King Saud University
College of Engineering
Chemical Engineering Department

Separation processes
CHE / 407
2^{nd} Semester, (1435/1436)

Tutorial (1)

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Q1) At 303K the concentration of CO_2 in water is ($0.9*10^{-4}$ Kg CO_2/Kg water). Using the Henry's law constant from the appendix A.3 in the book, what partial pressure of CO_2 must be kept in the gas to prevent the CO_2 from vaporizing from the aqueous solution?

Q2) It is desired to absorb 90% of the acetone in a gas containing 1.0 mol% acetone in air in a countercurrent stage tower. The total inlet gas flow to the tower is 30 Kg mol/h, and the total inlet pure water flow to be used to absorb the acetone is 108 Kg mol/h. The process is to operate isothermally at 300 K and a total pressure of 101.3 kPa. The equilibrium relation for the acetone (A) in the gas-liquid is (y_A=2.53x_A). Determine the number of theoretical stages required for this separation graphically and analytically using Kremser equation.

Tutorial (1)

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Solution

Q1) Let $A = CO_2$

⇒ Concentration of CO_2 in water $= 0.9 * 10^{-4}$ kg CO_2/kg H_2O

⇒ We take 1 kg water basis to find the mole fraction.

⇒ mole fraction for CO_2, $x_{CO_2} = \dfrac{\text{no. of moles of } CO_2}{\text{Total no. of moles}}$

⇒ no. of moles for $CO_2 = \dfrac{0.9 * 10^{-4} \text{ kg } CO_2}{44 \text{ kg } CO_2/\text{kg mol}} = 2.045 * 10^{-6}$ kg moles

⇒ no. of moles of $H_2O = \dfrac{1 \text{ kg } H_2O}{18 \text{ kg } H_2O/\text{kg mol}} = 0.055$ kg mol

⇒ $x_{CO_2} = \dfrac{\text{no. of moles of } CO_2}{\text{Total numbers of moles}} = \dfrac{2.045 * 10^{-6}}{(0.055 + 2.045 * 10^{-6})} = 3.68 * 10^{-5}$

* From appendix (A.3) in the book, for CO_2 in H_2O @ 303K

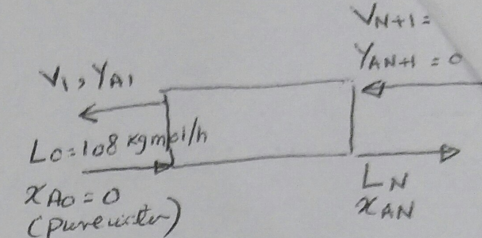
⇒ $H = 0.186 * 10^{4}$ atm/mole fraction

⇒ $P_{CO_2} = H x_{CO_2}$

$= 0.186 * 10^{4} * (3.68 * 10^{-5}) = 0.0684$ atm

⇒ $(0.0684 \text{ atm}) * \dfrac{(1.01325 * 10^{5}) \text{ Pa}}{\text{atm}} = 6.93 * 10^{3}$ Pa

Q2) pure water = 108 Kg mol H_2O/hr



* Given data:

⇒ $V_{N+1} = 30$ kg mol/hr gas

$T = 300K$

$P = 101.3$ KPa

equilibrium relationship ⇒ $Y_A = 2.53 x_A$

⇒ Acetone in $= Y_{AN+1} * V_{N+1} = 0.01 * 30 = 0.3$ Kg mol/hr

⇒ Acetone Leaving is 10% in order to absorb 90% in water

$= 0.1 * 0.3 = 0.03$ Kg mol/hr (*)

⇒ Acetone absorb in liquid phase (90% of acetone entering)

$= 0.9 * 0.3 = 0.27$ Kgmol/hr (*)

⇒ Total liquid stream leaving $L_N = 108 + 0.27 = 108.27 \frac{kgmol}{h}$ (*)

⇒ Inert gas $V' = 30(1 - 0.01) = 29.7$ kg mol/hr (*)

⇒ Total gas Leaving $(V_1) = 29.7 + 0.03 = 29.73$ kgmol/hr (*)
(inert gas) + (acetone not absorbed)

⇒ $x_{AN} = \frac{0.27}{108.27} = 0.0025$ (*) & $Y_{A1} = \frac{0.03}{29.73} = 0.001$ (*)

⇒ Plot the equilib Curve from equilib relation ($Y_A = 2.53 x_A$)

x_A	0	0.001	0.002	0.003	0.004
Y_A	0	0.00253	0.00506	0.0076	0.01012

⇒ plot the operating line and indicate (x_{A0}, Y_{A1}) & (x_{AN}, y_{AN+1})
OR $(0, 0.001)$ & $(0.0025, 0.01)$

⇒ No. of theoritical stage ≃ 3.7

B) Using analytical method :

$y_A = m x_A \Rightarrow m = 2.53$

$x_{A0} = 0.0$, $y_{A1} = 0.001$, $x_{AN} = 0.0025$, $y_{AN+1} = 0.01$

$L_0 = 108$, $V_1 = 29.73$, $L_N = 108.27$, $V_{N+1} = 30$

$$A_1 = \frac{L_0}{m_1 V_1} = \frac{108}{2.53 * 29.73} = 1.436$$

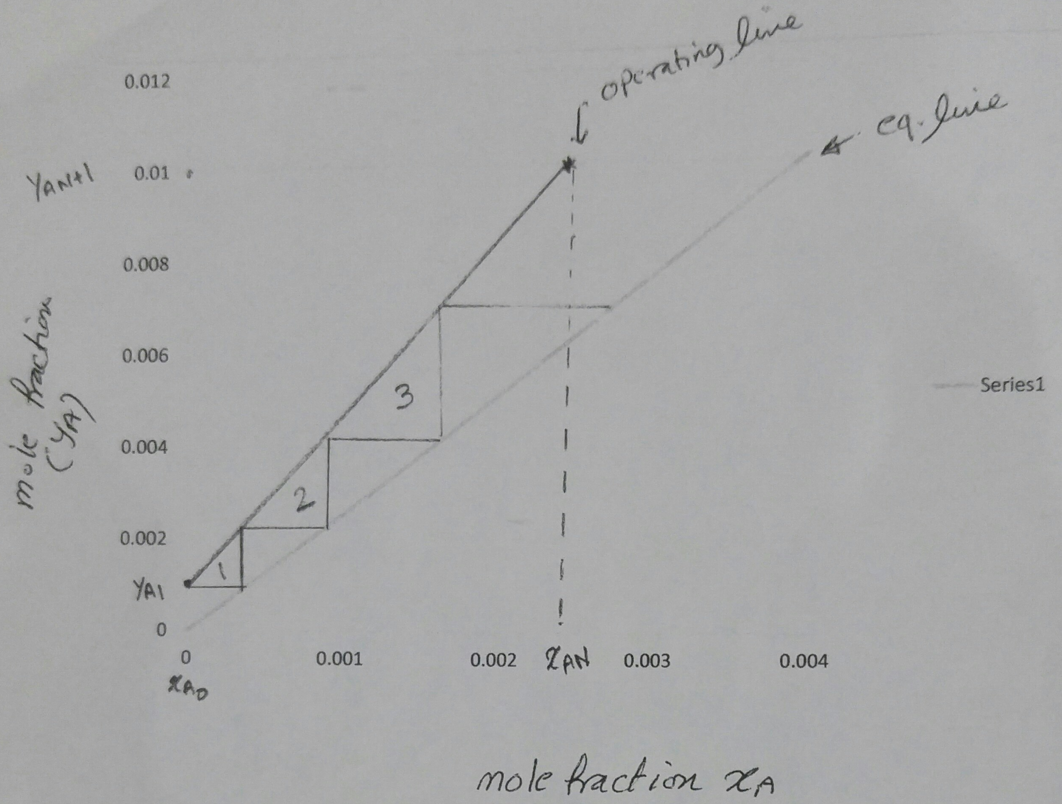
$$A_N = \frac{L_N}{m_N V_{N+1}} = \frac{108.27}{2.53 * 30} = 1.426$$

$$A = \sqrt{A_1 A_N} = \sqrt{1.436 * 1.426} = 1.431$$

$$\Rightarrow N = \frac{\ln\left[\frac{y_{N+1} - m x_0}{y_1 - m x_0}\left(1 - \frac{1}{A}\right) + \frac{1}{A}\right]}{\ln A}$$

$$= \frac{\ln\left[\left(\frac{0.01 - 0}{0.001 - 0}\right)\left(1 - \frac{1}{1.431}\right) + \frac{1}{1.431}\right]}{\ln(1.431)}$$

$= 3.66$ (*)


operating line
eq. line
0.012
0.01
0.008
0.006
0.004
0.002
0
0
0.001
0.002
0.003
0.004
Series1
3
2
1