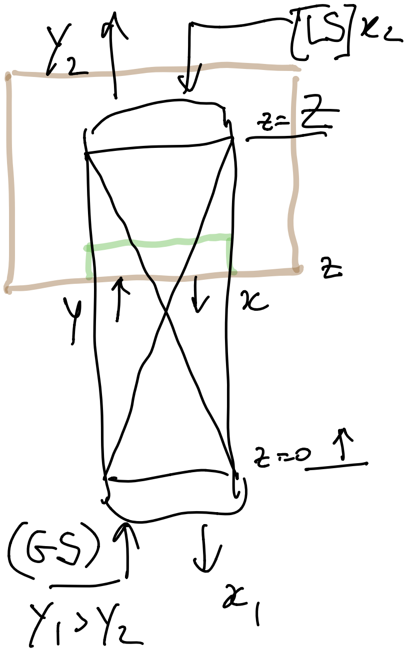
$$\boxed{N = K_G\,(y - y^*) = k_G\,(y - mx)}$$

2-film theory $\left[\frac{mol}{m^2 s}\right]$



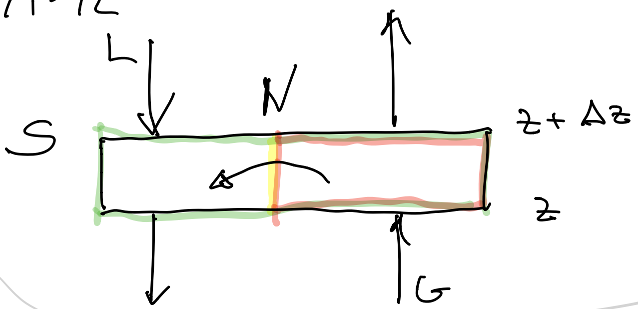
① $\boxed{G y + L x_2 = G y_2 + L x}$

② $\boxed{y^* = mx}$

③ mass transfer

steady state

(superficial fluxes)
G, L, N $\left[\frac{mol}{m^2 s}\right]$



S $[m^2]$

specific surface

③ $$\boxed{G\cancel{S}\,y(z) = G\cancel{S}\,y(z+\Delta z) + N\,a\,\underbrace{\cancel{S}\Delta z}_{\text{volume}}}$$

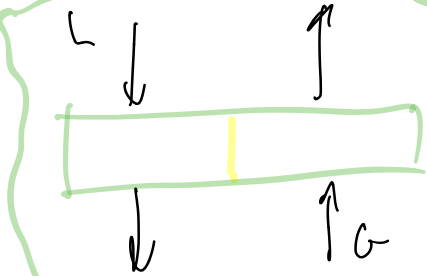
$a \left[\frac{m^2}{m^3}\right]$ $\frac{\text{interface area}}{\text{volume of packing}}$

$$\left\{ -aK_G\,(y - y^*) = G\,\frac{y(z+\Delta z) - y(z)}{\Delta z} \right\} \xrightarrow[\Delta z \to 0]{}$$

$$\boxed{-aK_G\,(y-y^*) = G\,\frac{dy}{dz}}$$

$$dz = -\frac{G}{aK_G}\,\frac{dy}{y-y^*}$$

$$③\ \int_0^Z dz = Z = -\frac{G}{aK_G}\int_{y_1}^{y_2}\frac{dy}{y-y^*} = \overset{\text{HTU}}{\boxed{\frac{G}{aK_G}}}\ \overbrace{\int_{y_2}^{y_1}\frac{dy}{y-y^*}}^{\text{NTU}} =$$



$$G\,y(z) + L\,x(z+\Delta z) = G\,y(z+\Delta z) + L\,x(z)$$

$$L\,\frac{dx}{dz} = G\,\frac{dy}{dz}$$

$$\overset{②}{=}\ \frac{G}{aK_G}\int_{y_2}^{y_1}\frac{dy}{y-mx} \overset{①}{=} \frac{G}{aK_G}\int_{y_2}^{y_1}\frac{A\,dy}{(A-1)y+y_2-Ay_2^*} = \left(\begin{array}{l} A = \frac{L}{Gm} \\ y_2^* = m x_2 \end{array}\right)$$

$$= \underbrace{\boxed{\frac{G}{aK_G}}}_{\text{HTU}}\ \underbrace{\frac{A}{A-1}\ \boxed{\ln\frac{1-\frac{\alpha}{A}}{1-\alpha}}}_{\text{NTU}} = Z$$

$$\boxed{\alpha = \frac{y_1-y_2}{y_1-y_2^*}}$$

packed columns

tray columns : $N = \frac{1}{\ln A}\ \boxed{\ln\frac{1-\alpha/A}{1-\alpha}}$

$\left(\frac{L}{G}\right)_{min} \Leftrightarrow A_{min}$?

$Z \xrightarrow[A\to\alpha_{min}]{} \infty$

specs

$$\alpha_{min} = \frac{y_1-y_2^{max}}{y_1-y_2^*}$$

same for tray and packed columns!!

HETP ← manufacturers

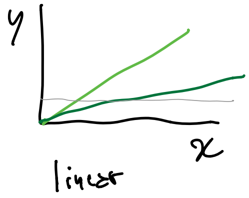
height equivalent theoretical plate

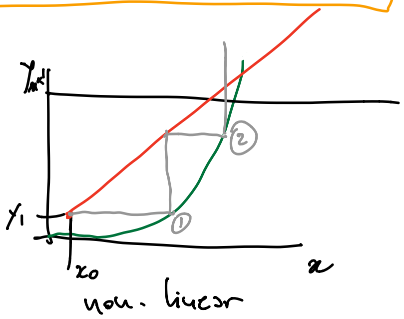
$Z = HETP \times \textcircled{N}$

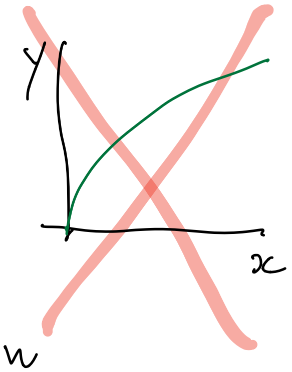
$$\frac{NTU}{m} = \frac{A \ln A}{A-1}$$

physical vs. chemical absorption

$y = mx$







Examples: CO_2 in an aqueous amine solution
H_2S in " " "

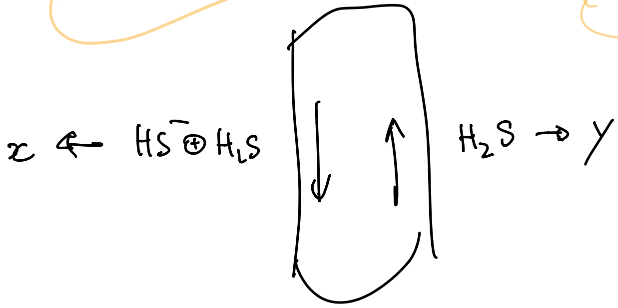
$$CO_2 \xrightarrow[H_2O]{in} \underset{\text{carbonic acid}}{H_2CO_3} \xrightarrow{\nearrow H^+} \underset{\text{bicarbonate}}{HCO_3^-} \xrightarrow{\nearrow H^+} \underset{\text{carbonate}}{CO_3^=}$$

$$H_2S + H_2O \overset{K_S}{\rightleftarrows} HS^- + H_3O^+ \qquad K_S \simeq 0.7 \cdot 10^{-7}$$

$$(HOCH_2 - CH_2)_2NH + H_2O \overset{K_E}{\rightleftarrows} (HOCH_2-CH_2)_2NH_2^+ + OH^- \qquad K_E \simeq 2 \cdot 10^{-5}$$

$$2H_2O \overset{K_W}{\rightleftarrows} H_3O^+ + OH^- \qquad K_W = 10^{-14}$$

di-ethanol amine



M.B. x, y

Eq. $y = m x_A$

$x_A < x$

$x_A = f(x)$

③

$A = [H_2S]$ $S = [HS^-]$ $E = [E_2NH]$ $P = [E_2NH_2^+]$ $H = [H_3O^+]$ $W = [OH^-]$

B = total sulfur D = total amine   DATA

(i) $K_s = \frac{SH}{A}$ $\simeq 10^{-7}$

(ii) $K_E = \frac{PW}{E}$ $\simeq 10^{-5}$

(iii) $K_w = HW$ $\simeq 10^{-14}$

(iv) $B = A + S$

(v) $D = E + P$

(vi) $P + H = S + W$

electroneutrality

$$A = \frac{H/K_s}{1 + H/K_s} B \qquad S = B - A = \frac{1}{1 + H/K_s} B$$

$$P = \frac{\frac{K_E}{K_w} H}{1 + \frac{K_E}{K_w} H} D \qquad E = D - P = \frac{1}{1 + \frac{K_E}{K_w} H} D$$

$$\boxed{H + \frac{\frac{K_E}{K_w} H}{1 + \frac{K_E}{K_w} H} = \frac{1}{1 + \frac{H}{K_s}} B + \frac{K_w}{H}}$$

pH ≃ 10 !! $\Leftrightarrow$ $H = 10^{-10}$

SIMPLIFICATION !!

$1 + \frac{H}{K_s} \simeq 1 \Rightarrow S \simeq B \Rightarrow A \simeq \frac{H}{K_s} B \rightsquigarrow$ all H_2S is HS^-

$\frac{H}{K_s} \simeq 0.001$

$\frac{K_E}{K_w} H \simeq 0.1 \Rightarrow 1 + \frac{K_E}{K_w} H \simeq 1 \Rightarrow E \simeq D \Rightarrow P = \frac{K_E}{K_w} H D$

$$\boxed{P \simeq \left(\frac{K_E}{K_w} D + 1\right) H = \frac{K_w}{H} + B \simeq B} \Rightarrow \boxed{P = B}$$

$$W = K_E \frac{D - P}{P} = K_E \frac{D - B}{B} = [OH^-]$$

$$H = \frac{K_w}{W} = \frac{K_w}{K_E} \frac{B}{D - B} = [H_3O^+]$$

$$A = \frac{K_w}{K_E K_s} \frac{B^2}{D - B} = [H_2S]$$

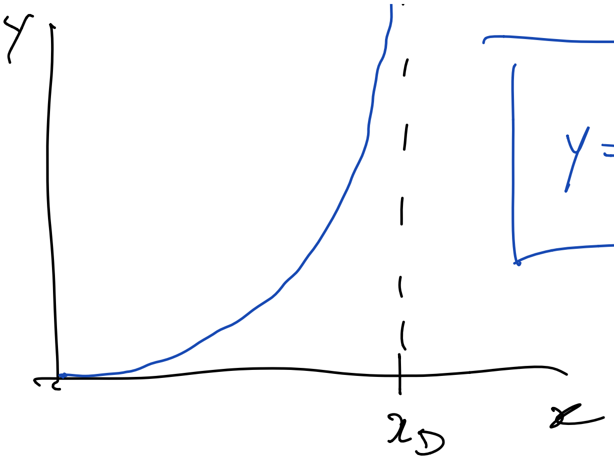
solution C_{tot} ?

$$x_A = \frac{A}{C_{tot}} \qquad \boxed{x_D = \frac{D}{C_{tot}}} \qquad \boxed{x = \frac{B}{C_{tot}}}$$

$$x_A = \frac{A}{C_{tot}} = \frac{K_w}{K_E K_s} \frac{B^2/C_{tot}^2}{(D - B)/C_{tot}} = \frac{K_w}{K_E K_s} \frac{x^2}{x_D - x}$$

$$y = m x_A = m' \frac{x^2}{x_D - x}$$

$$m' = m \frac{K_w}{K_E K_3}$$



$$\boxed{y = m' \frac{x^2}{x_D - x}}$$