Exercise 3 | Håkon Ølvik TKP4105

① If there is no reaction, Gibbs phase rule gives that

$$F = C - P + 2$$

by diffinition.

So in a case with 2 phases we get that the degrees of freedom, F is

$$F = C$$

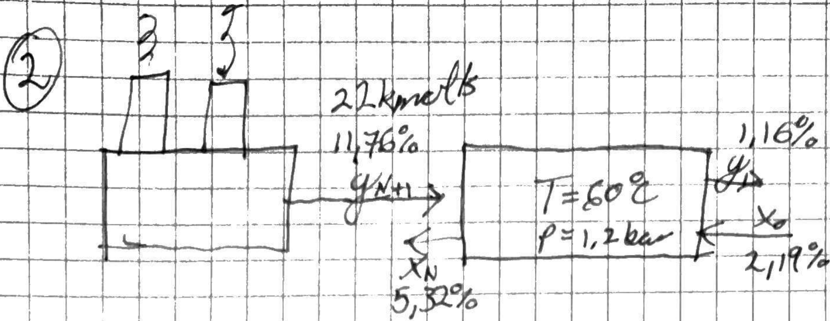
For distillation $C = 2$

For Absorbtion $C = 3$

Dist: Because x_A is defined for the system we get that the pressure determines the system

Abs: Because x_A is deffined for the system. We get that both T and p determines the system

(2)



$V_{N+1} = 22$ kmol/s

$y_{N+1} = 0,1176$, $y_1 = 0,0116$,

$x_0 = 0,0219$, $x_N = 0,0532$

a) We can find the inert air flow

$V' = V_{N+1}(1 - y_{N+1}) = 19,4128$ kmol/s

$y_{N+1} V_{N+1} + x_0 L_0 = x_N L_N + y_1 V_1$

$$\frac{V' y_{N+1}}{1 - y_{N+1}} + \frac{L' x_0}{1 - x_0} = \frac{L' x_N}{1 - x_N} + \frac{V' y_1}{1 - y_1}$$

$$2587,2 + L'\frac{219}{9781} = L'\frac{133}{2367} + 227,8313$$

$0,0338 \cdot L' = 2359,3687$

$L' = \underline{69,80 \text{ kmol/s}}$

$$L_0 = \frac{L'}{1 - x_0} = \frac{69,80}{1 - 0,0219} = \underline{71,36 \text{ kmol/s}}$$

$$L_N = \frac{L'}{1 - x_N} = \frac{69,8}{1 - 0,0532} = \underline{73,72 \text{ kmol/s}}$$

$V_1 = (y_{N+1} V_{N+1} + x_0 L_0 - x_N L_N) / y_1 = \underline{19,66 \text{ mol/s}}$

b) $v = 2\,m/s$

$v = \frac{\dot{V}}{A} \Rightarrow A = \frac{\dot{V}}{v}$

Find molar volume from ideal gas law

$pV_m = RT$

$V_m = \frac{RT}{p} = \frac{8{,}3144621 \cdot 333}{1{,}2 \cdot 10^5} = 0{,}0231\,m^3/mol$

$\dot{V} = 22000\,mol/s \cdot 0{,}0231\,m^3/mol = 508{,}2\,m^3/s$

We then get the diameter:

$A = \frac{\dot{V}}{v} \Rightarrow \frac{\pi d^2}{4} = \frac{\dot{V}}{v}$

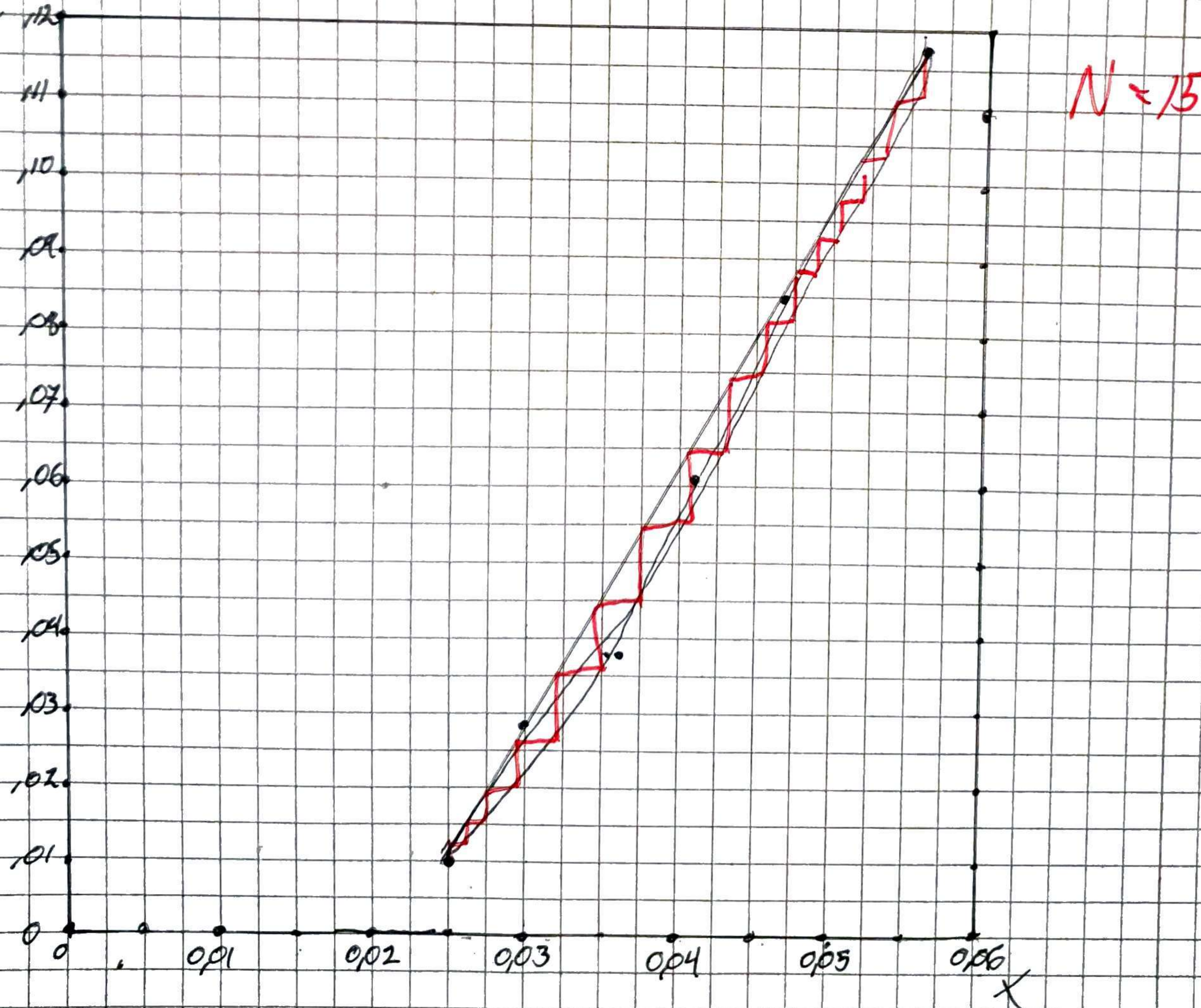
$d = \sqrt{\frac{4\dot{V}}{\pi v}} = \sqrt{\frac{4 \cdot 508{,}2}{\pi \cdot 2}} = \underline{\underline{17{,}99\,m}}$

c) $\frac{y_1}{x_1} = 0{,}52$

$\frac{y_3}{x_3} = 0{,}88$

$\frac{y_5}{x_5} = 2{,}18$

No it is not resonable to use Henry's law. Because the $\frac{y}{x}$ is not constant d)



e) Assuming diluted flows $y_n, x_n \ll 1$

We have the Mass equation

$$V_{N+1} y_{n+1} + L_0 x_0 = L_n x_n + V_1 y_1$$

We can then get the equation for the operating line y_{n+1}

$$y_{n+1} = \frac{L_n}{V_{n+1}} x_n + \frac{V_1 y_1 - L_0 x_0}{V_{n+1}} \qquad (1)$$

By looking at the whole system and using that in = out

We get that

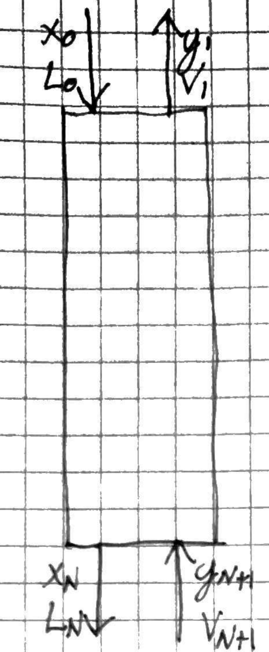
$$\frac{L_{in}}{V_{in}} \approx \frac{L_{out}}{V_{out}} \approx \frac{L'}{V'} \qquad (2)$$

By implementing this into eq (1) we get

$$y_{n+1} \approx \frac{L_0}{V_{N+1}} x_n + \frac{V_{N+1} y_1 - L_0 x_0}{V_{N+1}}$$

This makes it so that the operating line is not quite linear but goes through (x_0, y_1) and (x_N, y_{N+1})

(3)



$x_0 = 0{,}033$ EtOH $\quad y_{N+1} = 0$

y_1 have 99% of the EtOH from L_0

$P = 1\,\text{atm} = 101{,}32\,\text{kPa}$

Going to find $\frac{V_{N+1}}{L_0}$

a) Assuming constant molar flows

$\Rightarrow V_{N+1} = V_1$ and $L_0 = L_N$

~~there will be equilibrium in the whole tank due to the assumption of ∞ steps.~~

$x_N L_N = 0{,}01\, x_0 L_0 = L_0 \cdot 3{,}3 \cdot 10^{-4}$

$\Rightarrow x_N = 3{,}3 \cdot 10^{-4}$

Assuming pinch at feed

$$\frac{L_0}{V_{N+1}} = \frac{y_1 - y_{N+1}}{x_0 - x_N}$$

We want

$$\frac{V_{N+1}}{L_0} = \frac{x_0 - x_N}{y_1 - y_{N+1}} = \frac{0{,}033 - 3{,}3 \cdot 10^{-4}}{0{,}270 - 0} = \underline{\underline{0{,}121}} \ \frac{\text{mol steam}}{\text{mol feed}}$$

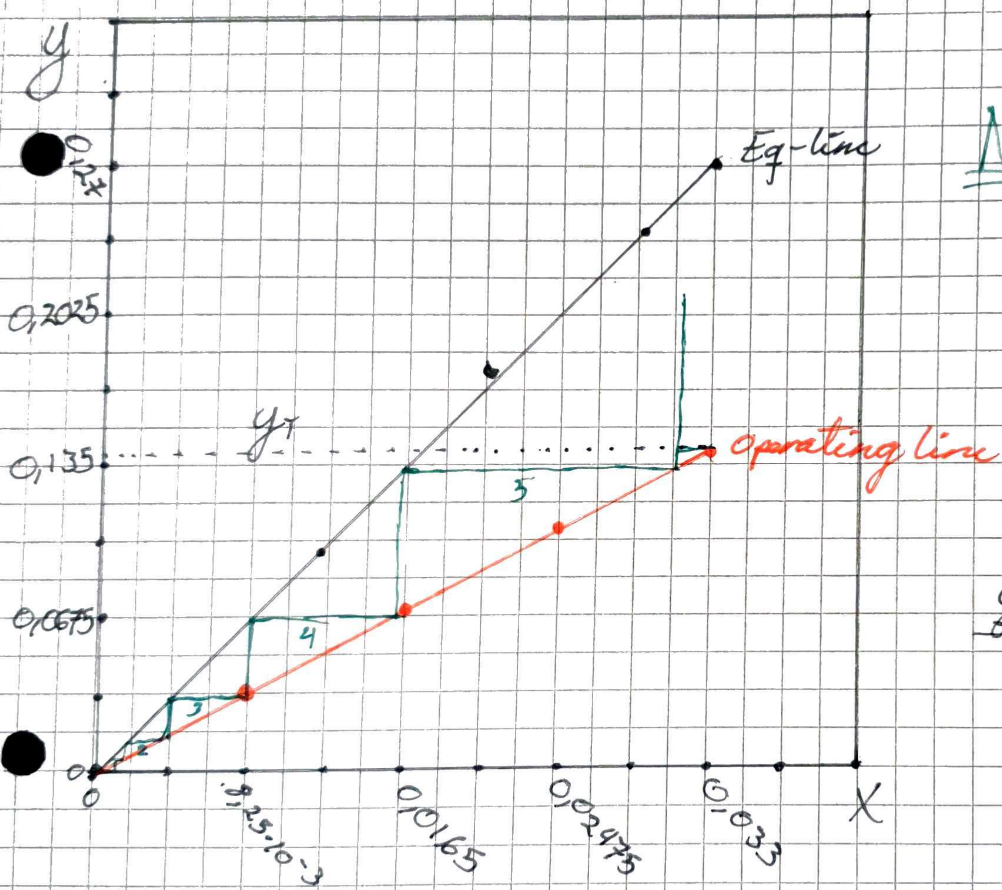
b) Still assuming pinch at feed. $V_{N+1} = 0,242$, $L_0 = 1$

Finding the operatingline from the eq:

$$y_{n+1} = \frac{L_0}{V_{N+1}} x_n + y_1 - \frac{L_0}{V_{N+1}} x_0$$

$$= \frac{1}{0,242} x_n + 0,270 - \frac{1}{0,242} \cdot 0,033$$

$$= 4,13 x_n +$$



$N = 5,1$

$y_T = 0,136$

c) Kremser eq: $\frac{y_{N+1} - y_1}{y_{N+1} - y_0^*} = \frac{A^{N+1} - A}{A^{N+1} - 1} = \varphi$

Simplyfied:

$$A^N = \frac{y_{N+1} - y_N^*}{y_1 - y_0^*}$$

$$\Rightarrow N = \frac{\ln\left(\frac{y_{N+1} - y_N^*}{y_1 - y_0^*}\right)}{\ln(A)}$$

$$= \frac{\ln\left(\frac{y_{N+1} - y_N^*}{y_1 - y_0^*}\right)}{\ln\left(\frac{y_{N+1} - y_1}{y_N^* - y_0^*}\right)}$$

$$A = \left(\frac{L}{VK}\right) = \frac{1}{0{,}121 \cdot K} = \frac{8{,}26}{K}$$

$$A = \frac{y_{N+1} - y_1}{y_N^* - y_0^*}$$

$$y_i^* = Kx_i$$

Don't know how to find the value of K.