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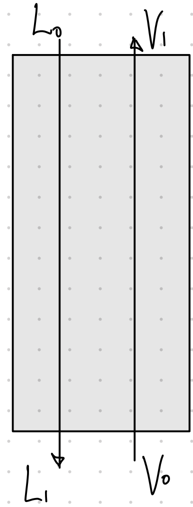
a)

Antar $L_0 = L_1 = L$ og $V_0 = V_1 = V$

as $X_n << X_W / y_p$



Assume equilibrium at inlet and outlet:

$$y_{n_1} = m \cdot X_{n_0} = 2{,}8 \cdot 30 \cdot 10^{-3} = 0{,}084$$

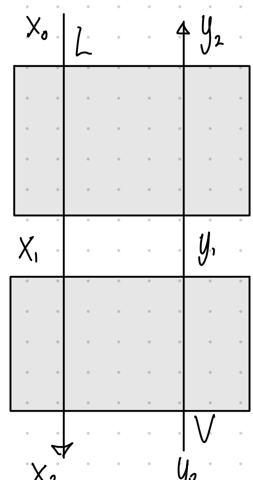
Balances of nikotin:

$$L \cdot X_{n_0} = L \cdot X_{n_1} + V \cdot y_{n_1}$$

$$X_{n_1} = 0{,}01 \cdot X_{n0}$$

$$\Rightarrow V = \frac{L(X_{n_0} - 0{,}01 X_{n_0})}{y_{n_1}} = \frac{L X_{n0}}{y_{n_1}} 0{,}99 = \frac{L}{m} \cdot 0{,}99$$

$$V = \frac{1000 \text{ kg/h}}{2{,}8} \cdot 0{,}99 = \underline{\underline{353{,}6 \text{ kg/h}}}$$



b) We have $L = 1000$ kg/h

$V = 600$ kg/h

Balances:

$$L x_0 + V y_1 = L x_1 + V y_2$$

$$L x_1 = L x_2 + V y_1$$

Antar likevekt mellom Linn og Vub

$$y_1 = m x_2$$

$$30 + 600 \cdot 2{,}8 \cdot x_2 = 1000 \cdot x_1 + 600 \cdot 2{,}8 \cdot x_1$$

$$1000 \cdot x_1 = 1000\, x_2 + 600 \cdot 2{,}8 \cdot x_2$$

(

$y_2 = m x_1$

$\hookrightarrow x_1 = 2{,}68\, x_2$

$\Rightarrow 30 + 600 \cdot 2{,}8 \cdot x_2 = 1000 \cdot 2{,}68\, x_2 + 600 \cdot 2{,}8 \cdot 2{,}68\, x_2$

$\Rightarrow x_2 = 0{,}00545$

$x_1 = 0{,}01461$

$y_2 = 0{,}04091$

$y_1 = 0{,}01527$

$$\%\, ut = 100\% \cdot \frac{V y_2}{L x_0} = \frac{600 \cdot 0{,}04091}{30} = 81{,}8\%$$

2 a) $T = 57{,}5°C$, $0{,}030$ kg H_2O/kg luft, $p = 1$ bar

$\hookrightarrow H_p \approx 22\%$

$$n = \frac{P_{H_2O} V}{RT}$$

$$m_{H_2O} = n \cdot M_{H_2O} = \frac{P_{H_2O} V}{RT} M_{H_2O}$$

$$P = P_{air} + P_{H_2O}$$

b)

$$H = \frac{m_{H_2O}}{m_{dry\ air}} = \frac{P_{H_2O}}{P - P_{H_2O}} \cdot \frac{M_{H_2O}}{M_{air}}$$

$$H_s = \frac{P^s_{H_2O}}{P - P^s_{H_2O}} \cdot \frac{M_{H_2O}}{M_{air}}$$

$$H_p = 100\% \cdot \frac{H}{H_s}$$

$$H_R = 100\% \cdot \frac{P_{H_2O}}{P^s_{H_2O}}$$

c)

$H = 0{,}03$ (gitt), Tabell $P^s_{H_2O} = 17{,}849$ kPa $\approx 17{,}8$ kPa

$$H_s = \frac{P^s_{H_2O}}{P - P^s_{H_2O}} \cdot \frac{M_{H_2O}}{M_{air}} = \frac{17{,}8\text{ kPa}}{\underset{1\text{ bar}}{100\text{ kPa}} - 17{,}8\text{ kPa}} \cdot \frac{18}{29} = 0{,}134$$

$$H_p = 100\% \cdot \frac{H}{H_s} = \frac{P_{H_2O}}{P^s_{H_2O}} \cdot \frac{1 - P^s_{H_2O}}{1 - P_{H_2O}} = \frac{0{,}03}{0{,}134} \cdot 100\% = 22{,}4\%$$

Nærme a) sin verdi

d) Dew point when the air is saturated with water

$\Rightarrow p_{H_2O} = p^s_{H_2O}(T^s)$

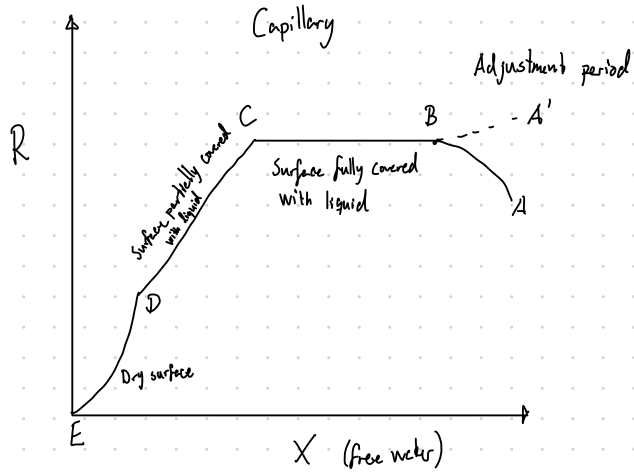
Fra diagrammet, $T^s \approx 30°C$

Finner $T = 57{,}5$ and $H = 0{,}03$

Følger adiabatisk linje til 90% kurven

$\Rightarrow T_s = 37{,}5°C$

e)



3 a) Advantages: Larger capacity, no flooding

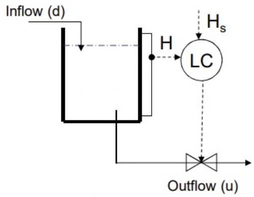
Disadvantage: Less efficient, only one equilibrium stage

b) When vapor rate is so large that liquid follows vapor upwards.

c) $\frac{dm}{dt} = m_{in} - m_{ut}$, assume constant ρ, $m = V\rho$

$\Rightarrow \frac{d(V\rho)}{dt} = \rho(V_{in} - V_{out})$

$\rho \frac{dV}{dt} = \rho(V_{in} - V_{out}) \Rightarrow \frac{dV}{dt} = (V_{in} - V_{out})$



$$V = \frac{\dot{q}}{K_c} = \frac{1\,m^3/\text{min}}{0{,}1\ \text{min}^{-1}} = 10\ m^3$$

$$V = \frac{1{,}5\ m^3/\text{min}}{0{,}1\ /\text{min}} = 15\ m^3$$

With integral control, it would have become constant (set-point)

$$\frac{dV}{dt} = (V_{in} - V_{out})$$

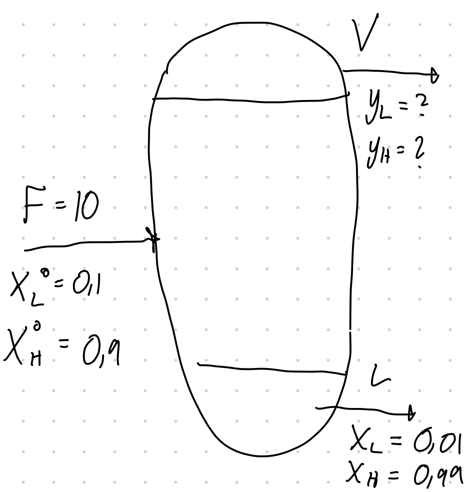
$$\frac{dV}{dt} = q_{in} - q_{out}$$

$$V = \frac{q_{out}}{K}$$

$$\frac{dV}{dq_{out}} = \frac{1}{K} \Rightarrow dV = \frac{1}{K}\, dq_{out}$$

$$\tau \frac{dy}{dt} = -y + d \qquad \Rightarrow k = 1,\ \tau = \frac{1}{K_c}$$

d)



$$F = V + L \Rightarrow V + L = 10 \Rightarrow L = 10 - V$$

$$X_L^0 F = V y_L + L x_L$$

$$0{,}1 \cdot 10 = V y_L + L x_L \Rightarrow V y_L + L x_L = 1$$

$$\Rightarrow V y_L + (10 - V) x_L = 1 \quad (x_L = 0{,}01)$$

$$\Rightarrow V y_L - 0{,}01 V = 0{,}9$$

$$V(y_L - 0{,}01) = 0{,}9$$

$$\alpha = \frac{y_L/x_L}{y_H/x_H} = 280$$

$$\Rightarrow \frac{y_L}{x_L} = \frac{y_H}{x_H} 280 = \frac{(1-y_L)}{(1-x_L)} 280 \qquad / x_L = 0{,}01$$

$$100\, y_L = \frac{280}{0{,}99}(1-y_L)$$

$$100\, y_L + \frac{280}{0{,}99} y_L = \frac{280}{0{,}99}$$

$$y_L = \frac{280}{0{,}99\left(100 + \frac{280}{0{,}99}\right)} = 0{,}739$$

$$\Rightarrow y_H = 0{,}261$$

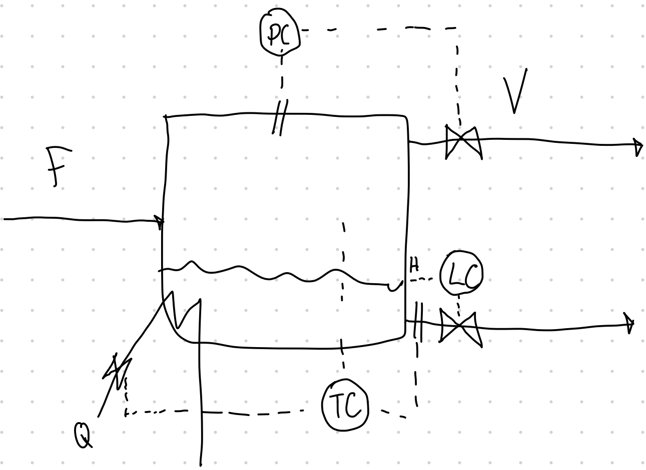
$$V = \frac{0{,}9}{0{,}739 - 0{,}01} = 1{,}22 \text{ mol/s}$$

$$\underline{L = 8{,}78 \text{ mol/s}}$$

$Q: Q = \Delta H_{vap} \cdot V$

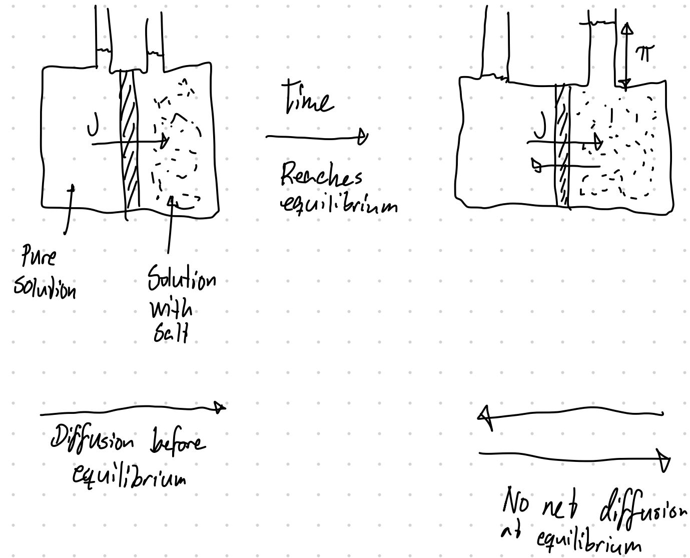
$Q = 16 \text{ kJ/mol} \cdot 1{,}22 \text{ mol/s}$

$\underline{Q = 19{,}52 \text{ kW}}$

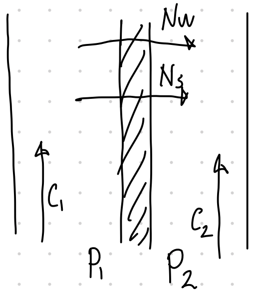


MV \ CV	H	P	X_L
q_V	(−)	(−)	/
q_L	0	(−)	/
Q	0	+	(−)

4 a) 1)



2)



$(P_1 > P_2)$

$P_1 - P_2 > \Delta\pi$

3) Separasjon uten varme, trenger ikke faseforandring, brukes til å lage ferskvann.

b) Fra van't hoff: $\pi = \frac{n}{V_m} RT$

$T = 4 + 273 = 277\,K$

Antar 100 kg vann $\Rightarrow m_{NaCl} = 3{,}5\,kg$, $n_{NaCl} = \frac{3{,}5\,kg}{58{,}45\,kg/kmol} = 0{,}0599\,kmol$

Volum vann 96,5 kg (100 kg − m_{salt})

$\rho_{H_2O} = 1000\ kg/m^3$

$\Rightarrow V_{H_2O} = 0{,}0965\ m^3$

$C_1 = \frac{3{,}5\ kg}{0{,}0965\ m^3} = 36{,}3\ kg/m^3$

$C_1 \gg C_2 \Rightarrow \pi_2$ er negligerbar

$R = 8314{,}34\ \frac{m^3\ Pa}{kg \cdot mol \cdot K}$

$kg\ mol = 10^3\ mol$

= # atom i en kg ren karbon-12

$= 10^3\ N_A$

$n_{ion} = 2 \cdot n_{salt}$ (Na^+ og Cl^-)

$$\Delta\pi \approx \pi_1 = \frac{n_{ion}}{V_{H_2O}} \cdot R \cdot T$$

10^{-5} bar = Pa

$$\pi_1 = \frac{2 \cdot 0{,}599\ \cancel{kmol}}{0{,}0965\ \cancel{m^3}} \cdot 8314{,}34\ \frac{\cancel{m^3} \cdot Pa}{\cancel{10^3}\ \cancel{mol} \cdot \cancel{K}} \cdot 277\ \cancel{K}$$

$$\pi_1 = 28{,}6\ bar$$

c) $R = \frac{C_1 - C_2}{C_1} = 1 - \frac{C_2}{C_1} = 1 - \frac{0{,}1}{36{,}3} = 99{,}7\%$

$C_2 = 0{,}1\ kg/m^3$

$$C_1 = \frac{3{,}5\ kg}{100\ kg\ sol} = \frac{3{,}5\ kg}{(100-3{,}5)\ kg_{H_2O}} = \frac{3{,}5\ kg}{\frac{100-3{,}5}{1000}\ m^3} = \frac{3{,}5\ kg}{0{,}0965} = 36{,}269\ kg/m^3$$

$m = \rho \cdot V \Rightarrow V = \frac{m}{\rho}$

d) $N_w = A_w (\Delta P - \Delta \pi) = 3{,}04 \cdot 10^{-4} \frac{kg\ H_2O}{s \cdot m^2\ bar} (55\ bar - 28{,}6\ bar)$

$$N_w = 8{,}0256 \cdot 10^{-3} \frac{kg\ H_2O}{s \cdot m^2}$$

e) $\dot{m}_{H_2O} = t \cdot A \cdot N_w$

$$\Rightarrow A = \frac{\dot{m}_{H_2O}}{t \cdot N_w} = \frac{15000\ L \cdot \frac{1\ m^3}{1000\ L} \cdot 1000\ kg\ H_2O/m^3}{1\ døgn\ \frac{24\ timer}{døgn} \cdot \frac{3600\ s}{timer} \cdot 8{,}0256 \cdot 10^{-3} \frac{kg\ H_2O}{s \cdot m^2}} = 21{,}6\ m^2$$