Assignment 5

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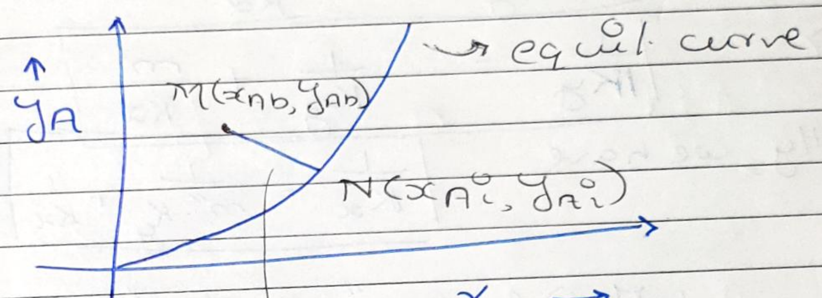
18CH30031

Section 1

Q.1.1) Lewis & Whitman realized that two stagnant fluid films exist on either side of the interface & mass transfer occurs through these films by purely molecular diffusion. Beyond these films, the concentration in a phase is equal to the bulk concentration

Q.1.2)



$$\text{slope} = \frac{-k_x}{k_y}$$

Q.1.3) Overall mass transfer coeff. is a combination of individual coeffs.

Individual concentrations are not directly measurable quantities & cannot be specified as such in a practical problem. So, it is necessary to develop a method of calculation of mass transfer or or molar flux using bulk concentration.

→ Two overall coeffs. are defined.

Gas phase : K_y

liquid phase : K_x

Q.1.4. $N_A = k_y(y_{Ab} - y_{Ai}) = k_x(x_{Ai} - x_{Ab})$

$= K_y(y_{Ab} - y_{Ab}^*)$

$\therefore y_{Ab} - y_{Ab}^* = (y_{Ab} - y_{Ai}) + (y_{Ai} - y_{Ab}^*)$

$= (y_{Ab} - y_{Ai}) + m'(x_{Ai} - x_{Ab})$

$m' = \dfrac{y_{Ai} - y_{Ab}^*}{x_{Ai} - x_{Ab}^*}$

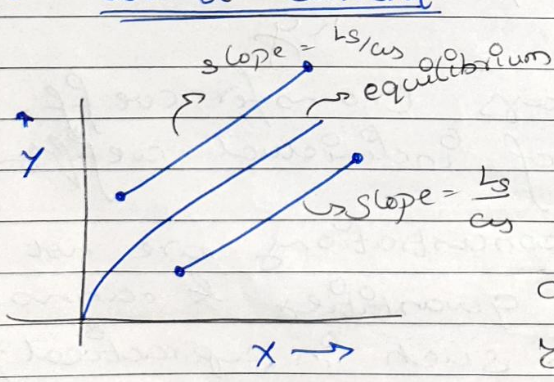
$\Rightarrow \dfrac{N_A}{K_y} = \dfrac{N_A}{k_y} + \dfrac{m' N_A}{k_x}$

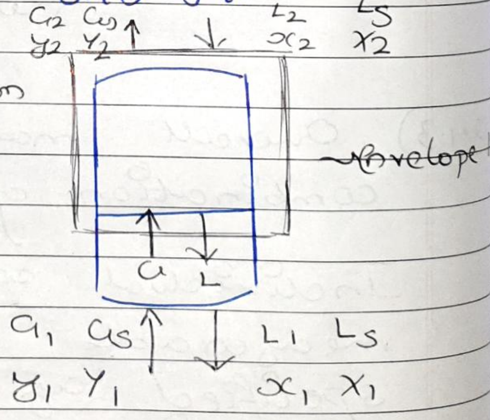
$\Rightarrow \boxed{\dfrac{1}{K_y} = \dfrac{1}{k_y} + \dfrac{m'}{k_x}}$

|||ly, we have $\boxed{\dfrac{1}{K_x} = \dfrac{1}{m'' \cdot k_y} + \dfrac{1}{k_x}}$

where $m'' = \dfrac{x_{Ab}^* - x_{Ai}}{y_{Ab} - y_{Ai}}$

Q.1.5 (a) <u>Counter current</u>





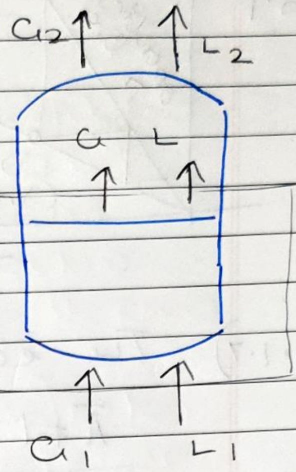
rate of input $= L_s X_2 + G_s \cdot Y$
rate of output $= L_s X + G_s \cdot Y_2$

$$L_s \cdot X_2 + G_s \cdot Y = L_s \cdot X + G_s Y_2$$

$$\Rightarrow \boxed{L_s (X - X_2) = G_s (Y - Y_2)}$$

operating line.

(b) Co-current



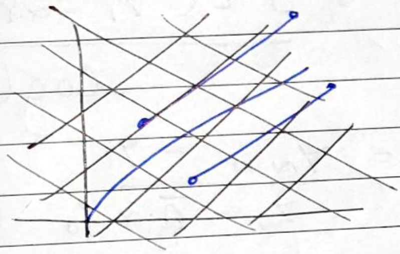
Output = input

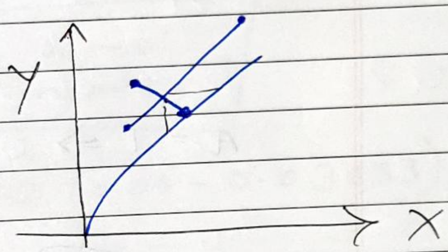
$$\Rightarrow G_s \cdot Y + L_s \cdot X = G_s \cdot Y_1 + L_s \cdot X_1$$

$$\Rightarrow \boxed{G_s (Y_1 - Y) = L_s (X - X_1)}$$

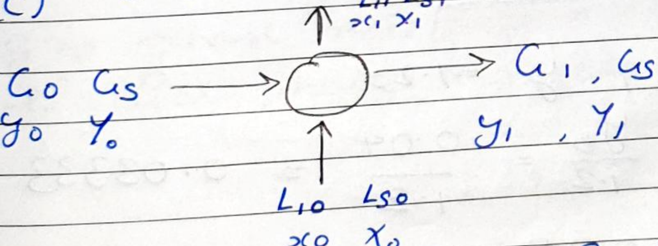
operating line

slope $= \frac{-L_s}{G_s}$





(c) cross current



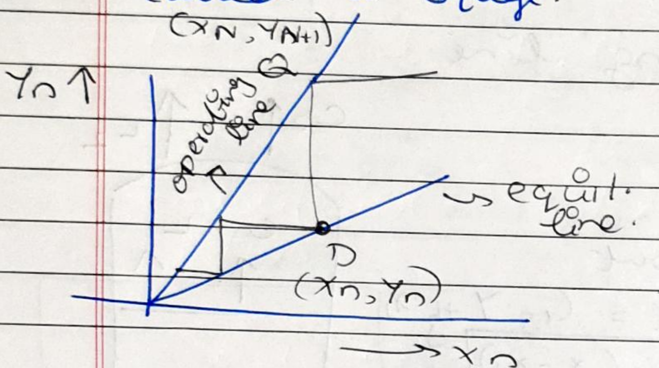
$$G_s \cdot Y_0 + L_{s1} \cdot X_s = G_s \cdot Y_1 + L_{s1} \cdot X_1$$

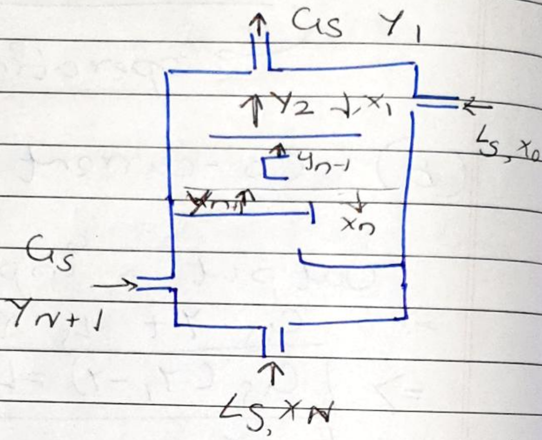
$$\boxed{G_s (Y_0 - Y_1) = L_{s1} (X_1 - X_0)}$$

slope $= -L_{s1}/G_s$

Q.1.6) Stage

Any device or combination of devices in which two immiscible phases are brought into intimate contact in order to achieve mass transfer from one phase to other is called a stage.





Q.1.7) The eqn is known as Kremser eqn

$\bar{A} \neq 1 \Rightarrow \quad N = \dfrac{\log\left[\left(\dfrac{Y_{N+1} - \alpha X_0}{Y_1 - \alpha X_0}\right)\left(1 - \dfrac{1}{\bar{A}}\right) + \dfrac{1}{\bar{A}}\right]}{\log(\bar{A})}$

$\bar{A} = 1 \Rightarrow \quad N = \dfrac{Y_{N+1} - Y_1}{Y_1 - \bar{A}\cdot\alpha X_0}$

Section 2

Q.2.1) $y_b = 0.04, \quad y = 1.2x$

$x_b^* = \dfrac{y_b}{1.2} = \dfrac{0.04}{1.2} = 0.03333$

$x_b = 0.025$

$y_b - y_b^* = 0.04 - 1.2x_b = 0.01$

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$x_b^* - x_b = 0.0333 - 0.025 = 0.0083.$

(a) $k_y = 7.2 \frac{kmol}{h \cdot m^2 \Delta y}$ $\quad k_x = 4.6 \frac{kmol}{h \cdot m^2 \cdot \Delta x}$

$N_A = k_y (y_b - y_i) = k_x (x_i - x_b)$

(1) $7.2 \times (0.04 - y_i) = 4.6 (x_i - 0.025)$

(2) $y_i = 1.2 x_i$

$\Rightarrow \boxed{x_i = 0.03044}$

$\boxed{y_i = 0.03653}$

(b) $\frac{1}{K_y} = \frac{1}{k_y} + \frac{m}{k_x}$ $\quad m = 1.2$

$\therefore \boxed{K_y = 2.501 \frac{kmol}{h \cdot m^2 \cdot \Delta y}}$

$\frac{1}{K_x} = \frac{1}{m k_y} + \frac{1}{k_x}$

$\Rightarrow \boxed{K_x = 3.012 \frac{kmol}{h \cdot m^2 \Delta x}}$

(c) $N_A = k_y (y_b - y_i) = 7.2 (0.04 - 0.03653)$

$= 0.025 \frac{kmol}{h \cdot m^2}$

gas phase resistance $= \frac{1}{K_y} \cdot \frac{1}{k_y} = \boxed{0.347}$

liquid phase resistance

$= \frac{1}{K_x} \cdot \frac{1}{K_x} = \boxed{0.653}$

Q.2.2 $\quad k_y = 60 \frac{kmol}{h \cdot m^2 \Delta y}$ $\quad k_x = 35 \frac{kmol}{h \cdot m^2 \cdot \Delta x}$

$y = 0.8 x$

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$\therefore m = 0.8$

$\therefore \frac{1}{K_y} = \frac{1}{k_y} + \frac{m}{k_x}$

$\therefore \boxed{K_y = 25.3 \ \frac{kmol}{h \cdot m^2 \cdot \Delta y}}$

theoretical flux $= K_y (y_b - y_b^*) = 25.3\,(0.08 - 0.8 \times 0.03)$

$= 1.417 \ \frac{kmol}{h \cdot m^2}$

additional flux $= 1.2 \ \frac{kmol}{h \cdot m^2}$

$\therefore$ actual overall flux $= \frac{1.2}{0.08 - 0.8 \times 0.03} = 21.43 \ \frac{kmol}{h \cdot m^2 \Delta y}$

interfacial resistance $= \frac{1}{K_{y\,true}} - \frac{1}{K_y} = \boxed{0.00714 \ \frac{h \cdot m^2 \cdot \Delta y}{kmol}}$

Q.23. $P = 1.45$ bar , $T = 303K$

$P_b = 0.065 \times 1.45 = 0.09425$ bar

$k_y = \frac{P}{RT} \cdot k_c = \frac{1.45 \times 90.3}{0.08317 \times 303} = 5.196 \ \frac{kmol}{h \cdot m^2 \cdot \Delta y}$

$x_i^o = 0.00201$

$P_i = 3.318 \times 10^4 \times 0.00201 = 66.7$ mmHg

$= 0.0889$ bar

$y_i^o = \frac{P_i}{P} = 0.0613$

$\therefore y = \frac{p}{P} = \frac{3.318 \times 10^4 \times x^*}{1.45 \times 760/1.013} = 30.5x^*$

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(a) $N_A = k_y(y_b - y_i) = 5.196 \times (0.065 - 0.0613)$
$= 0.01922 \ \frac{kmol}{h.m^2}$

(b) gas phase resistance $= \frac{1}{k_y}$
$= 0.1924 = 13.6\%$ of total.

$\therefore$ total mass transfer resistance $= \frac{0.1924}{0.136} = 1.415$

liquid phase resistance $= \frac{1.415}{1-0.136} = 1.2223 = \frac{m}{K_x}$.

$m = 30.5 \Rightarrow \boxed{K_x = 24.95}$

$N_A = 0.01922 \cdot (x_i - x_b) \cdot K_x$
$\boxed{x_b = 0.00124}$

(c) $\frac{1}{K_x} = \frac{1}{k_x} + \frac{1}{m k_y}$
$\Rightarrow K_x = 21.55 \ \frac{kmol}{h.m^2.\Delta x}$.

(d) $\Delta y = y_b - y_i = 0.065 - 0.0613 = \boxed{0.0037}$

Q.2.4] Gas flow rate
14.2 % SO_2, 85.8 % air.
= 1.5 lit per min at 20°C & 1 atm

$Y_{in} = \frac{0.142}{1-0.142} = 0.165$

$Y_{out} = \frac{0.11}{1-0.11} = 0.1236$

air flow rate $= 0.0535 \ \frac{\text{g mol}}{\text{min}}$

rate of absorption $= 0.0535 \times (0.165 - 0.1236)$

$= 0.002215 \ \frac{\text{g mol}}{\text{min}}$

water flow rate $= \frac{27}{18} = 1.5 \ \frac{\text{g mol}}{\text{min}}$

SO_2 effluent $= \frac{0.002215}{1.5} = 1.476 \times 10^{-3}$

(a) $x_b = 1.476 \times 10^{-3}$, $y_b = 0.11$

$y = mx$

$\Rightarrow m = 31.3$

$\therefore y_b^* = m x_b = 31.3 \times 1.476 \times 10^{-3}$

$\therefore \boxed{y_b^* = 0.0462}$

rate of absorption $= 0.002215 \ \frac{\text{g mol}}{\text{min}}$

$= 1.329 \times 10^{-4} \ \frac{\text{kmol}}{\text{h}}$

Area of mass transfer $= 31.5 \, m^2$

$1.329 \times 10^{-4} = k_y \times (0.00315)(y_b - y_b^*)$

$k_y = 0.6613 \ \frac{\text{kmol}}{h \cdot m^2 \cdot \Delta y}$

$$\frac{1}{K_y} = \frac{1}{k_y} + \frac{m}{k_x}$$

$\therefore k_x = 25.06 \ \frac{\text{kmol}}{h \cdot m^2 \, \Delta x}$

$k_L = \frac{k_x}{C}$, $C = 55.5 \ \frac{\text{kmol}}{m^3}$

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$\therefore K_L = 0.4515 \ \frac{m}{h}$

$S = \frac{K_L^2}{D_{AB}} = 10.4$ per second.

(b) $0.002883 = \frac{Q \cdot x_b}{18}$

$0.002883 \times 10^{3} \times 60 = k_y (0.00315)(y_b - y_b^*)$

$y_b = 0.1$

$x_b = \frac{y_b^*}{m} = 5.42 \times 10^{-4}$

$\boxed{Q = 95.8 \ \frac{ml}{min}}$

Q.25 $P = 52$ mm Hg

liquid conc. $= \frac{0.7g \ SO_2}{100 \ g}$

$P = 4.5$ bar

$P = \frac{4.5 \times 760}{1.013}$ mmHg

$y = \frac{52 \times 1.013}{4.5 \times 760} = 0.0154$

$x = \frac{0.7/64}{0.7/64 + 100/18} = 0.001965$

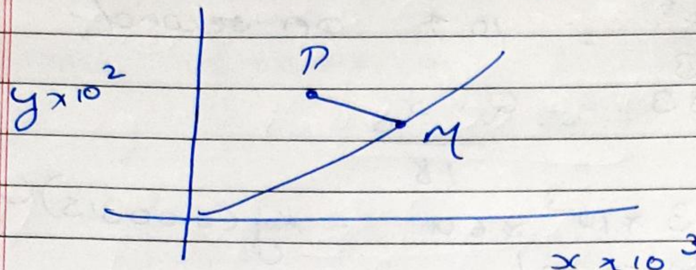
x	0.0562	0.1403	0.28	0.422	0.564	0.842
$(\times 10^{+3})$	1.403	1.965	2.79			

(a) $x_b = 0.0014$ $y_b = 0.02$

$P(0.0014, 0.02)$

Slope of PM $= \frac{-k_x}{k_y} = \frac{-80}{15} = -5.33$

$x_i^o = 0.00206 \quad , \quad y_i^o = 0.0164 \rightarrow M.$



(b) $\frac{1}{K_y} = \frac{1}{k_y} + \frac{m}{k_x} = 0.1373$

$K_y = 7.28 \ \frac{\text{Kmol}}{\text{h m}^2 \Delta y}$

$\frac{1}{K_x} = \frac{1}{m k_y} + \frac{1}{k_x} = 0.0243$

$\therefore K_x = 41.1 \ \frac{\text{Kmol}}{\text{m}^2 \text{h} \Delta x}$

$\therefore \boxed{N_A = K_y (y_b - y_i) = 0.054}$

(c) $K_y = \frac{k_y'}{(1-y)_m} \quad , \quad K_x = \frac{k_x}{(1-x)_m}$

$\therefore (1-y)_m = (1-x)_m = 1$

$\therefore \boxed{k_x' = k_x \quad , \quad k_y' = k_y}$

Q.2.6) feed conc = 12 % feed ration

C_s = a solute free basis

$C_s = 6000 \times (1 - 0.12)$

$\boxed{C_s = 5280 \text{ Kg}}$

Mass of solute entering $= 6000 \times 0.12 = 720 \text{ kg}$

fraction of solute removed $= 0.99$

$$Y_{N+1} = \frac{0.12}{0.88} = 0.136$$

$$Y_1 = 0.00136$$

$$x_0 = 0, \quad L_S = 7085 \text{ kg/h}$$

$$\frac{G_S}{Y_{N+1} - Y_1} = \frac{L_S}{x_N - x_0}$$

$$\boxed{x_1 = 0.0915}$$

Operating line

$$G_S (Y_{N+1} - Y_1) = L_S (x_N - x_0)$$

$$\therefore Y_{N+1} = 1 - 455 x_A + 0.00136$$

$$Y = \alpha X, \quad \alpha = 1.32$$

no. of real trays $= \frac{23.8}{0.4} = 59.5 \cong 60$

$$\bar{A} = \frac{L_S}{\alpha G_S} = 1.103$$

$$N = \frac{\log \left[\left(\frac{Y_{N+1} - \alpha X_0}{Y_1 - \alpha X_0} \right) \left(1 - \frac{1}{\bar{A}} \right) + \frac{1}{\bar{A}} \right]}{\log \bar{A}}$$

$$\therefore \boxed{N = 23.7}$$

$\therefore$ no. of real trays $= \frac{23.7}{0.4} = 59$

$$\bar{A} = 1.103$$

$$\frac{Y_1 - \alpha X_0}{Y_{N+1} - \alpha X_0} = \frac{0.00138 - 0}{0.138} = 0.01$$

$$\therefore \boxed{N = 22.5}$$

Q.27) $X = \dfrac{\text{kg of solute}}{\text{kg of solute free clay}}$ $Y = \dfrac{\text{kg of solute}}{\text{kg of solute free } H_2O}$

Mass of clay taken = 60g
Mass of solution taken initially = 1000g
↳ 900g → water

% solute A in the solution after eq = 6.93%

Mass of A in soln in eqn $= \dfrac{900}{1 - 0.0693}$

$= 67\,g$

Mass of A absorbed = 100 − 67 = 33g

$X = \dfrac{33}{60} = 0.55$ $Y = \dfrac{67}{900} = 0.0744$

(a) $Y = 0.173\,X^{1.36}$

$\alpha = 0.173$
$\beta = 1.36$

(b) M (kg) of adsorbant used at eq. ⇒

$X = \dfrac{90}{M}$, $Y = \dfrac{10}{900} = 0.011$

$\therefore \boxed{M = 678\,kg}$

(c) Two stage contact use

$678/2 = 339$ kg of clay in each stage

$C_s = 900$ kg

$L_s = 339$ kg

slope $= -L_s/C_s = -0.376$

$Y_0 = 100/900 = 0.111$

$X_0 = 0$

$\Rightarrow Y_2 = 0.006$

$\Rightarrow$ mass of solute leaving second stage $= 900 \times 0.006$

$= 5.4$ kg.

Section 3

Q.3.1] $y_A^* = 0.75 x_A$

$k_y = 0.02716 \ \dfrac{\text{kmol}}{m^2 s}$

$0.7 \cdot \dfrac{1}{(k_y)} = \dfrac{1}{K_y}$

$\therefore k_y \times 0.7 = K_y$

$\therefore K_y = 0.7 \times 0.02716$

$\boxed{K = 0.019 \ \dfrac{\text{kmol}}{m^2 s}}$

$x_A = 0.9, \quad y_A = 0.45$

$y_A^* = 0.75 \times 0.9 = \boxed{0.675}$

$$x_A^* = \frac{y_A}{0.75} = \frac{0.45}{0.75} = 0.6$$

$$N_A = K_y (y_A^* - y_A) = 0.019 (0.675 - 0.45) \times 10^3$$

$$\boxed{N_A = 4.275 \times 10^{-3} \ \frac{kmol}{m^2 S}}$$

$$k_y (y_{Ai} - y_A) = 4.275 \times 10^{-3}$$

$$\therefore 0.02716 (y_{Ai} - 0.45) = 4.275 \times 10^{-3}$$

$$\therefore \boxed{y_{Ai} = 0.607}$$

$$K_x (x_A - x_A^*) = K_y (y_A^* - y_A)$$

$$\therefore K_x (0.9 - 0.6) = 0.019 (0.675 - 0.45)$$

$$\therefore \boxed{K_x = 0.01425 \ \frac{kmol}{m^2 . S}}$$

Q. 3.2)

$$y = 10.5 x \quad m$$

$$k_x = 10.21 \ \frac{lb.mol}{h . ft^2}$$

$$k_y = 4.35 \ \frac{lb. mol}{h. ft^2}$$

$$\frac{1}{K_y} = \frac{1}{k_y} + \frac{m}{k_x}$$

$$\therefore \boxed{K_y = 6.79 \ \frac{lb. mol}{h. ft^2}}$$

$$\frac{1}{K_x} = \frac{1}{m k_y} + \frac{1}{k_x}$$

$\therefore$ $\boxed{K_x = 8.344 \ \frac{lb.mol}{h.ft^2}}$

gas phase resistance = $1/k_y$. $1/k_y$ = $\boxed{0.182}$

liq. phase resistance = $1/k_x$. $1/k_x$ = $\boxed{0.8172}$

$\therefore$ liquid phase will be controlling.

Q.3.3. $K_G = 2.75 \times 10^{-6} \ \frac{kmol}{m^2.s.Pa}$

$$\frac{1}{K_G} \ 0.85 = \frac{1}{k_G}$$

$\therefore$ $\boxed{k_G = 3.23 \times 10^{-6} \ \frac{kmol}{m^2.s.Pa}}$

$$\frac{1}{K_G} = \frac{1}{k_G} + \frac{m}{k_L}$$

$m = 1.64$

$\Rightarrow$ $\boxed{k_L = 3.03 \times 10^{-5} \ \frac{kmol}{m^2 s \Delta C_A}}$

$k_y = P.k_G$ $P = 1atm - 10^5$ Pa

$\therefore$ $k_y = 10^5 \times 3.23 \times 10^{-6}$

$\boxed{k_y = 3.23 \times 10^{-1} \ \frac{kmol}{m^2 s}}$

$N_A = K_G (P_A - P_A^*)$

$x_A = \frac{0.115}{100}$

$y_A = 1.64\, x_A$

$y_A^* = 1.64 \times \frac{0.115}{100}$

$\therefore \boxed{y_A^* = 1.88 \times 10^{-3}}$

$\boxed{y_A = 0.08}$

$P_A = y_A \cdot P \quad ; \quad P_A^* = y_A^* \cdot P$

$N_A = k_G (P_A - P_A^*) = k_y (y_A - y_{Ai})$

$P_A = 0.08 \times 10^5$ Pa

$P_A^* = 1.88 \times 10^{-3} \times 10^5$ Pa.

$\therefore \boxed{y_{Ai} = 0.0135}$

$y_{Ai} = 1.64\, x_{Ai}$

$\therefore \boxed{x_{Ai} = 0.00822}$