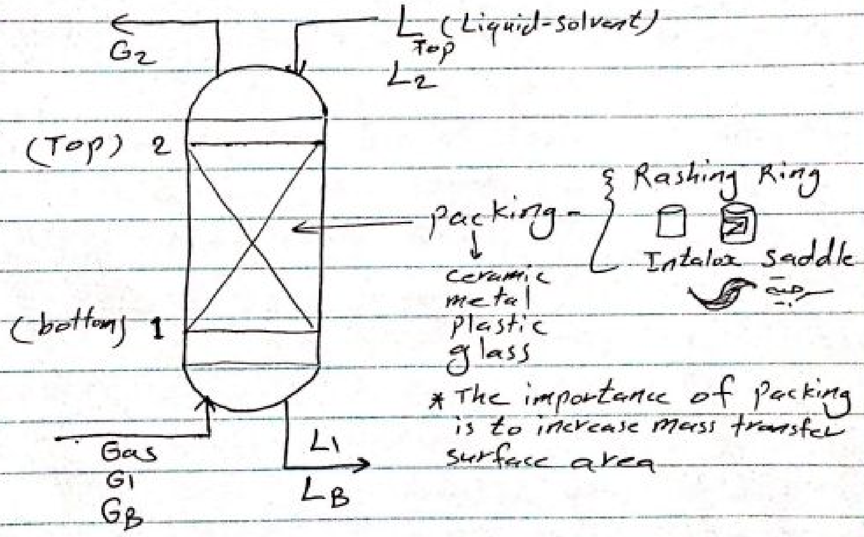
Absorption ①

Absorption: the removal or recovered of one or more selected components from a mixture of gases in a suitable liquid (solvent) for example:

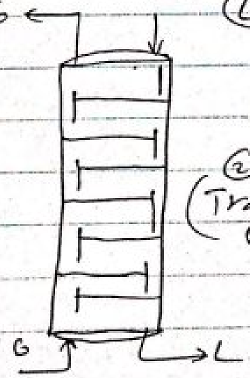
1- Acetone can be recovered from an acetone-air mixture by passing the gas stream into water.
2- Ammonia may be removed from an ammonia-air mixture by absorption in water.



* The importance of packing is to increase mass transfer surface area

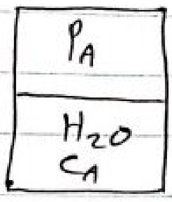
L: Liquid , G: gas

* (① packed Tower)



② (Tray Tower)

* When two phase brought into contact they tend to reach equilibrium.
* Water in contact with air, evaporates until the air is saturated with water vapor



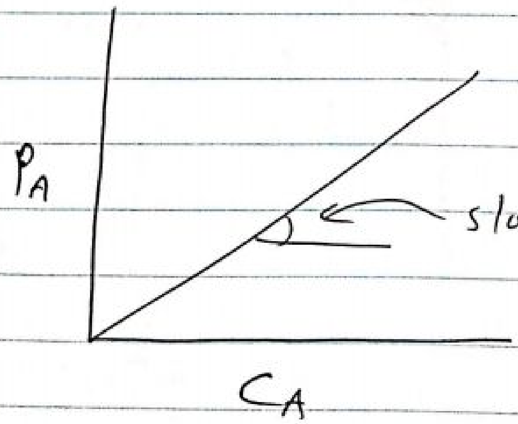
* The equilibrium relationship is given by Henry's law

$$\boxed{P_A = H\, C_A}$$

where: P_A = Partial pressure of the component A in the gas phase

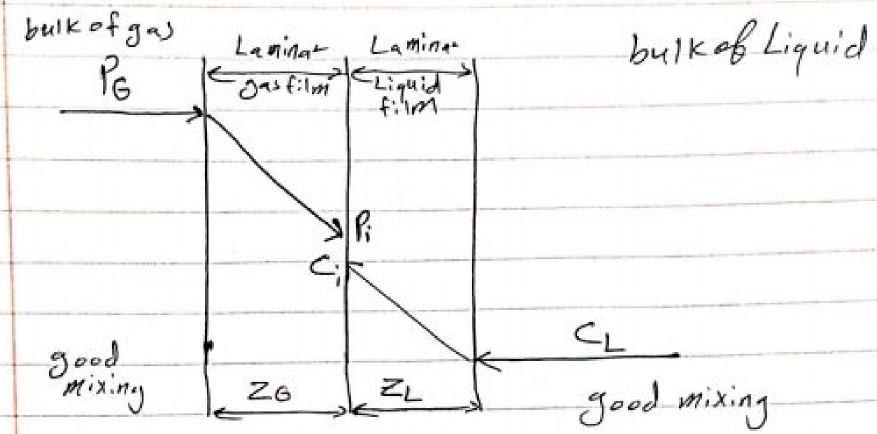
C_A = The concentration of the component in the liquid

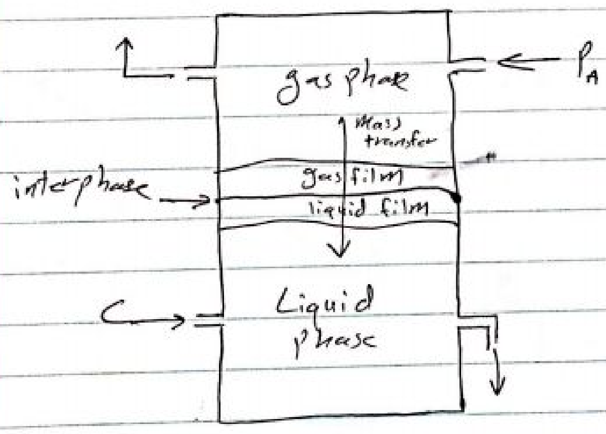
H = Henry's constant



$$\boxed{P_A = H\, C_A}$$

Two film Theory





At the gas film

$$N_A = \frac{-D_{AB}}{RT}\frac{dP_A}{dZ} \quad \text{—— (1)}$$

$$N_A = \underbrace{\frac{-D_{AB}}{RT\,Z_G}}_{K_G}\, dP_A$$

$$N_A = K_G(P_G - P_i) \quad \text{—— (2)}$$

At the liquid film

$$N_A = \underbrace{\frac{-D_{AB}}{Z_L}}_{K_L}\,(C_i - C_L) \quad (3) \Rightarrow N_A = K_L(C_i - C_L) \quad \text{—— (4)}$$

where (K_G) = Gas film transfer coefficient $= \frac{-D_{AB}}{RTZ_G}$ $(\frac{s}{m})$

(K_L) = liquid film transfer coefficient $= \frac{-D_{AB}}{Z_L}$ $(\frac{m}{s})$

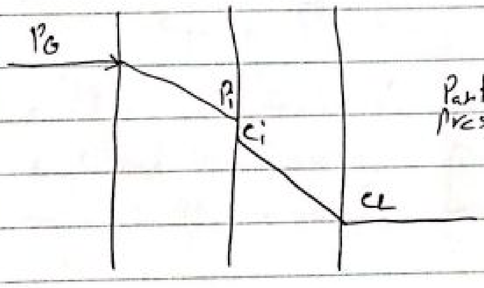
* In absorption, the feed gas is introduced at the bottom of the column and the solvent (Liquid) is feed at the top. The liquid absorbed gas and leaves from the bottom while the remains gas leaves from the top.

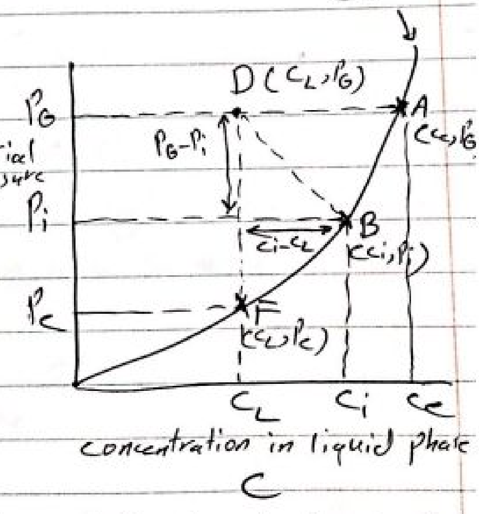
The general equation for mass transfer is:

$$N_A = K_G(P_G - P_i) = K_L(C_i - C_L) \quad (5)$$

or

$$\frac{K_G}{K_L} = \frac{C_i - C_L}{P_G^{\circ} - P_i} \quad (6)$$





Point (D) (C_L, P_G) = represent condition in the bulk of the gas & liquid.

(P_G) = Partial pressure of A in the main bulk of gas stream

(C_L) = average concentration of A in the main bulk of liquid stream.

Point A (C_e, P_G) = concentration C_e in the liquid in equilibrium with P_G in the gas.

point B (C_i, P_i) = the concentration in the liquid in equilibrium with P_i in the gas and gives conditions at the interphase.

Point F (C_L, P_e) = partial pressure P_e in the gas phase in equilibrium with C_L in the liquid

$D_E = (P_G - P_i)$ = driving force causing transfer in the gas phase

$BE = (C_i - C_L)$ = driving force causing transfer in the liquid phase.

then $$\frac{P_G - P_i}{C_i - C_L} = \frac{K_L}{K_G} \quad \text{——} (6)$$

and the concentration at the interphase (Point B) are found by drawing a line through D of slope $\frac{K_L}{K_G}$ to cut the equilibrium curve in B.

$$N_A = K_G (P_G - P_i) = K_L (C_i - C_L) \quad \text{——} (6)$$

overall coefficient

$$N_A = K_{OG} (P_G - P_e) = K_{OL} (C_e - C_L) \quad \text{——} (7)$$

where:

K_{OG} = the overall gas phase coefficient (s/m)

K_{OL} = the overall liquid phase coefficient (m/s)

Relation between film & overall coefficient:

$$N_A = K_G(P_G - P_i) = K_L(C_i - C_L) = K_{OG}(P_G - P_e) = K_{OL}(C_e - C$$

$$\frac{1}{K_{OG}} = \frac{1}{K_G}\left[\frac{P_G - P_e}{P_G - P_i}\right] = \frac{1}{K_G} = \left[\frac{P_G - P_i + P_i - P_e}{P_G - P_i}\right]$$

$$\frac{1}{K_{OG}} = \frac{1}{K_G}\left[\frac{\cancel{P_G - P_i}}{\cancel{P_G - P_i}}\right] + \frac{1}{K_G}\left[\frac{P_i - P_e}{P_G - P_i}\right]$$

$$\frac{1}{K_{OG}} = \frac{1}{K_G} + \frac{1}{K_G}\left[\frac{P_i - P_e}{P_G - P_i}\right]$$

but $\frac{1}{K_G} = \frac{1}{K_L}\left[\frac{P_G - P_i}{C_i - C_L}\right]$ from eq. (5)

$$\frac{1}{K_{OG}} = \frac{1}{K_G} + \frac{1}{K_L}\left[\frac{\cancel{P_G - P_i}}{C_i - C_L}\right]\left[\frac{P_i - P_e}{\cancel{P_G - P_i}}\right]$$

$$\frac{1}{K_{OG}} = \frac{1}{K_G} + \frac{1}{K_L}\left[\frac{P_i - P_e}{C_i - C_L}\right]$$

But $\frac{P_i - P_e}{C_i - C_L}$ is the slope of the equilibri[um] curv[e]

$$H = \frac{dP}{dC} \simeq \frac{P_i - P_e}{C_i - C_L}$$

$$\boxed{\frac{1}{K_{OG}} = \frac{1}{K_G} + \frac{H}{K_L}} \quad \text{——— (8)}$$

Similarly $\boxed{\frac{1}{K_{OL}} = \frac{1}{K_L} + \frac{1}{(H)\,K_G}}$

Rate of absorption in term of mole fraction:-

$$N_A = K_G (y - y_i) = K_{OG} (y - y_e) \text{ —— } (10)$$

$$N_A = K_L (x_i - x) = K_{OL} (x_e - x) \text{ —— } (11)$$

where:

x = mole fraction of soluble component A in the liqui

y = mole fraction of the soluble component A in the gasph

(K_G, K_L, K_{OG}, K_{OL}) are transfer coefficient defined in term of mol fraction.

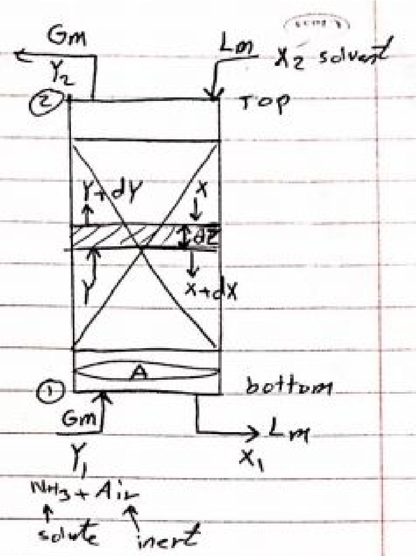
IF (m) is the slope of the equilibrium cu

$$m = \frac{y_i - y_e}{x_i - x_e}$$

$$\boxed{\frac{1}{K_{OG}} = \frac{1}{K_G} + \frac{m}{K_L}} \text{ —— } (12)$$

(1)

Packed Tower



packed tower is used for absorption because it has large interfacial area of contact (large mass transfer area).

consider:

A: cross section area of column m^2

dZ: hight of packing m

The actual area of interface between the two fluid $= a$

$=$ interfacial area per unit volume of column $\frac{m^2}{m^3}$

$=$ surface area of interface per volume of column,

$N_A = K_G (P_G - P_i)$

surface area of packing $= \underset{\substack{\uparrow \\ c.s.A \\ \downarrow \\ m^2}}{A} \; \underset{\substack{\uparrow \\ length \\ \downarrow \\ m}}{dZ} \; \underset{\frac{m^2}{m^3}}{a}$

$= m^2$

$N_A \, A dZ a = K_G a (P_G - P_i) A \, dZ$ — (13)

$\frac{kmol}{m^2 \cdot s} \times \cancel{m^2}$ $= K_L a (C_i - C_L) A \, dZ$ — (14)

$\frac{kmol}{s}$ = gas diffusion