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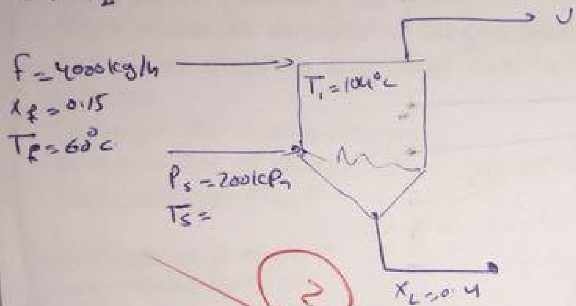
Heat and Mass Transfer Operations **First semester 2016/2017**

Student name: Dina ALOsah **Student No.:** 0143502 **Seat No.:** 22

Quiz #1 **October 12, 2017**

A single effect evaporator is fed with 4000 kg/h of 15 wt% $CaCl_2$ aqueous solution at 60 °C to be concentrated to 40 wt% solids. The pressure of the saturated steam used is 200 kPa and the solution temperature inside the evaporator is 104 °C. The overall heat transfer coefficient is 1500 W/m^2.K. The heat capacity of the feed is assumed to be around 3.8 kJ/(kg.K). Estimate **the pressure of vapor space evaporator, the steam economy, and the heating surface area. Say your assumptions.**

$CaCl_2$



U = 1500 W/m².k
Cp_f = 3.8 kJ/kg.k
P_1 ??
V/S ??
A ??

(2)

$T_s = 122°C$

$\lambda = 2203$ kJ / kg

$x_f F = L x_L$

$L = 1500$ kg/h , $V = 2500$ kg/h

(2)

$T_f = 60°C = 140°F$
$T = 104°C = 219.2 F$

$F h_f + S\lambda = V H_V + L h_L$

$S\lambda = V H_V + L h_L - F h_f$
$= V(H_V) + (F-V) h_L - F h_f$
$= V(H_V - h_L) + F(h_L - h_f)$
$= V(H_V - h_L) + F\, c_p (T_1 - T_F)$

~~Assuming no BPE.~~

~~λ @ T=104°C~~

$T_1 = 122.9°C > 104°C$

The V is superheated

λ @ 122.9° = 2700 kJ/kg

$S = (4000(3.8)(~~122.9~~-60) + 2500(2700))/2203$

$S = 3498$ kJ/h

$V/S = 0.715$

$A = \frac{S\lambda}{U(T_s - T_1)} = \frac{kJ}{h} \cdot \frac{kJ}{kg} \cdot \frac{s \cdot kg \cdot K}{J \cdot K}$

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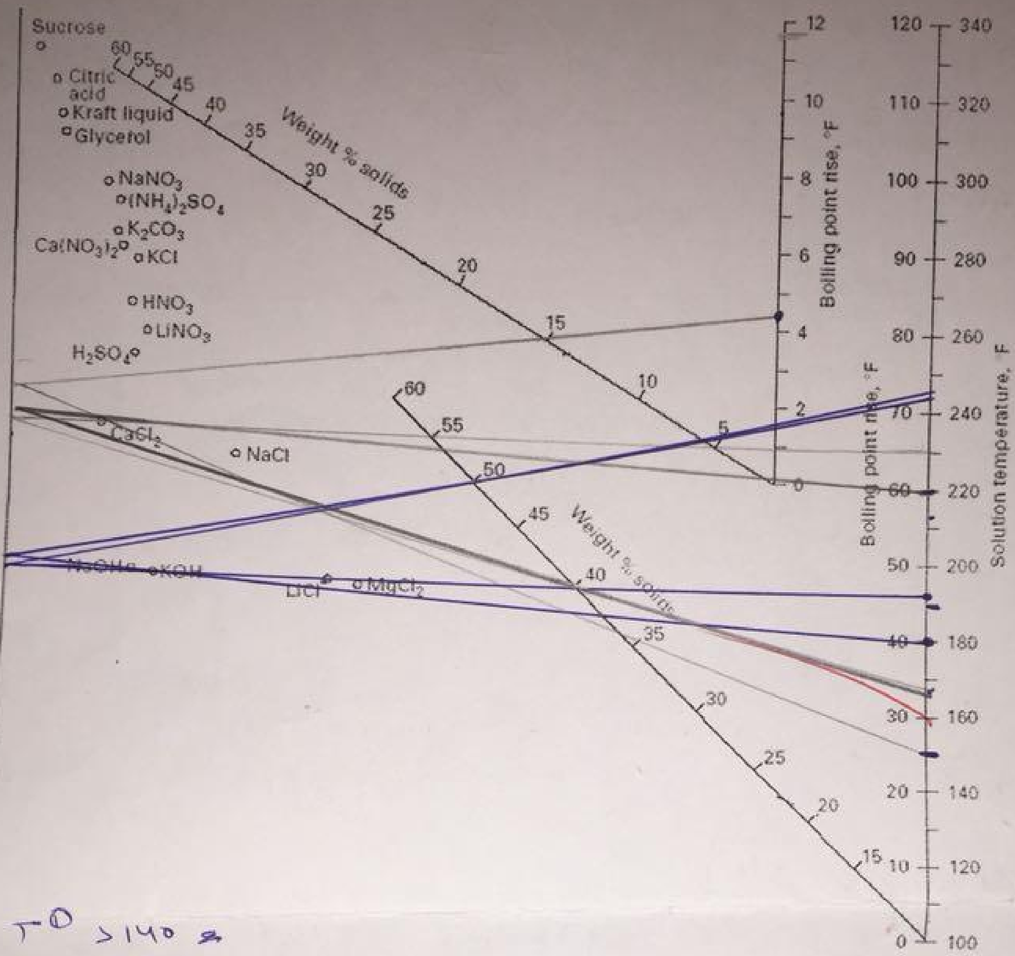

Figure 17.33 Nomograph for boiling-point elevation of aqueous solutions. [From *Perry's Chemical Engineers' Handbook*, 6th ed., R.H. Perry, D.W. Green, and J.O. Maloney, eds., McGraw-Hill, New York (1984) with permission.]

$T^{①} > 140$

$T^{①} = 150$ F

$T_{1} = 219.2$ f

$T^{①} = 230$ F

~~D = 34~~ $= T_{solut} - T_{solven}$

$T_{solut} = 253.2$ F $=$ ~~122.9°C~~

3! =

BP

34

1 kg | 2.20 lbm

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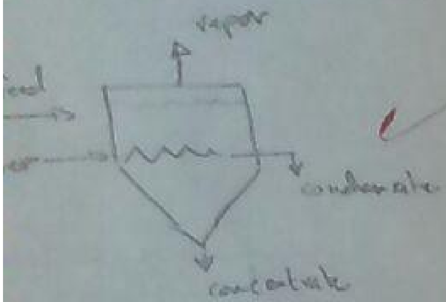
eat and Mass Transfer Operations **Second semester 2016/2017**

tudent name: داود علاء **Student No.:** 0132815 **Seat No.:** 19

uiz #1 **February 19, 2017**

single effect evaporator is used to concentrate 5000 kg/h of 5 wt% KCl aqueous solution entering at 60 °C a product of 25 wt% solids. The pressure of the saturated steam used is 313 kPa and the vapor space aporator is under atmospheric pressure of 100 kPa. The overall heat transfer coefficient is 1200 $W/m^2.K$. he heat capacity of the feed is assumed to be around 3.7 kJ/(kg.K). It is found that the time taken to empty, ean and refill the evaporator is 4.17 h, the cost of a shutdown is JD 300, and the operating cost during oiling is JD 40 /hour. In addition, the overall heat transfer coefficient U ($kW/m^2.°C$) is related to the boiling me t (s) by $1/U^2 = 5 \times 10^{-5}\, t + 0.4$

stimate the **steam economy**, the **heating surface area**, and **the cost required to evaporate one kg of water** ich that the throughput is maximum { $t_{b,optimum} = t_c + (2/a)(abt_c)^{0.5}$ and $Q_b = (2\,A\,\Delta T/a)\,[(at_b+b)^{0.5} - b^{0.5}]$ }. ake boiling point elevation into consideration.



F = 5000 kg/hr
x_F = 0.05 of kcl
T_F = 60 C

x_L = 0.25 % wt
P_s = 313 kpa
P_1 = 100 kpa.

U = 1200 W/m².K
Cp = 3.7 KJ/kg
t = 4.17 h.

F = V + L
→ solid composition is neglected at vapor stream → $x_F F = x_L L$
5000 × 0.05 = 0.25 × L
L = 1000 kg/hr.

energy balance :-
$h_F F + \lambda S = H_V V + h_L L$

5000 = V + 1000
V = 4000 kg/hr

① the temperature of feed stream is estimated to be 60 C with its composition almost "dilluted". OK

② 60 C → 140 F. for T B.P of solution

③ Boiling point elevation :- to 25 % wt ≅ 5 F
→ solution T_1 = 5 + (140) why!
T_1 = 145 F.
≅ 63 C

h_F at 60 C pure = 251.18 KJ/kg OK
λ = ($H_V - h_L$) at 100 kpa ≅ 2257 KJ/kg.
H_V at 313 kpa ≅ 2726 KJ/kg OK
h_L at 63 C ≅ 260 KJ/kg.

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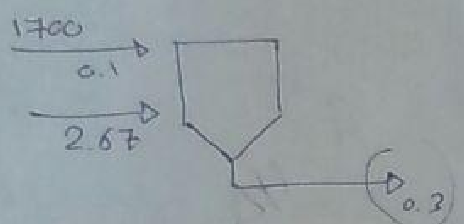
Heat and Mass Transfer Operations — **First semester 2016/2017**

Student name: [illegible] **Student No.:** 0149018 **Seat No.:** 7

Quiz #1 — **October 9, 2016**

In order to concentrate 1700 kg/h of an NaOH solution containing 10 wt% NaOH to a 30 wt%, a single effect evaporator is being used with an area of 10 m². The steam economy was 0.8 and the corresponding overall heat transfer coefficient is 1500 W/(m².°C). Saturated steam at 2.67 atm is used for heating. Calculate the **capacity**, the **solution temperature, boiling point elevation** and **absolute pressure inside the evaporator. Approximate the temperature of the feed.**



A = 10 m²
S.E = 0.8
U = 1500 W/m²C

S = 1/0.8 1133.3 = 1416.6

Cp = ? sol. temp = ? BPE P₁

assume the temp feed = 60C°

Fh_F = Lh_L [L = 566.7, V = 1133.3]

P₁ From s.Table = 120 kPa
sol Temp = 80°C

λ at 2.67 = 2177
128°C

Fh_F + S(λ) = L(h_L) + VH_V

S(λ) = F(H_V − h_F) + L(h_L − H_V)

h_F at 60°C and 0.1 NaOH = 215

h_L BPE From chart 0.3 and 128°C = 145°C
h_L = 550 kJ/kg

H_V From s.Table 2127 kJ/kg

Cp = UAΔT = 1500(10)(80 − 145) = 975000

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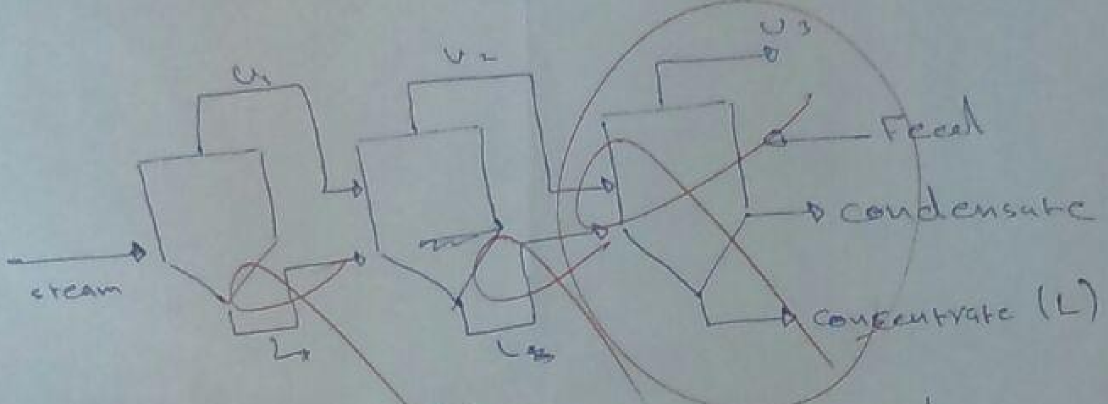
Heat and Mass Transfer Operations **Second semester 2015/2016**

Student name: **Student No.:** 0119318 **Serial No.:** 10

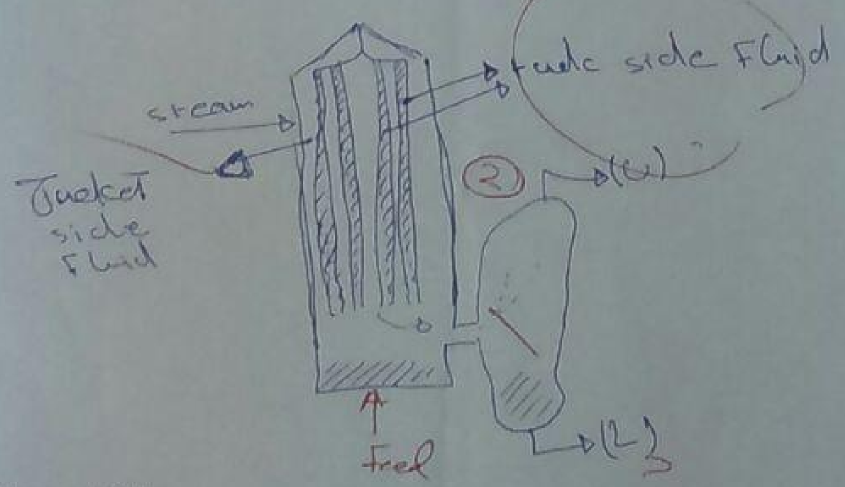
Quiz #1 **February 22, 2016**

- Draw a simplified schematic diagram of **backward-feed double-effect evaporator**. For which cases such arrangement is effective?



Backward is effective than Forward

- Draw a simplified schematic diagram of **vertical-type long-tube evaporator**? What is the tube-side fluid and what is the jacket-side fluid?



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Example. A liquid-liquid ternary phase diagram for isopropyl alcohol (IPA), toluene, and water at 25°C is given below. Feed flow rate is 100 kg/hr, and feed compositions 40 wt% IPA and balance toluene. Fresh solvent is pure water at a flow rate of 100 kg/hr. The outlet raffinate stream contains 3 wt% IPA.

- Show plait point, raffinate, and extract curves.
- Estimate the number of equilibrium stages required.
- The flow rates of the exit extract and raffinate streams.
- Calculate the overall recovery and solute concentration of the extract stream.
- The minimum and reasonable flow rate of solvent.

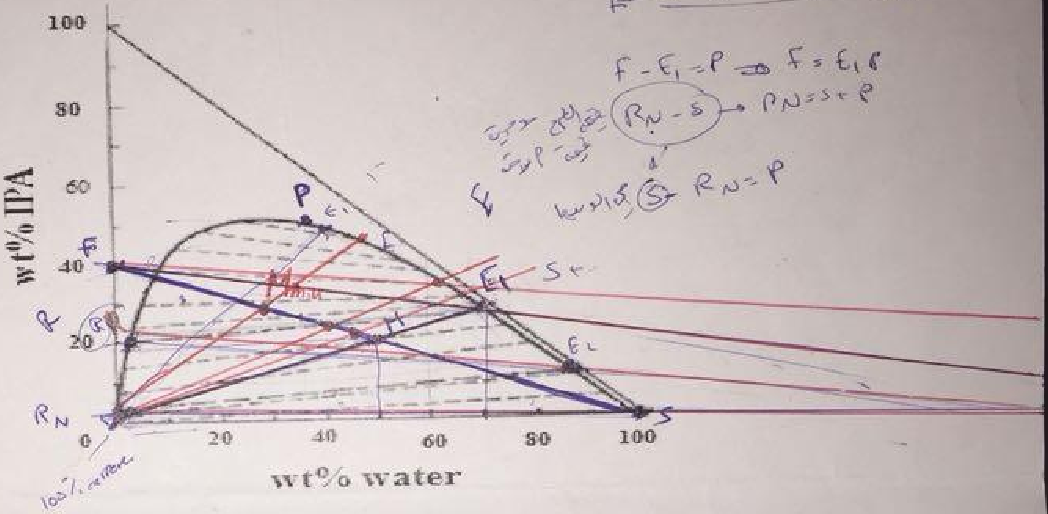
$F = 100$ kg/hr

$x_{solute,F} = 0.4$

$x_{toluene,F} = 0.6$

$S = 100$ kg/hr water

$x_{R_N} = 0.03$



$E_1 \leftarrow$ [N stages] $\leftarrow S$; $F \rightarrow$ [N stages] $\rightarrow R_N$

$F - E_1 = P \Rightarrow F = E_1 + P$

$R_N - S \rightarrow P_N = S + P$

$R_N = P$

$\frac{S}{M} = \frac{100}{200} = \frac{FM}{8}$

$= 0.5 \times 8 = 4 = FM$

$100 = 5.7$ cm

$3 = 0.171$

$\frac{R_N}{M} = \frac{ME_1}{R_N E_1} = \frac{1.7}{5.6} = \frac{R_N}{200} \rightarrow R_N = 60.7$ kg/h

y_{E_1}

$\vec{SP} = E_1$

S, R_N

M, R_N, E_1

R_N — E_1

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Heat and Mass Transfer Operations **First semester 2017/2018**

Student name: Dina ALOsaly **Student No.:** 0143502 **Seat No.:** 22

Quiz #2 **October 29, 2017**

Combined mixer-settler unit is used for extraction of solute A from solute (A) -carrier (C) solution using pure solvent S. A liquid-liquid ternary phase diagram for solute-carrier-solvent is given below. Feed flow rate of solute-carrier solution is 120 kg/hr, and feed compositions 50 wt% (solute) and balance carrier. Fresh solvent is introduced at flow rate of 200 kg/hr. The outlet raffinate stream contains 15 wt% solute.

- **Draw schematic diagram of the combined mixer-settler.**
- **Use phase diagram and lever rule to find the flow rates and concentration of the exit extract streams.**
- **Calculate the overall recovery.**
- **Is it possible to reduce solute concentration to 2.5 wt% in outlet raffinate stream by introducing more solvent? Why?**

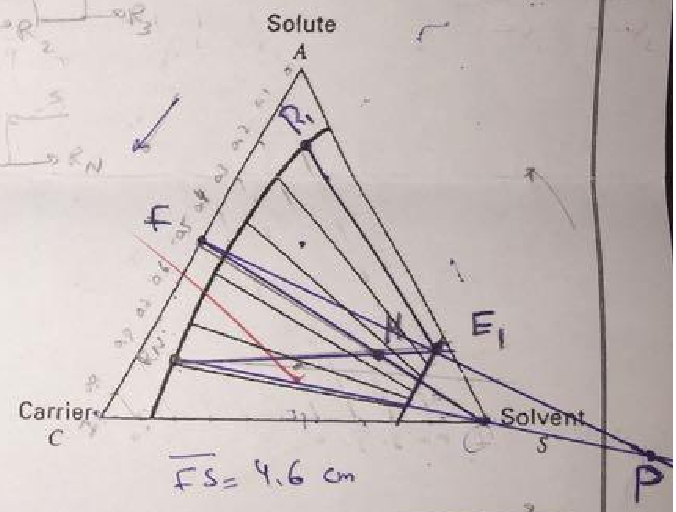
no because it's out of 2phase region

$F = 120 \frac{kg}{hr}$, $S = 200 \frac{kg}{hr}$

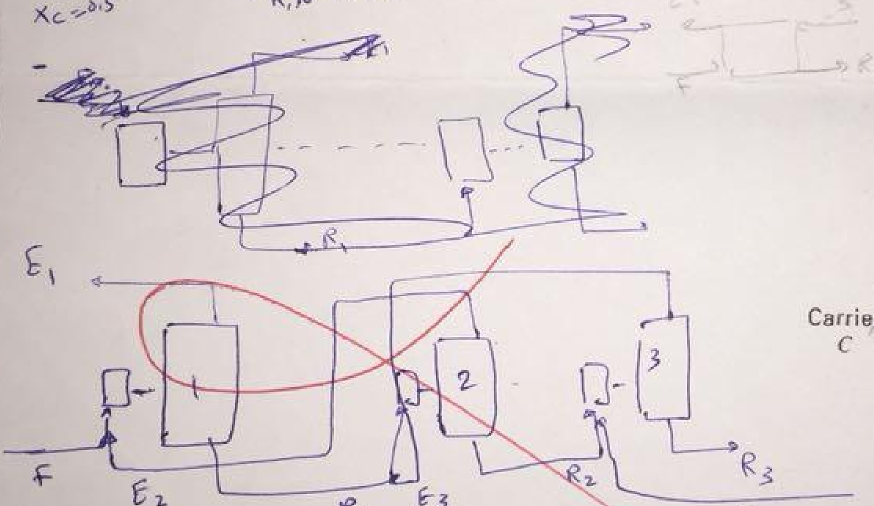
$x_A = 0.5$

$x_C = 0.5$

$x_{R,N} = 0.15$



$\overline{FS} = 4.6$ cm



$I = 5$ cm

$x = 1.1$ cm

$I = 5$ cm

$0.15 = ??$

$x = 0.75$ cm

$F + S = M = E_1 + R_N = 320$ kg/h

$\frac{S}{E} = \frac{200}{320} = \frac{\overline{FM}}{\overline{FS}} = \frac{\overline{FM}}{4.6\text{cm}} \rightarrow \overline{FM} = 2.875$cm

(2)

$\frac{E_1}{M} = \frac{R_N M}{E_1 R_N} = \frac{2.8}{3.8} = \frac{E_1}{320} \rightarrow E_1 = 235.8$ kg/h

$R_N = 84.2$ kg/h

(1)

$y_A = 0.22$

$y_C = 0.01$

$y_S = 0.77$

(2)

- recovery $= 1 - \frac{R x_{rn}}{F x_e} = 1 - \frac{(84.2)(0.15)}{(120)(0.5)} = 0.79 = 79\%$

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First semester 2016/2017

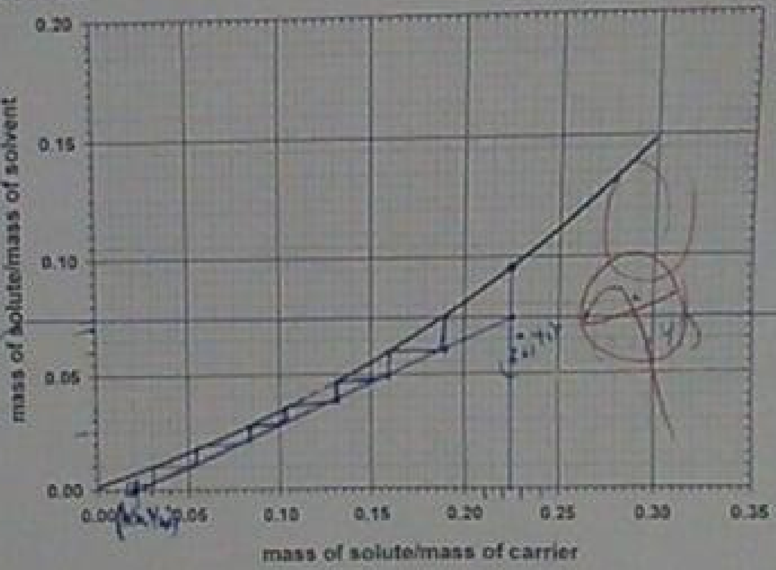
Heat and Mass Transfer Operations

Student name: [handwritten name] **Student No.:** 0119018 **Seat No.:** 7

October 30, 2016

Quiz #2

A feed solution of 1000 kg/h, contains 23 wt% solute and balance carrier, is to be extracted in a countercurrent multistage process with pure solvent of 2200 kg/h in order to reduce the solute concentration to 2 wt% in the final raffinate. The carrier is immiscible in the solvent and the equilibrium curve for solute is given below. Use graphical method to find the number of theoretical stages required. Is the solvent flow rate reasonable? Why? Calculate the percent recovery of solute.



$R' = (0.77)(1000) = 770$

$\therefore Y_1 = 0.098$

$\Rightarrow X_0 = \frac{x}{1-x} = 0.298$

$\Rightarrow Y_1 = 0.098$

$\Rightarrow X_n = \frac{0.02}{1-x_n} = 0.02$

# of stage = 7

- reasonable - cause the stage is away from equilibrium curve

$\text{recovery} = 1 - \frac{R x_n}{F x_F} = 1 - \frac{770(0.02)}{1000(0.23)} = 0.933\%$

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Heat and Mass Transfer Operations **First semester 2017/2018**

Student name: Dina ALOsh **Student No.:** 0143802 **Seat No.:** 22

Quiz #3 **November 15, 2017**

In a single–stage leaching of oil from certain vegetable seeds, 200 kg of the seeds containing 20 wt% oil is leached using pure hexane solvent. The mass ratio of solution to insoluble solid for the slurry underflow is essentially constant at 0.5 kg solution/kg insoluble solid. Find the reasonable amount of solvent required. With such reasonable amount of solvent, calculate the amounts and compositions of the overflow and the underflow slurry leaving the stage.

$x_2 = 0$
V_2??

V_1

L_0

$y_0 = 1$

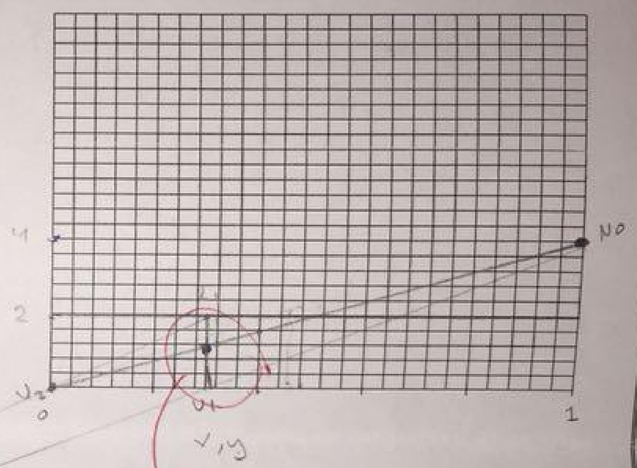
$\frac{L_1}{B} = 0.5$

$L_0 = 0.2(200) = 40$ kg
$B = 160$ kg
Feed = 200 kg

$N_0 = \frac{B}{L_0} = 4 \frac{\text{kg solid}}{\text{kg solution}}$

$N_1 = 2 \frac{\text{kg solid}}{\text{kg solution}}$

$N_1 = \frac{B}{L_1} \rightarrow L_1 = 80$ kg



$L_0 + V_2 = L_1 + V_1$

$40 + V_2 = 80 + V_1$

$y_1 =$

$V_{2min} \rightarrow$

$y = x$

$V = 1.5 V_{min}$

$(40)(1) + V_2(0) = (80) y_1 + V_1 x_1$

$40 = x(80 + V_1)$

$x_1 = y_1 = 0.153$

$\frac{L_1}{V} = \frac{1.1 \text{ cm}}{0.4 \text{ cm}} = \frac{80}{V}$

$V_1 = 181.81$ kg

$V_2 = 221.81$ kg

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Heat and Mass Transfer Operations — **Second semester 2016/2017**

Student name: فرح مصطفى محمد — **Student No.:** 2131139 — **Seat No.:** 53

Quiz #4 — **March 18, 2017**

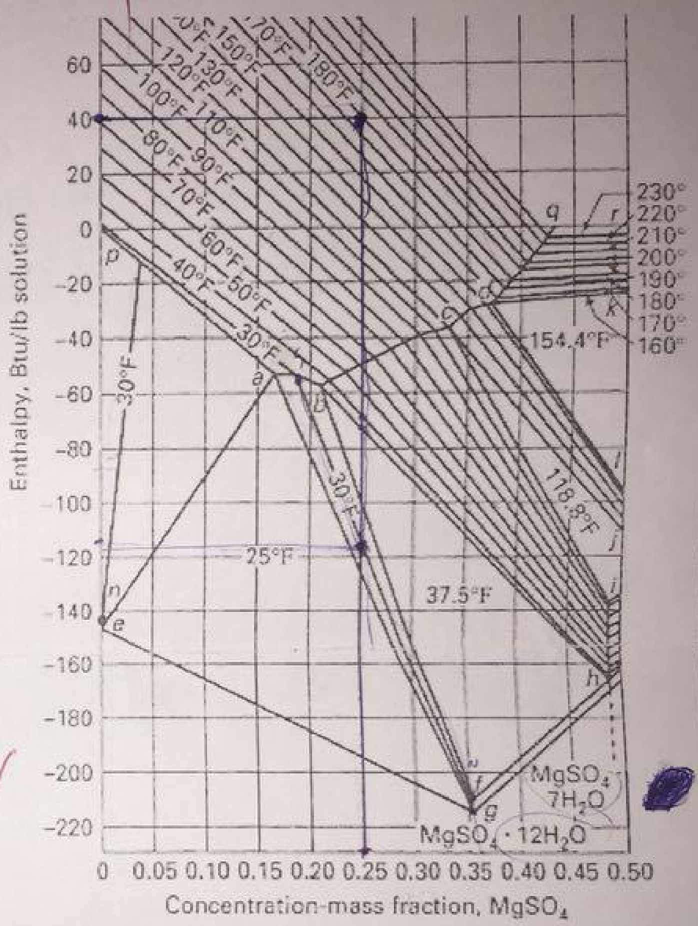
$MgSO_4$ aqueous solution contains 33.5 lbm $MgSO_4$/100 lbm total water and temperature of 180 °F. This solution is fed to cold crystallizer at rate of 1000 lbm/h in order to produce crystals. The crystallizer operates at 30 °F. Assume that no water is vaporized from crystallizer.

a) Which type of hydrated crystals is going to be produced at these conditions?

b) Estimate the solubility of $MgSO_4$ in water at 30 °F.

c) Calculate the yield of crystals.

d) Estimate the required cooling rate.



$F = 1000$ lbm/h → 30°F → W, S, C

$\left(\frac{33.5}{33.5+100}\right)100 = 25\%$ $MgSO_4$

$\left(\frac{100}{33.5+100}\right)100 = 75\%$ water

$h_1 = 40$ btu/lb solution.

$h_2 = -115$ btu/lb

$q = F(h_2 - h_1)$

$q = (S + C)h_2 + h_v W - h_1 F$

$q = F\bar{C}_p(T_2 - T_1) - C\,\Delta h_{crys} - h_v W$

$0.17 = \frac{x}{x+100}$

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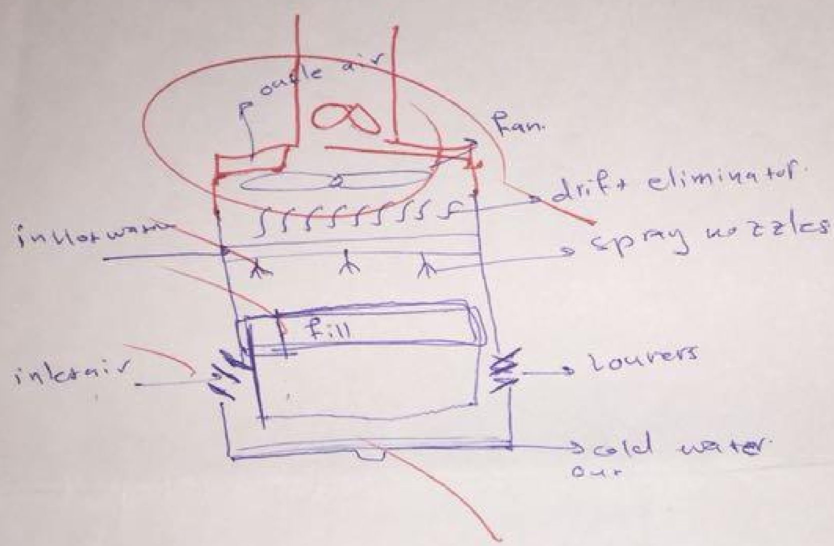
Heat and Mass Transfer Operations **First semester 2017/2018**

Student name: Dina Al-Osah **Student No.:** 0143502 **Seat No.:** 22.

Quiz #5 **December 21, 2017**

Draw a schematic diagram of the "Induced draft counter-flow cooling tower with packing". Show on the diagram all inlet/outlet streams, drift eliminator, louvers, fan, spray nozzles, and packing.



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Heat and Mass Transfer Operations — **Second semester 2016/2017**

Student name: فرح مصطفى محمد **Student No.:** 2131139 **Seat No.:** 53

Quiz #5 — **May 2, 2017**

Air enters a cooling coil of dehumidifier with flow rate of 3 m³/min, dry bulb temperature of 97 °C, and wet bulb temperature of 55 °C. The air leaves the dehumidifier at 47 °C with percentage humidity of 20%. a) Find the condensation rate of water; Find the rate of cooling required in kW.

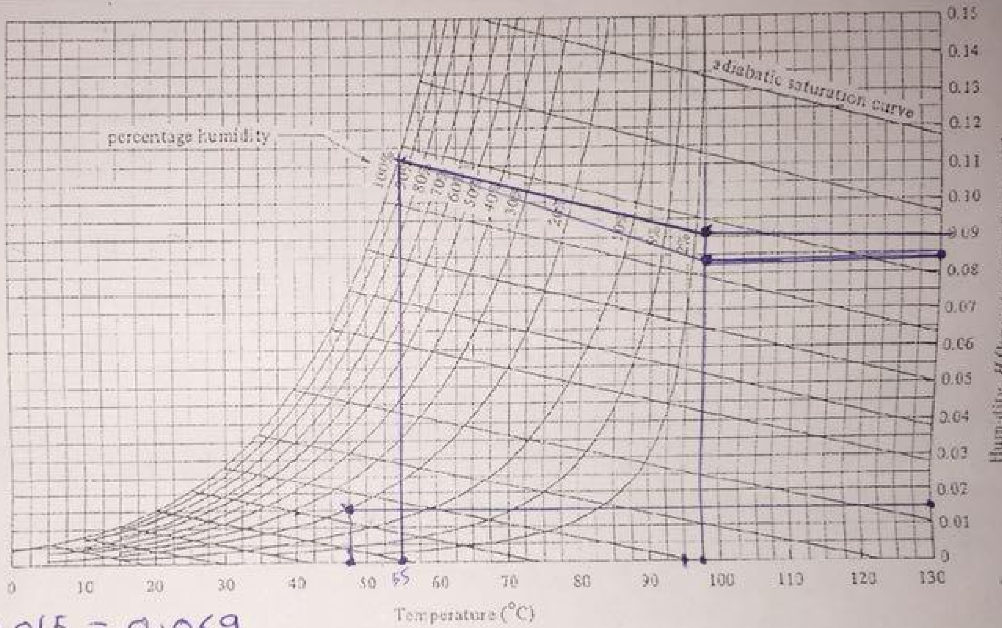
C_s [kJ/(kg dry air.K)]=1.005+1.88H ; v_H[m³/kg dry air]=(2.83×10⁻³+4.56×10⁻³H) ×T(K)

H_y[kJ/kg dry air]=1.005+1.88H×T(°C)+2502.3H

$H_1 = 0.084$

$H_2 = 0.015$

~~ΔH = ...~~



$\Delta H = 0.084 - 0.015 = 0.069$

~~mass flow rate = $\frac{3}{\Delta H} = \frac{3}{0.069} = 43.47$~~

$C_s = 1.005 + 1.88(0.084) = 1.16292$

$v_H = (2.83 \times 10^{-3} + 4.56 \times 10^{-3}(0.084)) \times 370 = 1.1888$

$\frac{\dot{V}}{v_H} =$ condensation rate

$H_y = 1.005 + 1.88(0.084) \times (97) + 2502.3(0.084)$

~~= 211.3~~ =

H_{y_1} ΔH_y, $Q = \Delta H_y \times$

H_{y_2}

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