CE 407 Exam 1 SOLUTION

Problem 1

General $x_F = 0.65$, $x_D = 0.97$, $x_B = 0.025$

Feed line passes through pt. $(x_F, x_F) = (0.65, 0.65)$ and is horizontal (slope = 0) because feed is saturated vapor

(Not required: From graph on p. ②, $x_D/(R_{min}+1) = 0.50 \Rightarrow$ $\boxed{R_{min} = 0.94}$)

Part (a): R-op. line passes through pt $(x_D, x_D) = (0.97, 0.97)$ and has intercept $x_D/(R+1) = 0.30$.

S-op. line passes through pt. $(x_B, x_B) = (0.025, 0.025)$ and pt of intersection of R-op & feed lines.

Draw effective equil. curve 3/4 of the way up from op. lines to equil. curve because $\eta_m = 0.75$.

Stages: Do not use eff. equil. curve for 1st step, which represents partial condenser. Count steps thereafter, & do not use eff. equil. curve for last step, which represents reboiler. From graph on p. ③, need $\boxed{6 \text{ stages}}$ in the column itself. Feed stage is stage # 3.

(perhaps 7 to be sure)

Part (b): $D = F\left(\frac{x_F - x_B}{x_D - x_B}\right) = \left(90 \frac{mol}{h}\right)\left(\frac{0.65 - 0.025}{0.97 - 0.025}\right)$

$= 52.9$ mol/h

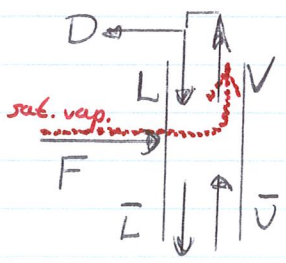
$R = \frac{L}{D} \Rightarrow L = RD = (2.23)(52.9) = 118.0$ mol/h

$V = L + D = 170.9$ mol/h

$\bar{V} = V - (1-q)F$ ⑤ $= V - F = \boxed{90.9 \text{ mol/h}}$

$R = L/D$

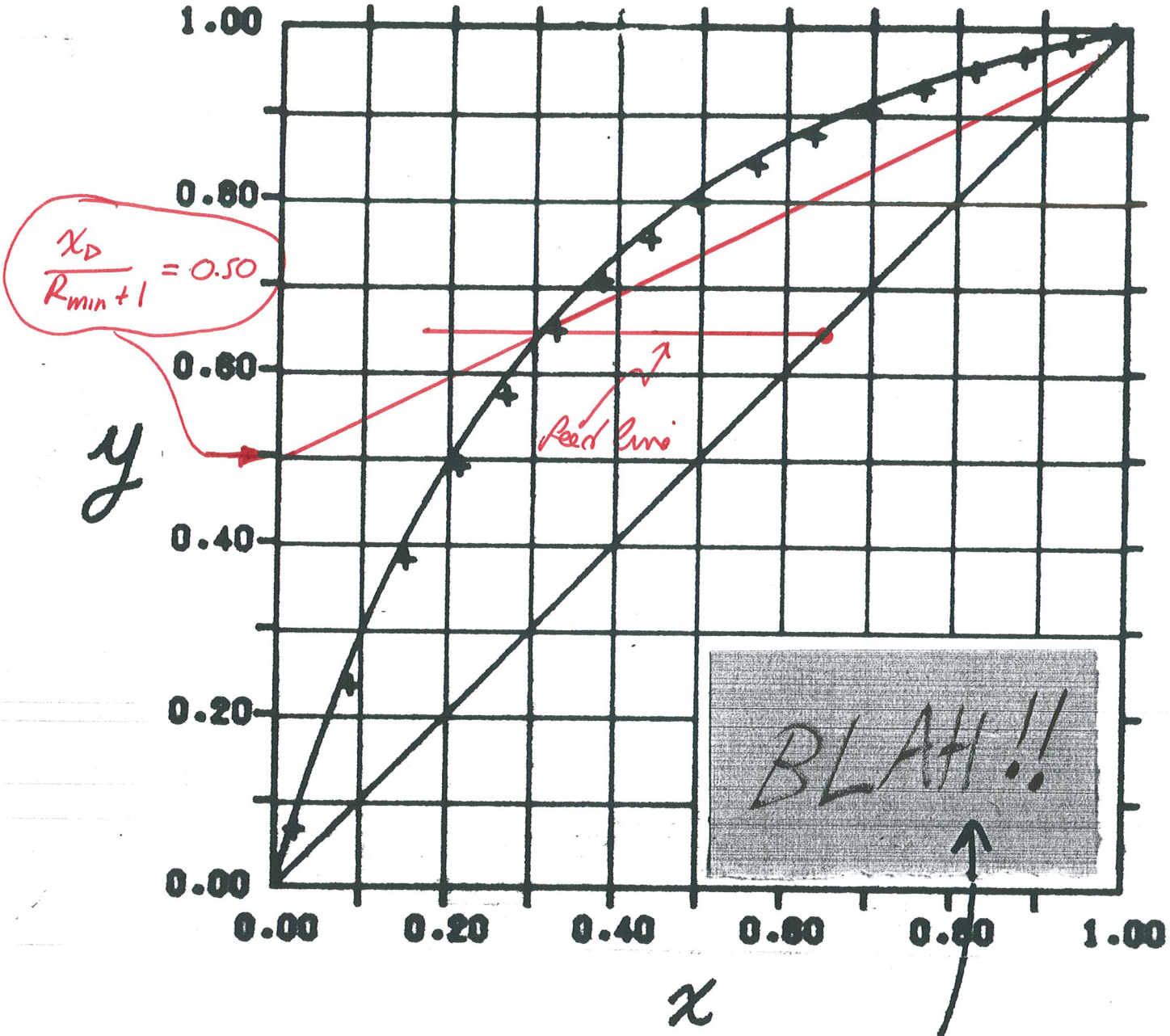
$\bar{L} = L + qF$



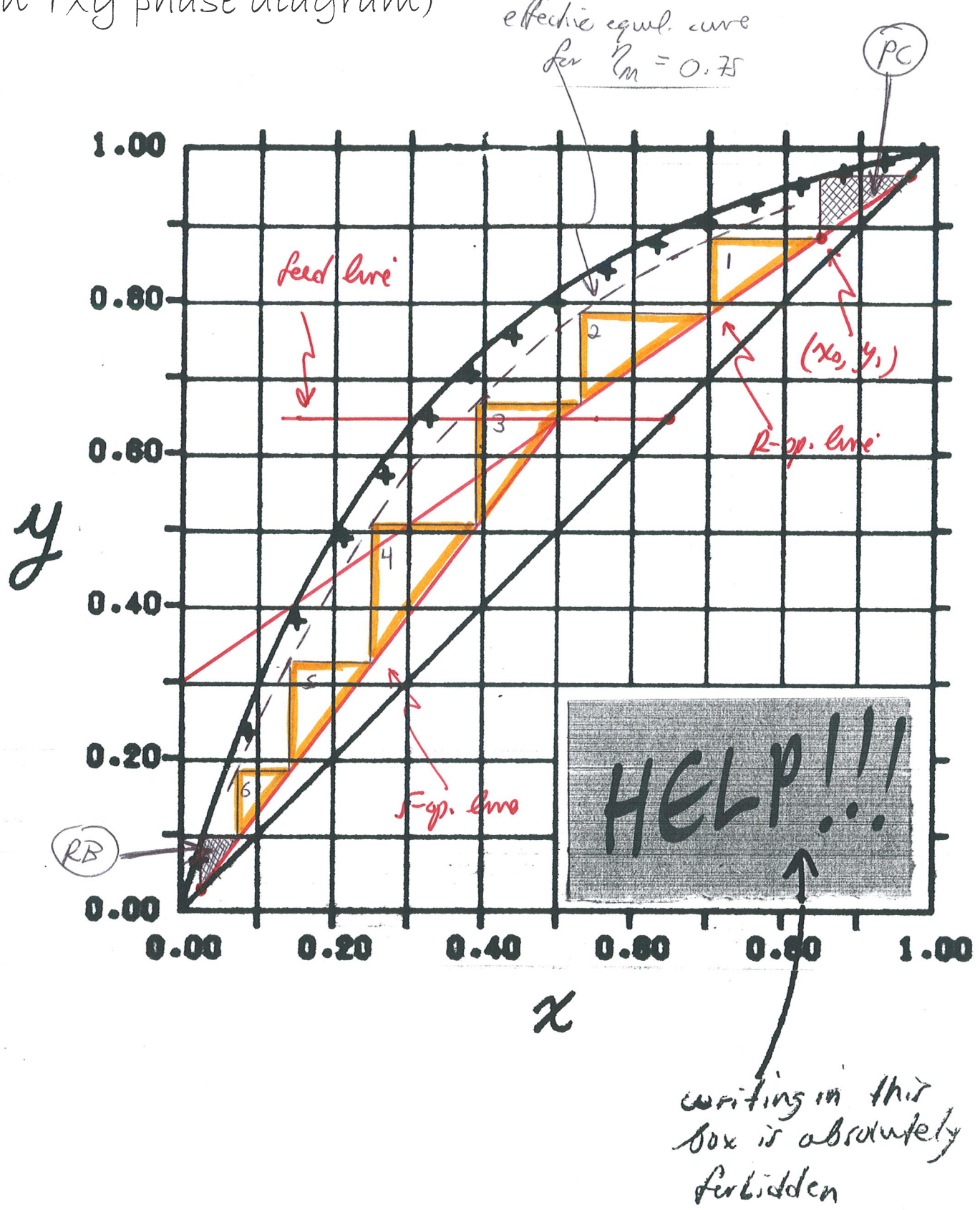
$V = \bar{V} + (1-q)F$

0

(Get xy pairs from a few horizontal lines drawn in Txy phase diagram)



(Get xy pairs from a few horizontal lines drawn in Txy phase diagram)



Part (c): Enthalpy formula:

$(H_y)_1 = 0 + 29,300 + 90(T-77)$

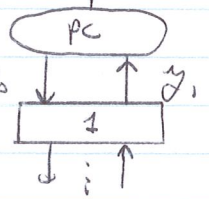
$(H_y)_2 = 0 + \underbrace{(270)(125.5-77)}_{\ell,\ 77°C \to 125.5°C} + \underbrace{33,900}_{\ell \to v \text{ at } 125.5°C} + \underbrace{260(77-125.5 + T - 77)}_{v,\ 125.5°C \to T}$

$= 34,285 + 260(T-77)$

$H_y = y(H_y)_1 + (1-y)(H_y)_2$

$= 34,285 - 4985y + (260-170y)(T-77)$

Vapor entering PC: $x_D = y'$ (see p. 5; or p. 3)



$y' = x_D = 0.97$

$x_0 = x$ in equil. w/ $y = 0.97$

$= 0.85$

$y_1 = [R/(R+1)]x_0 + x_D/(R+1) = 0.887$ (or look on op. diagram (p. 3) and see from pt. (x_0, y_1) that $y_1 \approx 0.89$).

Also, from Txy phase diagram, $T_{y_1} \approx 88°C$.

Enthalpy: With $y = 0.887$ and $T = 88°C$, calculate

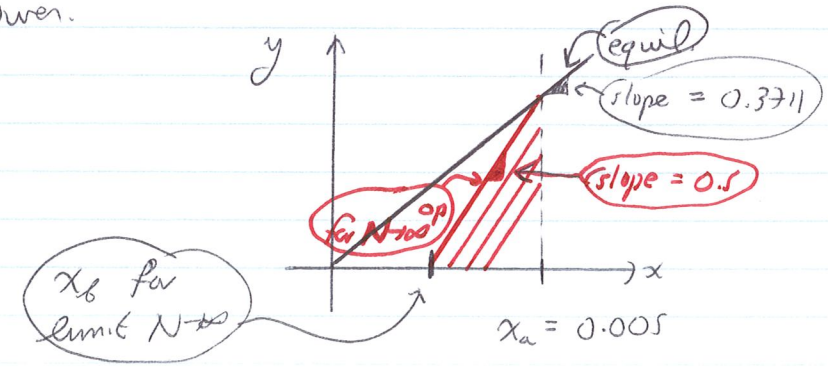
$\boxed{H_{y,1} = 31,055 \text{ J/mol}}$

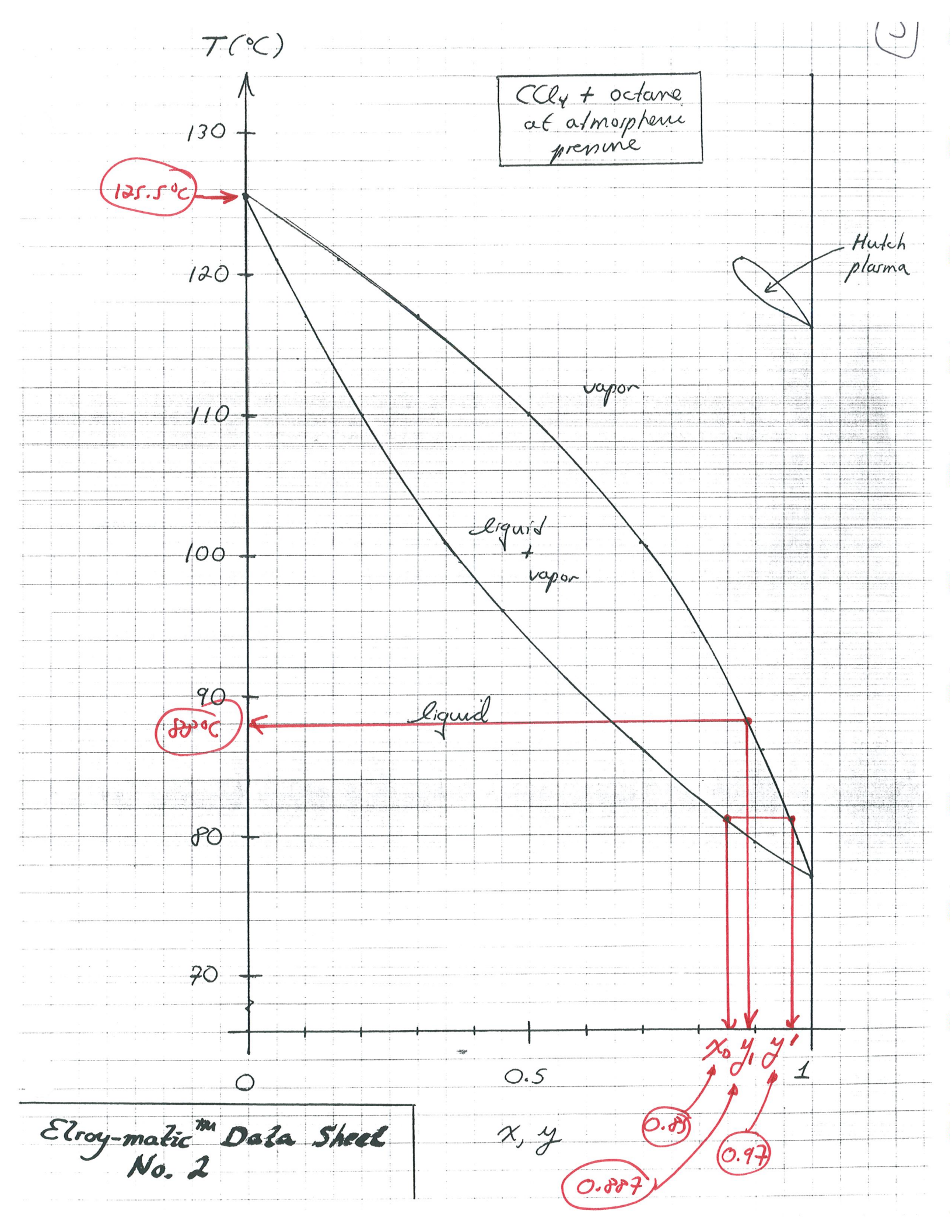
Problem 2

General: Equil. relation is $y = (k/P)x = (202/760)x$ (Henry's law const. for methanol)

$= 0.3711\ x$

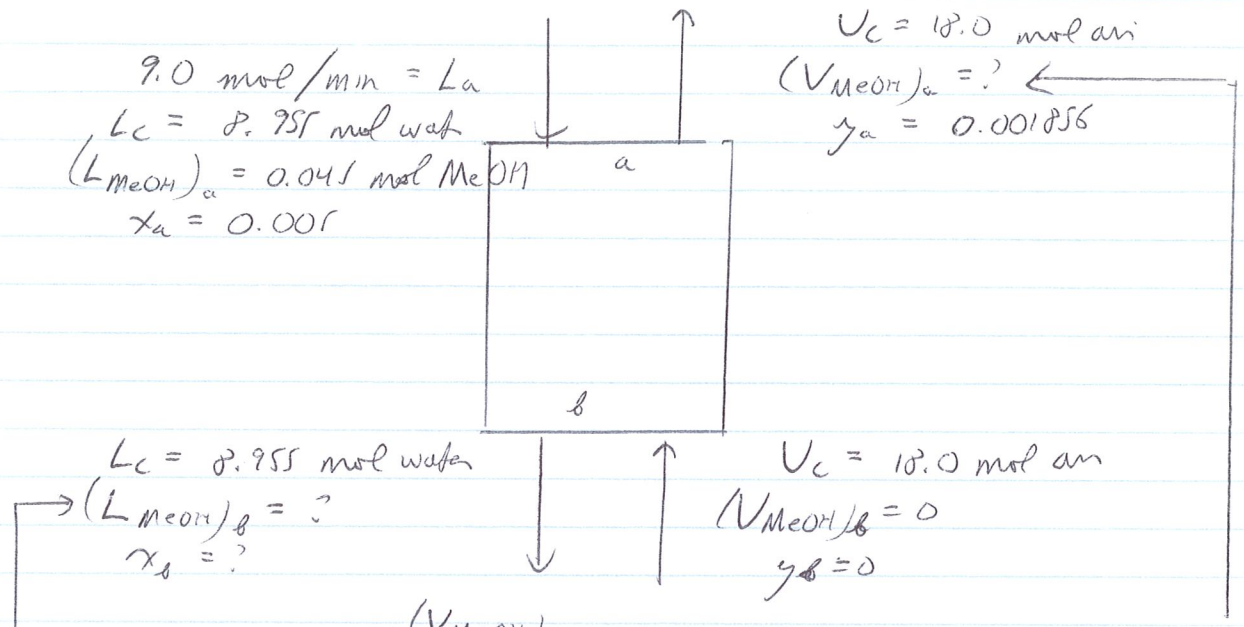
Part (a): Dilute solution $\Rightarrow$ op. line $\approx$ straight line w/ slope $L/V = 9/18 = 0.5$. Slope of op. line > slope of equil. curve. $\therefore$ 1st contact as $N \to \infty$ occurs @ a-end of tower.





Elroy-matic™ Data Sheet No. 2

So: $y_a/_{N\to\infty} = (0.3711)\,x_a = 0.001856$ [(x_a, $y_a/_{N\to\infty}$) satisfies equil. relation]. Material balance for $N\to\infty$ works out as follows:

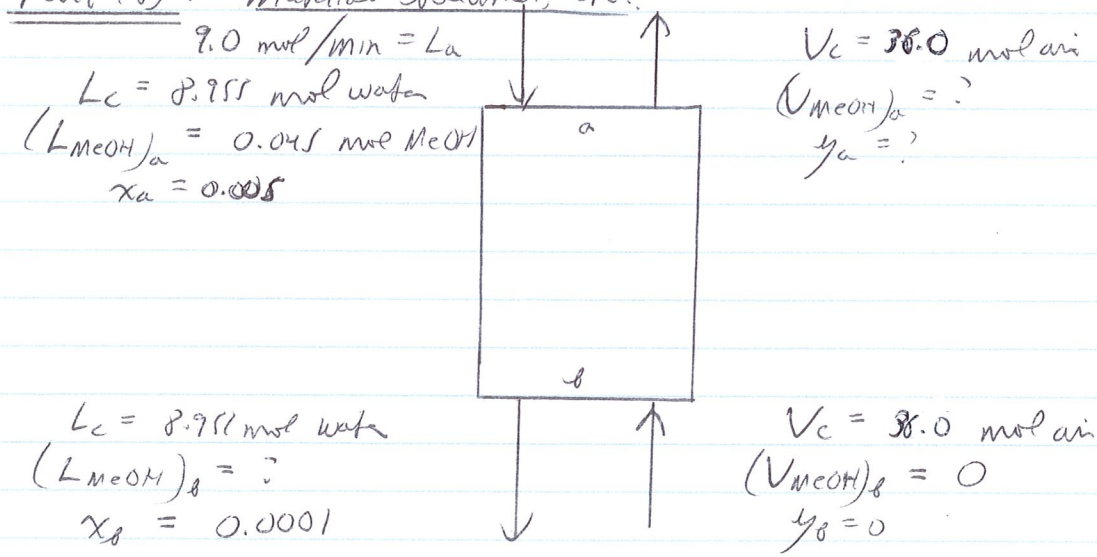


$$0.001856 = \frac{(V_{MeOH})_a}{18.0 + (V_{MeOH})_a} \Rightarrow (V_{MeOH})_a = 0.03347 \text{ mol MeOH}$$

Then $(L_{MeOH})_b = 0.045 \text{ mol} + 0 - (V_{MeOH})_a = 0.01153$ mol MeOH

and $x_b = \dfrac{0.01153}{0.01153 + 8.955} = \boxed{0.00129}$ ← This is $x_b/_{N\to\infty}$

Part (b): Material balances, etc.:



$$0.0001 = \frac{(L_{MeOH})_b}{8.955 + (L_{MeOH})_b}$$

$$\Rightarrow (L_{MeOH})_b = 0.0008956 \text{ mol MeOH}$$

Thus $(V_{MeOH})_a = 0.045 \text{ mol} + 0 - 0.0008956 \text{ mol} = 0.04410 \text{ mol}$

and $y_a = \dfrac{0.04410}{36.07\ 0.04410} = 0.001224$

Kremser eq.: $y_a^* = y^*(x_a) = (0.3711)(0.005) = 0.001856$

$y_b^* = y^*(x_b) = (0.3711)(0.0001) = 0.00003711$

$$N = \frac{\log\left(\frac{y_b - y_b^*}{y_a - y_a^*}\right)}{\log\left(\frac{y_b - y_a}{y_b^* - y_a^*}\right)} = \frac{\log\left(\frac{0 - 0.00003711}{0.001224 - 0.001856}\right)}{\log\left(\frac{0 - 0.001224}{0.00003711 - 0.001856}\right)}$$

$= \boxed{7.16 \text{ stages} \Rightarrow 8 \text{ stages}}$

Alternate Kremser eq.: $x_a^* = x^*(y_a) = \dfrac{y_a}{0.3711} = 0.003298$

$x_b^* = x^*(y_b) = \dfrac{y_b}{0.3711} = 0$

$$N = \frac{\log\left(\frac{x_a - x_a^*}{x_b - x_b^*}\right)}{\log\left(\frac{x_a - x_b}{x_a^* - x_b^*}\right)} = \frac{\log\left(\frac{0.005 - 0.003298}{0.0001 - 0}\right)}{\log\left(\frac{0.005 - 0.0001}{0.003298 - 0}\right)}$$

$= 7.16$ stages (same answer)