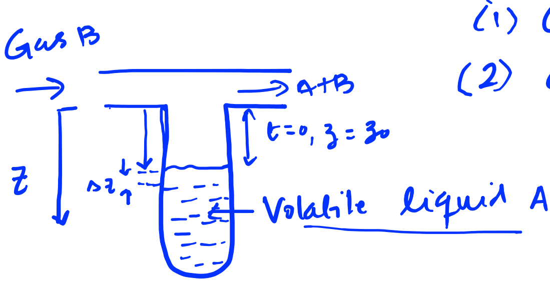
@ $t = t$: $P_{A1} - P_{A2} = P'_{A1} - P'_{A2}$

$$\Rightarrow \boxed{\ln\left(\frac{P}{P'_{A1} - P'_{A2}}\right) = \frac{a D_{AB}}{l}\left(\frac{1}{V_1} + \frac{1}{V_2}\right)t}$$

- P'_{A1} = partial pressure of A in bulb 1 after time t
- P'_{A2} = partial pressure of A in bulb 2 after time t.

$$\underline{D_{AB}} = \frac{l}{a\left(\frac{1}{V_1} + \frac{1}{V_2}\right)} \ln\left(\frac{P}{P'_{A1} - P'_{A2}}\right)$$

2) Stefan Tube:



This method can be applied for:
(1) Component A is volatile
(2) Component B is not soluble in component A

Measure the change in liquid level vs time.

$N_B = 0$ { This case is similar to : "Diffusion of A in non-diffusing B"

$$N_A = \frac{D_{AB} P}{RT z} \ln\left(\frac{P - P_{Az}}{P - P_{A0}}\right)$$

Lets assume the cross section of the tube = 'a'

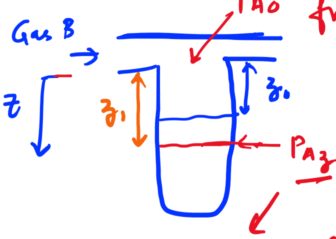
$$* \quad \frac{a \, dz \, \rho}{m_A} = a N_A dt$$

moles of component A evaporated in time 'dt'

$$\frac{\cancel{a} \rho_A dz}{m_A} = \cancel{a} \frac{D_{AB} P}{RT z} \ln\left(\frac{P - P_{Az}}{P - P_{A0}}\right) dt$$

$$\Rightarrow \frac{\rho_A}{m_A} \int_{z_0}^{z_1} z \, dz = \frac{D_{AB} P}{RT} \ln\left(\frac{P - P_{Az}}{P - P_{A0}}\right) \int_0^t dt$$

$$\Rightarrow D_{AB} = \frac{\rho_A RT (z_1^2 - z_0^2)}{2 P \ln\left(\frac{P - P_{Az}}{P - P_{A0}}\right) m_A t}$$



P_{A0} = Partial Pressure of A 'far' from the liquid

P_{Az} = Partial pressure of component A at liquid surface = Vapor pressure of the liquid at time T.

Diffusion in liquids :

$$N_A = x_A (N_A + N_B) - D_{AB} \left(\frac{\rho}{m}\right)_{av} \frac{dx_A}{dz}$$

$(\rho/m)_{av}$ = Average molar concentration