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Faculty of Engineering & Technology
Chemical Engineering Department

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كلية الهندسة و التكنولوجيا
قسم الهندسة الكيميائية

$\frac{2}{10}$

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

Student name: **Student No.:** [redacted] **Seat No.:** [redacted]

Quiz #3 **March 23, 2017**

2000 lbm of waxed paper per day is to be dewaxed in a continuous countercurrent multistage leaching. The waxed paper contains, by weight, 25% paraffin wax and 75% paper pulp. Pure kerosene is used as solvent to leach paraffin wax. The flow rate of paraffin wax in the final underflow slurry is 20% of the paraffin wax flow rate fed to the battery. Experiments show that the underflow slurry from each stage is essentially contains 2 lb of paraffin wax-kerosene solution per 3 lb of insoluble paper pulp. Use N-xy diagram to:

a. Find the reasonable flow rate of kerosene stream introduced to the leaching battery.

b. Determine the corresponding flow rate and composition for the overflow exit stream leaves leaching battery.

V_1, $x =$ ← [N stage] ← V_{n+1}, $x_{n+1} = 0$

2000 → $L_N = 250$ lbm

$L_A = 500$, $B = 1500$, $y_0 = 1$

$N_0 = \frac{1500}{500} = 3$

$L_{NA} = 20\% * 500$

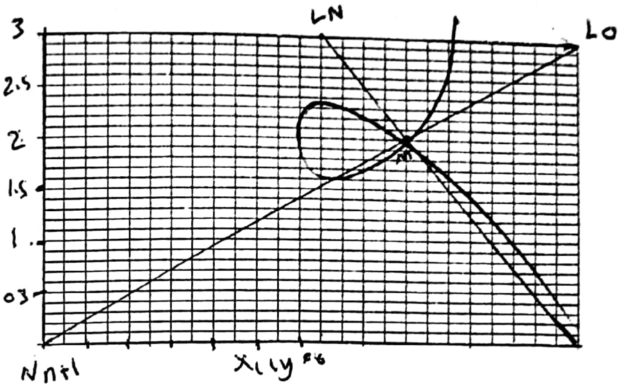
$L_{NA} = 100$ lbm

$\frac{L_{NA}}{L_{NC}} = \frac{2}{3}$

$L_{NC} = \frac{100*3}{2}$

$L_{NC} = 150$

$y_{AN} = 0.667$



$L_0 = 2000 * 0.25 = 500$ lbm

$B = 2000 * 0.75 = 1500$ lbm

$* \; M = L_0 + V_{n+1}$

$\frac{S_{min}}{(L_N)\,250} = \frac{1.8}{4.8}$

$S_{min} = 93.75$ lbm

$S_{res} = 1.55 * S_{min}$

$= 145.3125$ lbm

solution balance:

$500 + 145.31 = 250 + V_1$

$V_1 = 395.31$ lbm

solute balance:

$V_1 x_1 + L_N y_N = V_{n+1} * \text{zero} + y_0 L_0$

$395.31 * x_1 + 250 * 0.667 = 1 * 500$

$x = 0.8$

$L_0 + V_{N+1} = L_N + V_1$

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

Student name: [redacted] **Student No.:** [redacted] **Seat No.:** 35

Quiz #3 **March 23, 2017**

2000 lbm of waxed paper per day is to be dewaxed in a continuous countercurrent multistage leaching. The waxed paper contains, by weight, 25% paraffin wax and 75% paper pulp. Pure kerosene is used as solvent to leach paraffin wax. The flow rate of paraffin wax in the final underflow slurry is 20% of the paraffin wax flow rate fed to the battery. Experiments show that the underflow slurry from each stage is essentially contains 2 lb of paraffin wax-kerosene solution per 3 lb of insoluble paper pulp. Use N-xy diagram to:

a. Find the reasonable flow rate of kerosene stream introduced to the leaching battery.
b. Determine the corresponding flow rate and composition for the overflow exit stream leaves leaching battery.

Feed 2000 lbm

(A) = 0.25 × 2000 = 500 lbm solul. (paffin wax)

paper pulp = 1500 lbm. = (0.75×2000)

$L_0 = (0.25)(2000)$

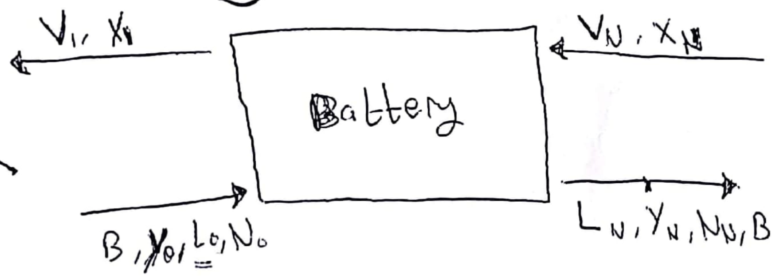
$N_0 = \frac{1500}{\text{solution}} = \frac{1500}{L_0}$

$\frac{2 \text{ solution}}{3 \text{ paper pulb}} \rightarrow N = \frac{3}{2} = 1.5$

in each stage

so →

$L_0 = \frac{1500}{1.5} = 1000$



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

Student name: [redacted] **Student No.:** [redacted] **Seat No.:** 34

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.

B = 200 kg
0.2 % oil leaching
0.5 kg solution / kg insoluble

V_1, L_0, N_0, B — V_2, x_0 — L_1, B

$N = \frac{B}{L}$

$M = V_1 + L_0 = V_2 + ...$

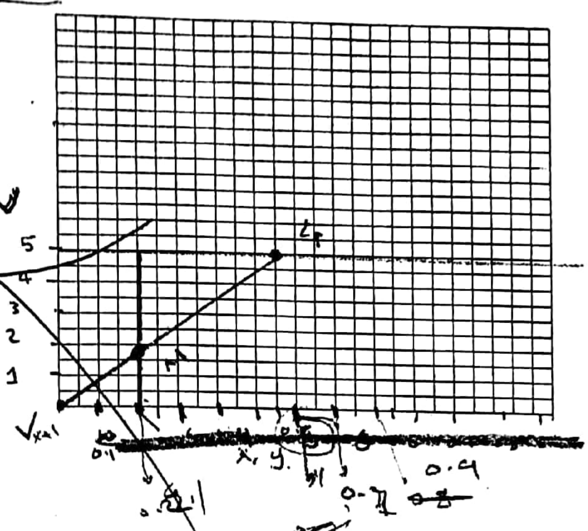
= 200 * 0.2 = 40

$N = \frac{B}{L} = \frac{200}{40} = 5$

pure hexane $x_2 = 0$

$y = 0.5$

$\frac{V}{M} = \frac{L_0 M}{x_0 V}$



200 kg
0.5 kg

$\frac{y_{N+1}}{N}$

200 kg seed
20 %
0.5 solution

200 * 0.5 = M = 200.5 kg

Lo = ?

$N = \frac{B}{L} = \frac{200}{0.5} = 400$

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Heat and Mass Transfer Operations — Second semester 2016/2017

Student name: [redacted] Student No.: [redacted] Seat No.:

Quiz #4 — March 18, 2017

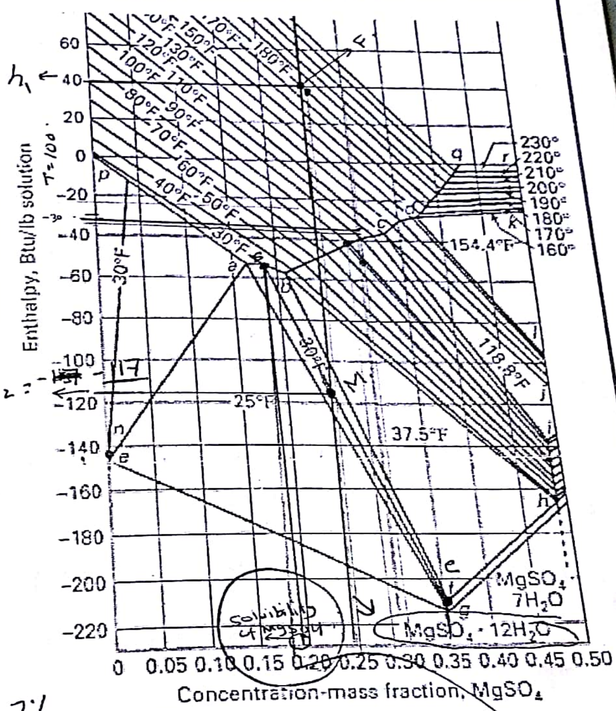
$MgSO_4$ aqueous solution contains 33.5 lbm $MgSO_4$/100 lbm total water and temperature of 180 °F. This solution is fed to cold crystallizer at rate of 1000 lbm/h in order to produce crystals. The crystallizer operates at 30 °F. Assume that no water is vaporized from crystallizer.

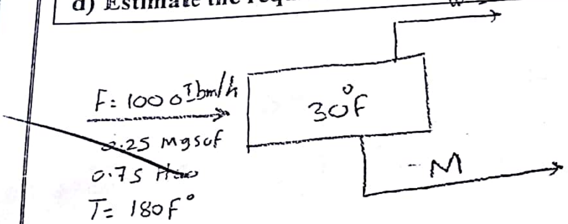
a) Which type of hydrated crystals is going to be produced at these conditions?

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

c) Calculate the yield of crystals.

d) Estimate the required cooling rate.





S =
MgSO4 = 19%
H2O = 81%

C
MgSO4 = 35.7% = Mwt MgSO4 / Mwt MgSO4·12 = 120 / (120 + 12×18)

H2O = 64.3%

ⓐ crystal hydrate type: MgSO4 · 12 H2O

X = 0.19 lbm MgSO4 / lbm sdut

solubility = 0.19 lbm / 0.81 lbm H2O × 100/100

ⓑ solubility = 0.19 lbm MgSO4 / 100 lbm total water

This is not solubility

This is X! Convert it to solubility

M = F = 1000 lbm/h.

by Lever Rule.

SM/SC = C/M

2.5/6.5 = C/1000

C = 384.6 lbm/h

ⓒ yield = Amount of crystal = 384.6 lbm/h

d)

q = h₂M − F*h₁

q = −117*1000 − 1000*40

q = −157*10⁺³ Btu/lbm solutio

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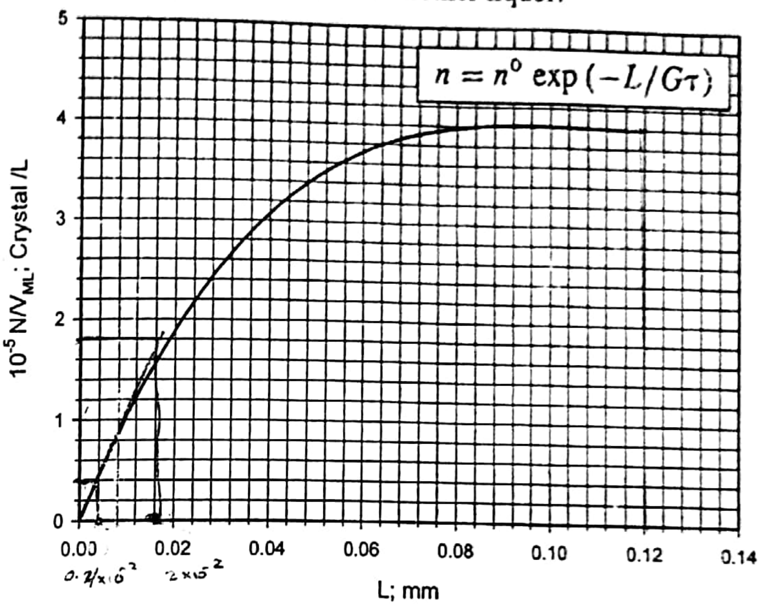
Heat and Mass Transfer Operations **First semester 2016/2017**

Student name: [redacted] **Student No.**[redacted] **Seat No.:**١٩

Quiz #4 **December 6, 2016**

Screen analysis (Tyler Standard Screen Scale) for crystal samples of certain salt resulted in the curve shown below with crystal growth rate of 0.15 mm/h. The crystallizer has a residence time of 2 h. Find the nucleation rate B^o and the total number of crystals, N_T, per unit volume of mother liquor:



$B^o = n_o G$

n_o = slop = $\frac{\Delta(N/V_{ML})}{\Delta L}$

$= \frac{(1.8\times10^{-5} - 0.4\times10^{-5})}{0.02-0.004}$

$n_o = 8.75\times10^{-4}$ $\frac{\text{Crystal}}{mm.L}$

$B^o = 8.75\times10^{-4} * 0.15$

$B^o = 1.31\times10^{-4}$ $\frac{\text{Crystal}}{L.h}$

$n = n^o \exp(\frac{-L}{G\tau})$

$= 8.75\times10^{-4} * \exp(\frac{0.12}{0.15*2})$

~~$n = 5.8\times10^{-4}$ $\frac{\text{Crystal}}{L.h}$~~

$N_T =$

$B^o = n^o G$

$B^o = n_o G^o$

n_o = slop = $\frac{(2-0.4)\times10^{5}}{0.2-0.4\times10^{-2}} = 1\times10^{7}$

$B^o = 1\times10 \times 0.15 = 1.5\times10^{6}$ C/L.h

$n = 1\times10^{7}\exp(-0.12/0.15*2)$

$n = 6.7\times10^{6}$ Cr.

$\frac{N}{V_{ML}} = \int n$

$\frac{N_T}{V_{ML}} = \int_0^{\infty} n = \int_0^{0.12} n\,dL = n\Delta L$

$= 6.7\times10^{6}(0.12-0)$

$N_T = 8.04\times10^{5}$ Crystal

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

Student name: [redacted] **Student No.:** [redacted] **Seat No.:** 34

Quiz #4 **December 3, 2017**

Use the following moment equation to find the cumulative and differential crystal distribution equations (on length basis) for constant growth rate:

$x_K = \frac{\int_0^z n z^k dz}{\int_0^\infty n z^k dz}$ $k=1$

$$x_k = \frac{\int_0^z nz^k\,dz}{\int_0^\infty nz^k\,dz}$$

Cumulative

(length)

$k = 1$

Cumulative

$x_L = 1 - (1+z)e^{-z}$

differential

$\frac{dx_L}{dz} = ze^{-z}$

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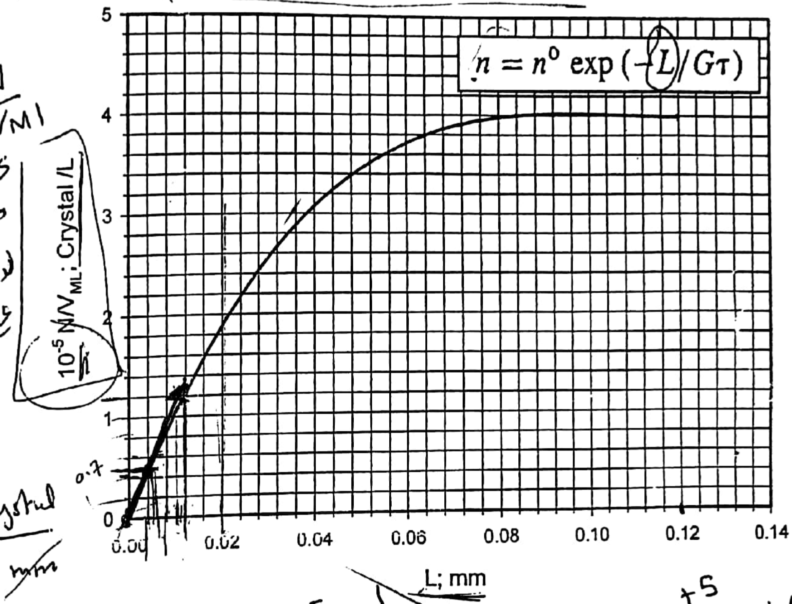
Heat and Mass Transfer Operations — **First semester 2016/2017**

Student name: [redacted] **Student No.:** [redacted] **Seat No.:** 25

Quiz #4 — **December 6, 2016**

Screen analysis (Tyler Standard Screen Scale) for crystal samples of certain salt resulted in the curve shown below with crystal growth rate of 0.15 mm/h. The crystallizer has a residence time of 2 h. Find the nucleation rate B^o and the total number of crystals, N_T, per unit volume of mother liquor:



$G = 0.15\ mm/h$

$\tau = 2h$

$B^o = G \cdot n^o$

n^o = slope @ $L = 0$

$B^o = 0.15\ \frac{mm}{h} \times 1\times10^{+7}\ \frac{Crystal}{L.mm}$

$= 1.5\times10^{+6}\ \frac{Crystal}{h.L}$

Slope $= \frac{0.5 - 1}{5\times10^{-3} - 0.01} = 100\times10^{+5}\ \frac{Crystal}{L.mm}$

$B^o = G n^o$

$N_T = \int_0^{0.12} n^o \exp^{-L/G\tau}\, dL$

$\frac{n^o e^{-L/G\tau}}{-1/G\tau}\Big|_0^{\infty} = \frac{1\times10^{-3} \times e^{-0.12/2\times0.15}}{-1/(0.15\times2)} + n^o e^{zero} \cdot G\tau$

$N_T = 98.04\times10^3\ \frac{Crystal}{L}$

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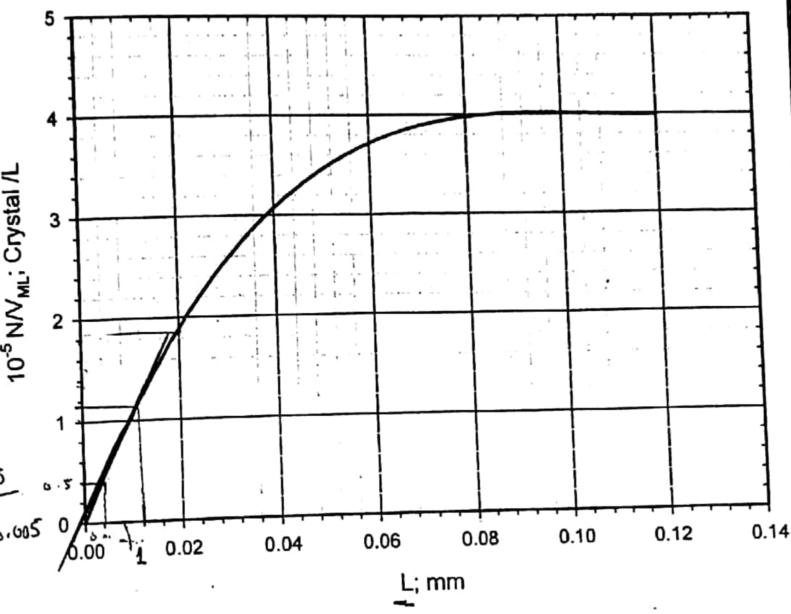
Heat and Mass Transfer Operations **Second semester 2015/2016**

Student name: [redacted] **Student No.** [redacted] **Serial No.:** 52

April 20, 2015

Quiz #4

a) If a crystal growth of some salt is G=0.15 mm/h, use the experimental curve below to approximate the nucleation rate B^o:



$\lim \frac{1}{V_{ml}} \frac{dN}{dt} = B^o$

(2)

~~$B^o = G n^o$~~

$n = n^o \exp(-L/G\tau)$

$1.8 \times 10^{-5} = n^o \exp(-0.02/0.15\tau)$

slope$_1$ = n^o

slope$_2$ = n n^o = slope = $\frac{1.1 - 0.5}{0.012 - 0.005}$

$B^o = G n^o$

b) For two-step theory, use diffusion and reaction rate equations to derive the following crystal growth overall coefficient:

$$\frac{1}{K_c} = \frac{1}{k_c} + \frac{1}{k_i}$$

Mention two significant parameters that affect such coefficient.

Diffusion–reaction Rate.

(1) mass transfer of solute from bulk of solution to the crystall solution

$\frac{dm}{dt} = k_c A (C - C_i)$

(2) pseudo First order rxn occure the crystall–solution interface.

$\frac{dm}{dt} = k_i A (C_i - C_s)$

$\frac{dm}{dt} = \frac{A(C - C_s)}{1/k_c + 1/k_i}$

→ k_c ~~[illegible]~~ depend velocity of the soluction determine, degree of aggitation. (R_e)

→ At low velocity → the growth rate controlled by mass transfer step

Overall Coeff (K_c) $\frac{dm}{dt} = K_c A (C - C_s)$

$$\frac{1}{K_c} = \frac{1}{k_c} + \frac{1}{k_i}$$

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

Student name: [redacted] **Student No.:** [redacted] **Seat No.:** 8

Quiz #4 **March 18, 2017**

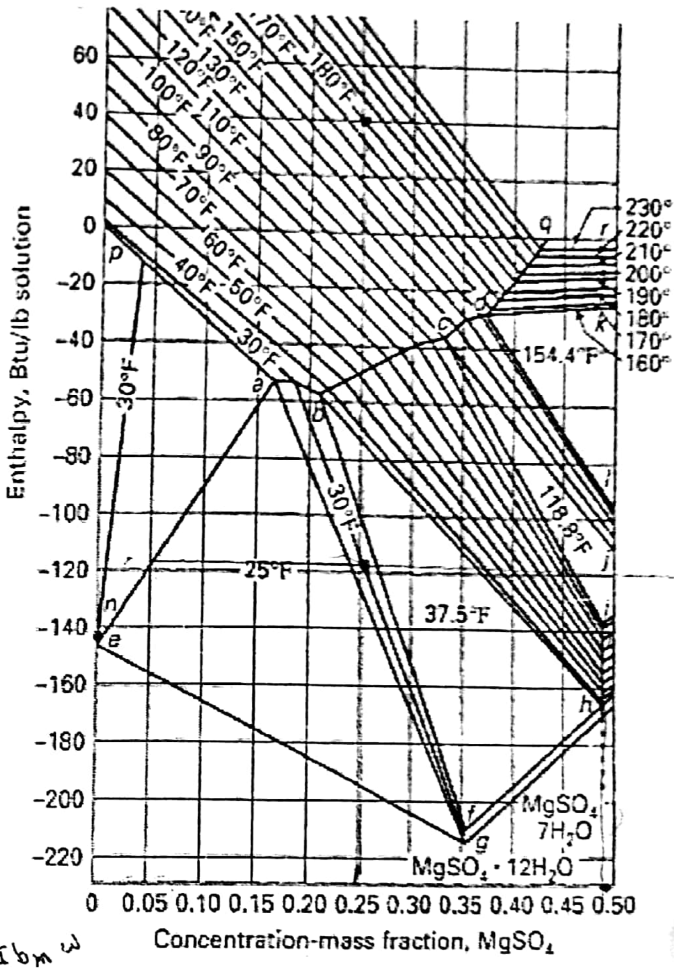
$MgSO_4$ aqueous solution contains 33.5 lbm $MgSO_4$/100 lbm total water and temperature of 180 °F. This solution is fed to cold crystallizer at rate of 1000 lbm/h in order to produce crystals. The crystallizer operates at 30 °F. Assume that no water is vaporized from crystallizer.

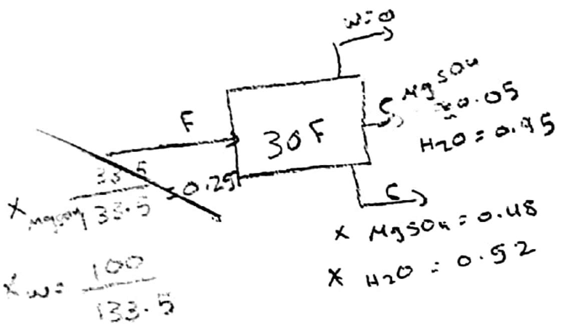
a) Which type of hydrated crystals is going to be produced at these conditions?

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

c) Calculate the yield of crystals.

d) Estimate the required cooling rate.





a) ~~MgSO4 7H2O~~

b) Solubility = 5/105 → Assum 100 lbm w

Solubility = 0.05 lbm MgSO4 / 100 lbm for water.

c) ~~0 = 0.95 S~~ + 0.52 C

1000 = S + C ⇒ ~~C = 1000 - S~~

0 = 0.95 S + 0.52 (1000 - S)

S = 353.74 lbm

~~C = 646.26 lbm~~

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Done.

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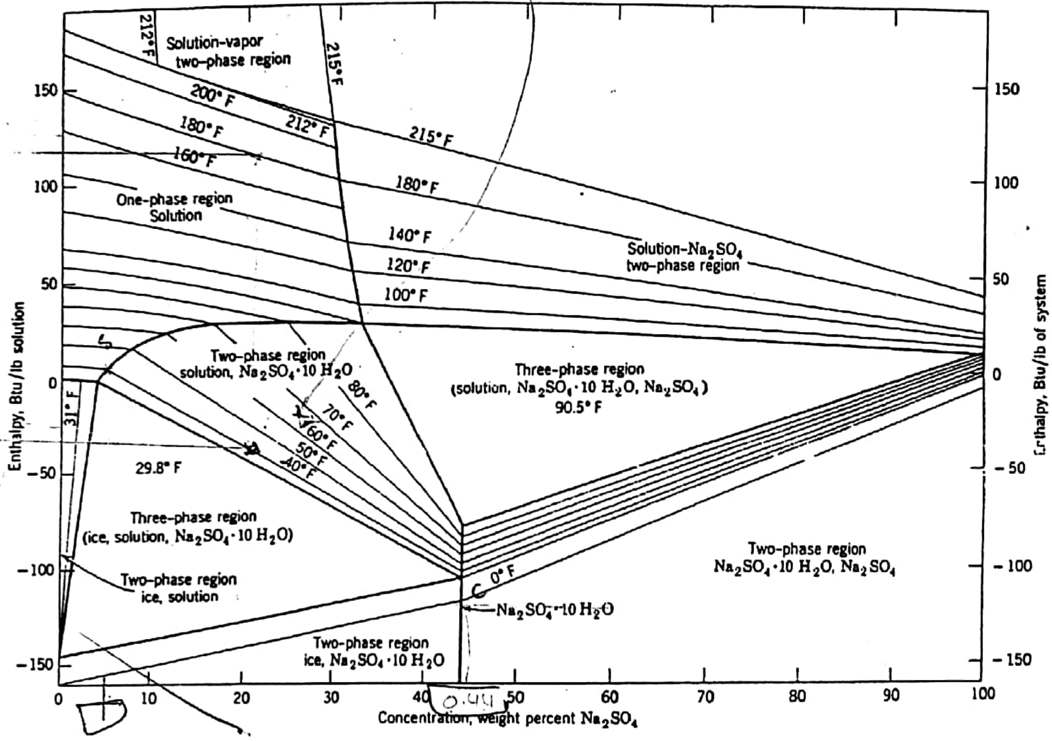
Heat and Mass Transfer Operations **Second summer semester 2016/2017**

Student name: [redacted] **Student No.:** [redacted] **Seat No.:** 15 .

Quiz #4 **August, 22, 2017**

A 500 lbm/h aqueous solution of Na_2SO_4 (25 kg Na_2SO_4/100 kg H_2O) at 180 °F is fed continuously to a crystallizer in which the equilibrium temperature is 40 °F. Neglect the amount of water evaporated.

a. Are the resulted crystals anhydrous or hydrated? Why? If they are hydrated which type of hydrated crystal will be produced? Hydrated , $Na_2SO_4 \cdot 10H_2O$
b. Find the solubility of solution inside the crystallizer.
c. Calculate the yield of crystals using lever rule.
d. Calculate the net heat added/removed from crystallizer. ?



$\frac{25}{100+25}$

W=0

500, 0.2 Na_2SO_4, 0.8 H_2O, $T_F = 180°F$ → S, C

* 40°F

F = S+C F=HI

لم نقطه المنحنى

~~solubility of the solution:~~

$\overline{SC} = 5.9\,cm$

$\overline{SF} = 2.4\,cm$

$\frac{C}{F} = \frac{SF}{SC}$

$C = (F)\left(\frac{SF}{SC}\right)$

$C = (500)\left(\frac{2.4}{5.9}\right)$

C = 203.38

S = 296.61

$q = -Fh_1 + Mh_2$

$q = -(500)(120) + 500(-37.5)$

$q = -78750$

solubility of the solution:-

$\frac{0.05}{0.05+0.44}$

$100 * \frac{0.05}{0.95}$

$= 0.1020 \frac{kg\ Na_2SO_4}{kg\ solution}$

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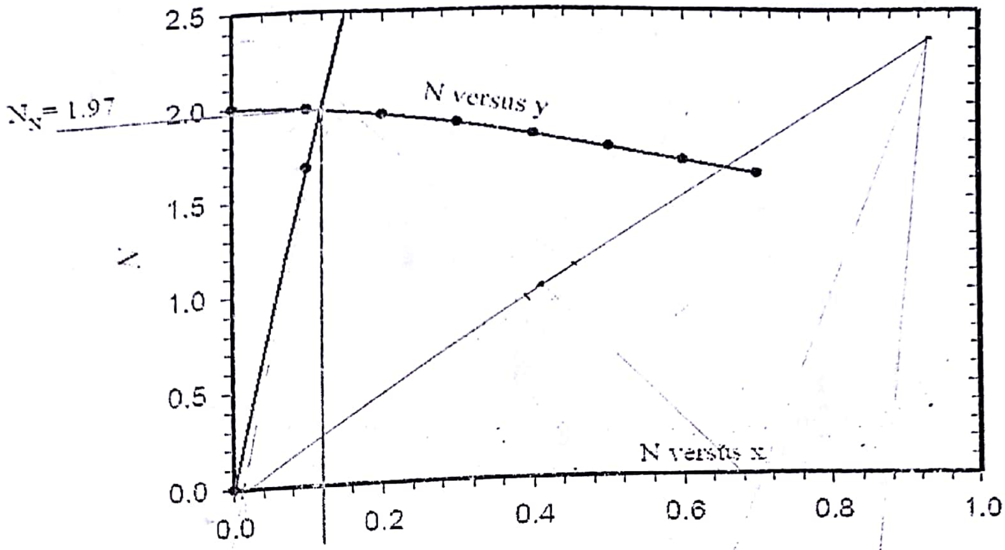
0.015



L_N 120 L

$$N = \frac{\frac{kg\ inert}{kg}}{\frac{y_N\ kg\ oil}{kg\ solut}}$$

$$N_N = \frac{kg\ solid}{kg\ solut} = \frac{\frac{kg\ sol}{kg\ solut}}{\frac{kg\ so}{kg\ solut\ y_N}}$$

$$\frac{kg\ sol}{kg\ sol} = y_N$$

$$N_N = \frac{2000}{120} y_N$$

$$N_N = 16.67\ y_N$$