Assignment - 4

4.9 a) $DF = 2 + c - \pi$

$c \rightarrow$ no of chemical species

$\pi \rightarrow$ no of phase in a system at eq.

$c = 2$ and $\pi = 2$

$DF = 2 + 2 - 2 = 2$

This means two intensive variables must be specified to determine the state of system (Temperature & Pressure).

b) $\log P^* = -\frac{\Delta H_v}{RT} + B$

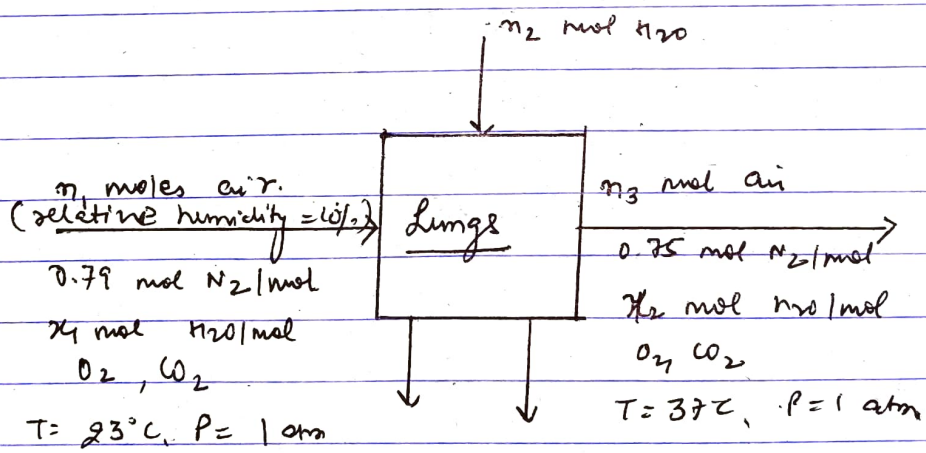
$= -\frac{1209.6}{(55 + 216)} + 6.9742 = 2.5107$

$P^* = 10^{2.5107} = 324 \text{ mm Hg}$

$y = \frac{P^*}{P} = \frac{324}{1200} = 0.27$

Now, $0.27 > 0.115$, thus it does not contain explosion hazard.

6.25



moles of air inhaled

$n_1 =$

12 breaths	60 min	24 hr	500 ml	1 L	273 K	1 mol
min	hr	day	breath	10^3 mL	(23 + 273 K	22.42 @ STP

$= 356$ mol inhaled / day.

- Inhaled air @ 10% rel. humidity

$$x_1 = \frac{(0.10)\, P^*_{H_2O\,(25^\circ C)}}{P} = \frac{0.10\,(21.07)}{760} = 2.77 \times 10^{-3} \text{ mol } H_2O / \text{mol}$$

- Inhaled air @ 50% rel. humidity

$$x_1 = \frac{(0.5)\, P^*_{H_2O\,(25^\circ C)}}{P} = \frac{0.5\,(24.07)}{760} = 1.39 \times 10^{-2} \text{ mol } H_2O / \text{mol}$$

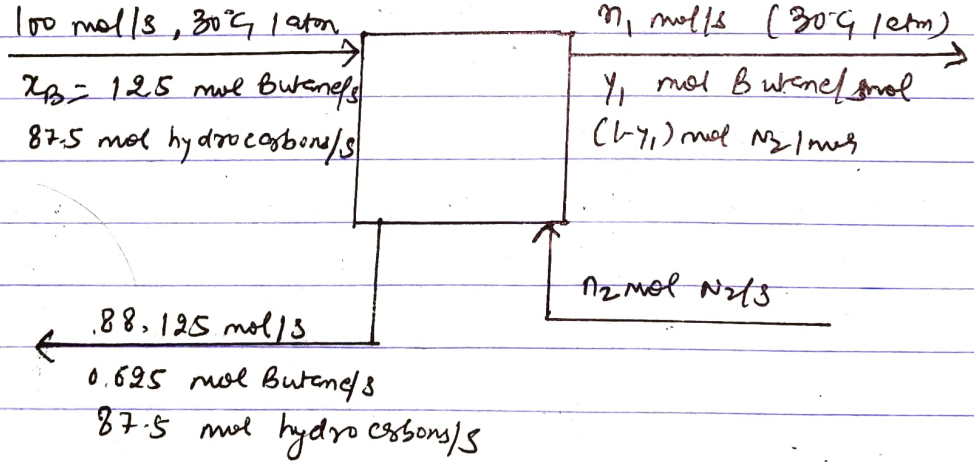
- Balancing H_2O

$$n_2 = n_3 x_2 - n_1 x_1$$

$$(n_2)_{@\,RH=10\%} - (n_2)_{@\,RH=50\%} = (n_1 x_1)_{@\,RH=50\%} - (n_2 x_2)_{@\,RH=10\%}$$

$$= \left(\frac{365 \text{ mole}}{\text{day}}\right)\left[(0.0139 - 0.00277)\left(\frac{\text{mol } H_2O}{\text{mol}}\right)\right]\left(18\,\frac{g}{\text{mol}}\right) = 71\ g/\text{day}$$

6.41 a) Let the basis be 100 mol/s feed stream.



$$P^*_B = P^*_{Butane} = 2120 \text{ mm Hg}$$

from Raoult's Law, $y_1 P = x_B P^*_{B\,@\,30^\circ C}$

$$y_1 = \frac{x_B P^*_{B\,(@\,30^\circ C)}}{P} = \frac{0.125 \times 2120}{760} = 0.3487$$

Now

$$n_1 (0.3487) = (12.5)\left(\frac{95}{100}\right)$$

$$n_1 = 34.06 \text{ mol/s}$$

Total mole balance on system :- $100 + n_2 = 34.06 + 88.125$

$$n_2 = 22.18 \text{ mol/s}$$

$$\frac{\text{mole gas fed}}{\text{moles liquid fed}} = \frac{30.68 \text{ mol/s}}{100 \text{ mol/s}} = 0.307 \frac{\text{moles gas fed}}{\text{moles liquid fed}}$$

b) $y_1 = 0.8 + 0.3487 = 0.2790$

Now

$$n_1 (0.2790) = (12.5)\left(\frac{95}{100}\right)$$

$$n_1 = 30.68 \text{ mol/s}$$

$$\frac{30.68 \text{ mol/s}}{100 \text{ mols}} = 0.307 \frac{\text{moles gas fed}}{\text{moles liquid fed}}$$

c) If we take N_2 as minimum as possible, the required column length is infinite which is erroneous. But as we increase the N_2 feed, column length decreases and so does it's cost. But, since more N_2 is now needed, it's price also increases. For determining optimum (gas / liquid) feed ratio, we need to know how the column size and cost and N_2 costs depend on the N_2 feed rate and find that rate at which the cost of production is minimum.

6.62 a) from Raoult's law

$$\frac{y_i}{x_i} = \frac{P_i^*}{P}$$

$$\alpha_{AB} = \frac{y_A / x_A}{y_B / x_B} = \frac{P_A^*/P}{P_B^*/P} = \frac{P_A^*}{P_B^*}$$

b) $P^*_{(styrene)\,@\,85^\circ C} = 10^{\left(7.01623 - \frac{1572.434}{85 + 214.985}\right)}$ (from $\log P^* = -\frac{\Delta H_v}{RT} + B$)

$= 109.95$ mm Hg

$P^*_{(ethylbenzene)\,@\,85^\circ C} = 10^{\left(6.9565 - \frac{1423.593}{85 + 213.091}\right)}$

$= 151.69$ mm Hg

$P^*_{(Benzene)\,@\,85^\circ C} = 10^{\left(6.89272 - \frac{1203.531}{85 + 219.888}\right)}$

$= 881.59$ mm Hg

$\alpha_{styrene,\,ethylbenzene} = \frac{109.95}{151.69} = 0.725 < 1$

$\alpha_{benzene,\,ethylbenzene} = \frac{881.59}{151.69} = 5.812 > 1$

Since $\alpha_{styrene,\,ethylbenzene}$ is closer to 1, hence styrene–ethylbenzene is the more difficult pair to be separated by distillation.

c) $\alpha_{ij} = \frac{y_i / x_i}{y_j / x_j}$, Now $y_j = 1 - y_i$, $x_j = 1 - x_i$

$$\alpha_{ij} = \frac{y_i / x_i}{(1-y_i)/(1-x_i)}$$

$$y_i = \frac{\alpha_{ij} x_i}{1 + (\alpha_{ij} - 1) x_i}$$

d) $\alpha_{(Benzene, ethylbenzene)} = 5.81$

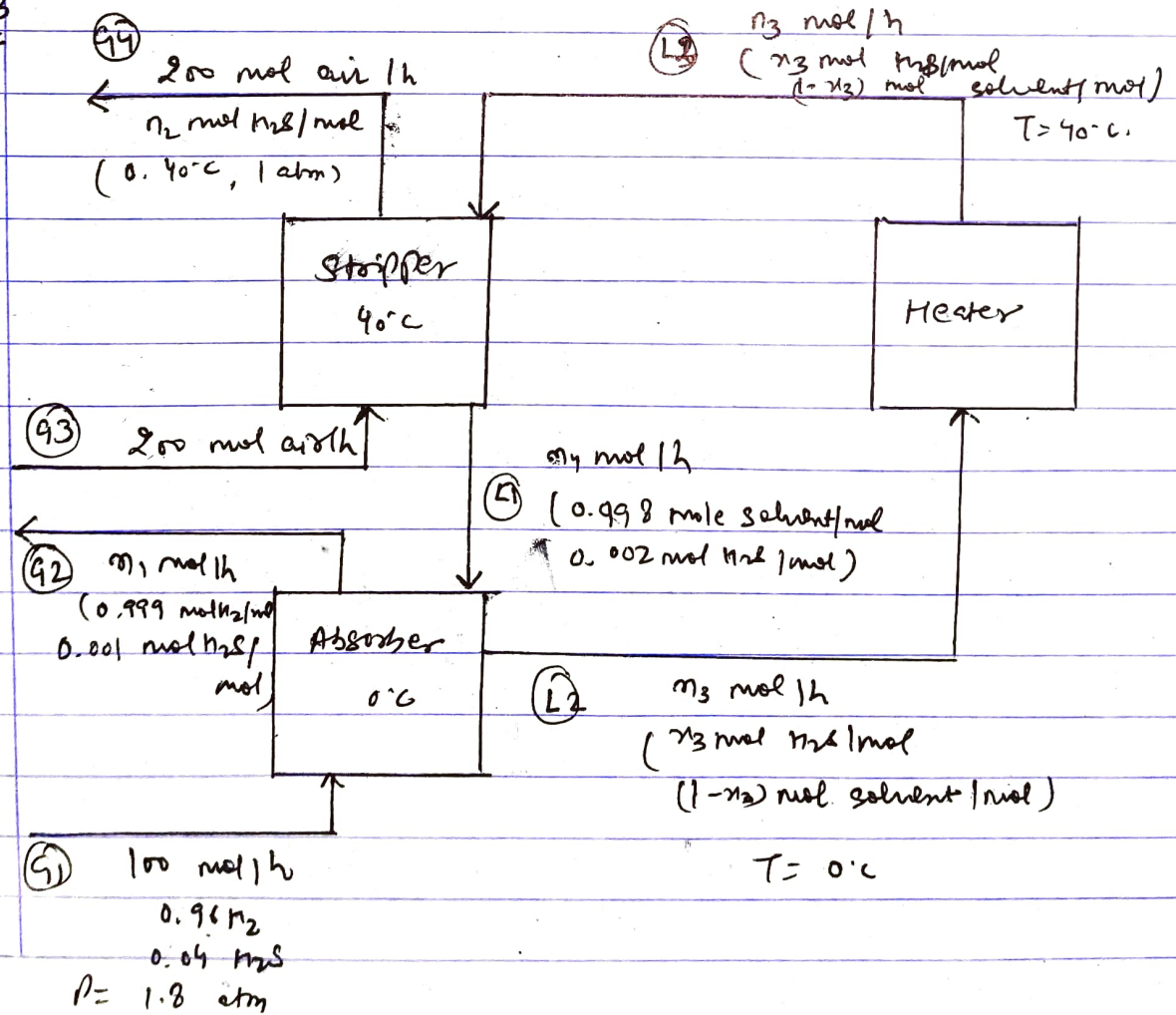
$$y_B = \frac{x_B \alpha_{(B,EB)}}{1 + (\alpha_{(B,EB)} - 1) x_B} = \frac{5.81 x_B}{1 + 4.81 x_B}$$

$$P = x_B P^*_B + (1 - x_B) P^*_{EB}$$

x_B mol B(l)/mol	y_B mol B(v)/mol	P mm Hg
0	0	152
0.2	0.592	298
0.4	0.795	444
0.6	0.897	590
0.8	0.959	736
1	1	882

6.73

b)



for equilibrium

(1) $P_{H_2S} = (0.04)(1.8) = 0.072$ atm

$$x_3 = \frac{P_{H_2S}}{H_{H_2S}} = \frac{0.072}{27} = 2.67 \times 10^{-3} \text{ mole } H_2S / \text{mol}$$

Overall n_2 balance

$$(100)(0.96) = 0.999 n_1$$

$$n_1 = 96.1 \text{ mol/h}$$

H_2S balance on system

$$100(0.04) = 0.001 n_1 + n_2 \quad , \quad n_1 = 96.1$$

$$n_2 = 3.9 \text{ mol } H_2S/h$$

Volumetric flow rate at Stripper outlet

$$V_{(4)} = \frac{(100 + 3.90) \text{ mol}}{h} \left| \frac{(273+40) \text{ K}}{273 \text{ K}} \right| \frac{22.4 \text{ L@STP}}{1 \text{ mol}}$$

$$V_{(4)} = 5240 \text{ L/h}$$

Balancing solvent & H_2S on absorber

$$(100)(0.04) + 0.002 n_4 = n_3 x_3 + 0.001 n_1$$

$$n_4 = 1.335 n_3 - 1952 \quad -(1)$$

$$0.998 n_4 = n_3 (1 - 2.67 \times 10^{-3}) \quad -(2)$$

Solving (1) & (2)

$$n_3 \text{ & } n_4 = 5830 \text{ mol/h}$$

Solvent flow rate $= 0.998 n_4 =$ 5820 mol solvent / h