Exercise 1 Flash

(1) butanol - water

$C = 2$

a) $f = 2 - 1 + 2 = \underline{\underline{3}}$

b) $f = 2 - 2 + 2 = \underline{\underline{2}}$

c) $f = 2 - 3 + 2 = \underline{\underline{1}}$

(2) benzene (A) - toluene (B)

a) Raoult's law: $P_A = x_A \cdot P_A(T)$

Assuming that it is the second to last row of the two last columns we calculate for.

$P_T = 101,325 \text{ kPa}$, $P_A = 204,2 \text{ kPa}$, $P_B = 86,0 \text{ kPa}$

$P_T = P_A + P_B$

$= x_A \cdot P_A + (1 - x_A) \cdot P_B$

$101,325 \cdot 10^3 = 204,2 \cdot 10^3 x_A + 86 \cdot 10^3 - 86 \cdot 10^3 x_A$

$15,325 \cdot 10^3 = 118,2 \cdot 10^3 x_A$

$\underline{\underline{x_A = 0,12965}}$

$$y_A = \frac{1 - \frac{P_B}{P_T}}{1 - \frac{P_B}{P_A}} = \frac{1 - \frac{86}{10,1325}}{1 - \frac{86}{204,2}} = \underline{0,2512}$$

b) $T: 358,2\text{K} \rightarrow 383,8\text{K}$

$$\alpha = \frac{y_A / x_A}{y_B / x_B} = \frac{y_A / x_A}{(1 - y_A)/(1 - x_A)}$$

T	358,2	363,2	368,2	373,2	378,2	383,8
α	2,54	2,51	2,46	2,41	2,36	[redacted]

c) $T = 358{,}2K$, $P = 1\cdot 10^5 Pa$, $x_A = 0{,}411$

The table above is at VLE, therefor we can see that with $x_A = 0{,}411$ the temperature needs to be $368{,}2K$ for it to boil, and $y_A = 0{,}632$

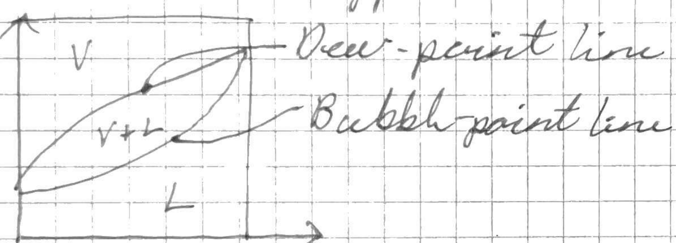
d) $T = 373{,}2K$ $x_A = 0{,}5$, $x_B = 0{,}5$

$$P_T = x_A P_A + x_B P_B = 0{,}5 \cdot 179{,}2 \cdot 10^3 + 0{,}5 \cdot 74{,}3 kPa = \underline{1{,}27 \text{ bar}}$$

$$y_A = \frac{1 - P_B/P_T}{1 - P_B/P_A} = \underline{\underline{0{,}708}}$$

$$y_B = \frac{1 - P_A/P_T}{1 - P_A/P_B} = \underline{\underline{0{,}291}}$$

e) A dew-point is the point where the first condensation appear



$y_A = 0{,}5$ $y_B = 0{,}5$ $P_T = 911 mmHg = 121{,}45 kPa$

Using Dalton's law

$P_A = x_A P_A^{sat}$ $P_A = y_A P$ | $P_B = x_B P_B^{sat}$ $P_B = y_B P$

$\Rightarrow x_A = \frac{y_A P}{P_A^{sat}}$ | $\Rightarrow x_B = \frac{y_B P}{P_B^{sat}}$

$$x_A + x_B = 1 = \frac{y_A P}{P_A^{sat}} + \frac{y_B P}{P_B^{sat}} = \frac{60725}{P_A^{sat}} + \frac{60725}{P_B^{sat}}$$

Trial and error:

$T = 368{,}2$ $\frac{60725}{155{,}7 \cdot 10^3} + \frac{60725}{63{,}3 \cdot 10^3} = 1{,}357 \neq 1$ need higher P_i^{sat}

$T = 373{,}2$ $\frac{60725}{179{,}2 \cdot 10^3} + \frac{60725}{74{,}3 \cdot 10^3} = 1{,}167 \neq 1$ need higher P_i^{sat}

$\underline{T = 378{,}2}$ $\frac{60725}{204{,}2 \cdot 10^3} + \frac{60725}{86 \cdot 10^3} = 1{,}003 \approx 1$

$121{,}45 = x_A P_A^{sat} + x_B P_B^{sat}$ $\Rightarrow$ $\underline{\underline{x_A = 0{,}2963}}$ $\underline{\underline{x_B = 0{,}7037}}$

$\underline{\underline{T = 378{,}2}}$

③ propane (1) n-butane (2) $\alpha = 6$

Stream F_a : $80 \, mol/s$, sat vap 1atm $y_1 = 0,5$ $y_2 = 0,5$

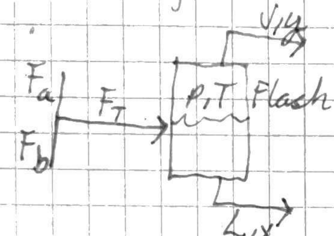
Stream F_b : $70 \, mol/s$, sat liq 1atm $x_1 = 0,5$ $x_2 = 0,5$

Adiabatic flash @ 1atm → L and V

a) $T_A > T_V = T_L > T_B$

From basic chemistry we know that n-butane because of its longer C-chain will have a higher boiling point than the shorter propane. T_A is only vapor while T_V and T_L are at VLE. therefore $T_A > T_V = T_L > T_B$ and L will have a bigger part of n-butane than V.

b)



$V = F_a = 80 \, mol/s$
$L = F_b = 70 \, mol/s$

Two components => $2(2)+3 = 7$ Independent EQ
MESH

Adiabatic flash gives $Q=0$, $p = 1atm$, unknowns are: T, V, L, y_i, x_i

$F_T = (80+70) \, mol/s = 150 \, mol/s$ => $75 \, mol/s$ prop n but

We have a constant relative volatility of 6 and we have that

$$y_1 = \frac{\alpha x_1}{1+(\alpha-1)x_1} = \frac{6x_1}{1+5x_1}$$

$$75 \, mol/s = x_1 70 \, mol/s + y_1 80 \, mol/s = x_1 70 + \frac{480 x_1}{1+5x_1}$$

$$75 + 375x_1 = 70x_1 + 350x_1^2 + 480x_1$$

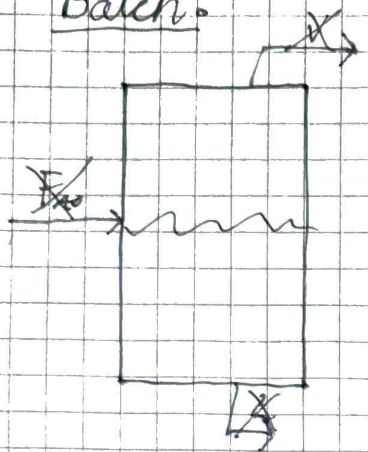
$$350x_1^2 + \underbrace{550x_1 - 375x_1}_{175x_1} - 75 = 0$$

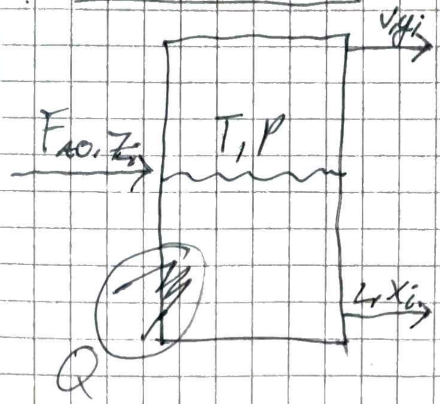
$$x_1 = \frac{-175 \pm \sqrt{175^2 - 4(350)(-75)}}{2(350)} = \frac{-175 \pm 368,27}{700} \Rightarrow \underline{x_1 = 0,2761}$$

$$\Rightarrow \underline{y_1 = 0,6959}$$

④ $\alpha = 2{,}45$ $x_0 = 0{,}357$ $\Delta P = 0$

i) Batch: Continuous:





ii) a) $$\int_{L_0}^{L_1} \frac{dL}{L} = \int_{x_0}^{x_1} \frac{dx}{y-x}$$

$$y = \frac{\alpha x_1}{1+(\alpha-1)x_1} \Rightarrow \frac{1}{y-x} = \frac{1}{\left(\frac{\alpha x}{1+(\alpha-1)x}\right) - x}$$

$$= \frac{1}{\alpha-1}\left(\frac{1}{x} + \frac{\alpha}{1-x}\right)$$

$$\int_{L_0}^{L_1} \frac{dL}{L} = \frac{1}{\alpha-1}\int_{x_0}^{x_1}\left(\frac{1}{x} + \frac{\alpha}{1-x}\right)dx$$

$$\ln\left(\frac{L_1}{L_0}\right) = \frac{1}{\alpha-1}\left(\ln(x_1) - \alpha\ln(1-x_1) - \ln(x_0) + \alpha\ln(1-x_0)\right)$$

b) $$\ln\left(\frac{L_1}{L_0}\right) = \frac{1}{2{,}45-1}\left(\ln(0{,}258) - 2{,}45\ln(1-0{,}258) - \ln(0{,}357) + 2{,}45\ln(1-0{,}357)\right)$$

$$\ln\left(\frac{L_1}{L_0}\right) = -0{,}466$$

$$\frac{L_1}{L_0} = e^{-0{,}466} = 0{,}628$$ (percentage liquid left)

$1 - 0{,}628 = 0{,}372 \approx \underline{37{,}2\%}$

iii) Continuous flash

a) $\alpha = 2{,}45 \quad x_0 = 0{,}357 \quad x_1 = 0{,}258$

$F = L + V$

$Fx_F = Lx + Vy$

$Fx_0 = Lx_1 + Vy_1$

$Fx_0 = Lx_1 + (F-L)y = Lx_1 + Fy - Ly \quad \Big| \cdot \frac{1}{F}$

$x_0 - y = \frac{L}{F}x_1 - \frac{L}{F}y$

$\frac{x_0 - y}{x_1 - y} = \frac{L}{F}$

$y = \frac{\alpha x_1}{1+(\alpha-1)x_1} = 0{,}46$

$\frac{L}{F} = \frac{0{,}357 - 0{,}46}{0{,}258 - 0{,}46} = 0{,}51$

$1 - 0{,}51 = 0{,}49 = \underline{\underline{49\%}}$

b) Batch 37% cap, Cont 49% cap

Batch is more efficient because you only need to evaporate 37%.