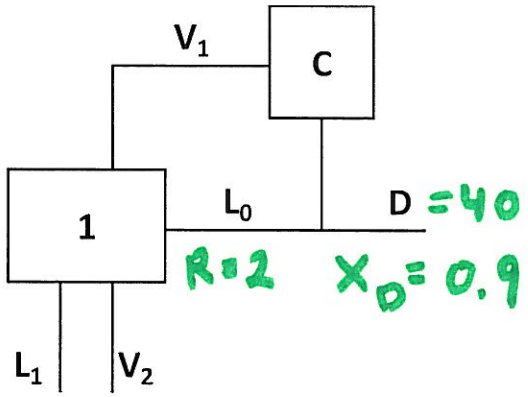
CHE 305 "Separation Processes"

Spring, 2012 - Exam 2A

Key

1. 100 mol/h of an equimolar benzene/toluene saturated liquid is fed to a distillation column equipped with a total condenser and a partial reboiler. The distillate flow rate is 40 mol/h with 90 mol% benzene and the reflux ratio is 2. Using the TXY diagram, identify all condenser and stage 1 compositions, flow rates, and temperatures.

← info not used




$L_0 = 2 \times 40 = 80 = L_1$

$V_1 = 80 + 40 = 120 = V_2$

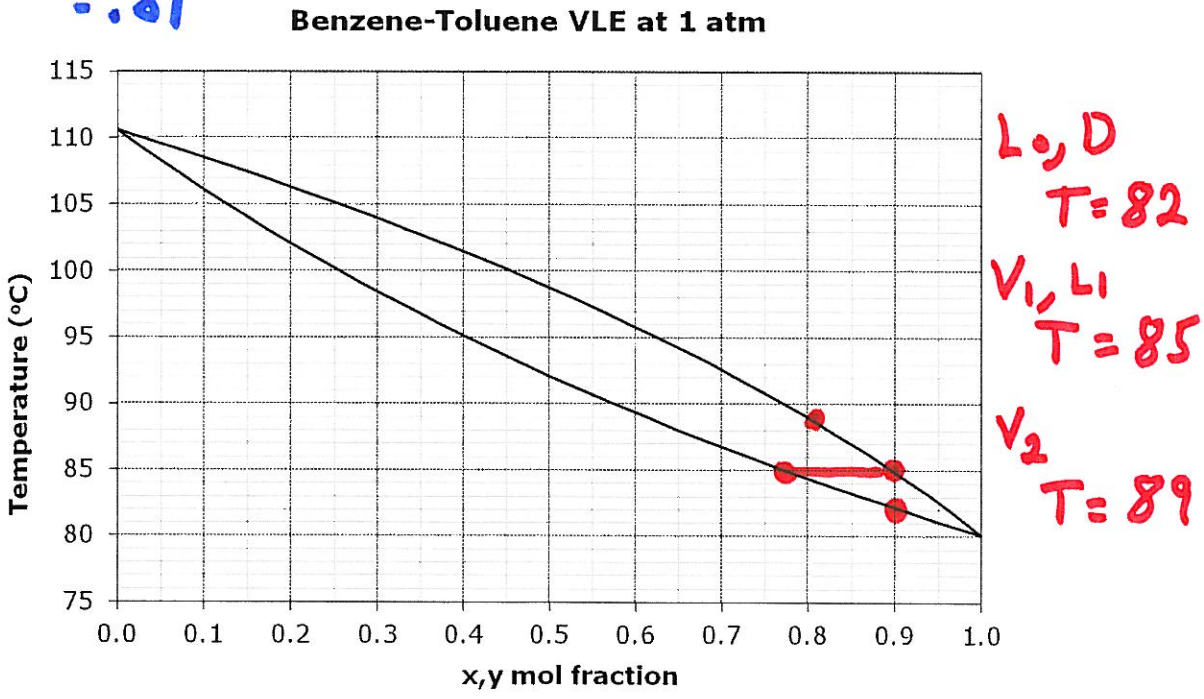
$Y_1 = X_0 = X_D = .9$

$X_1 = 0.77$ (in eq. w/ $Y_1$)

$Y_2 V_2 + X_0 L_0 = Y_1 V_1 + X_1 L_1$

$Y_2 = (.9 \times 120 + .77 \times 80 - .9 \times 80)/120$

$= .81$



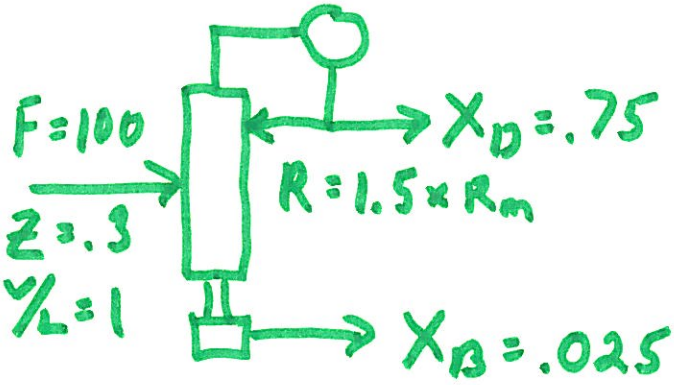

$L_0, D$ $T = 82$

$V_1, L_1$ $T = 85$

$V_2$ $T = 89$

2. A distillation column equipped with a total condenser and a partial reboiler is fed 100 kmol/h of a 30 mol% ethanol/70 mol% water mixture with equal amounts of vapor and liquid. The distillate product is a saturated liquid with composition 75 mol% ethanol and the bottoms product is also a saturated liquid with composition 2.5 mol% ethanol. The reflux ratio is 1.5 x $R_{min}$. The VLE data for 1 atm is on the facing page.

a. Make a sketch of the system, labeling the given information. Use material balances to calculated bottoms and distillate flow rates.




$D + B = 100$

$.75D + .025B = 30$

$D = 38$

$B = 62$

b. What is the feed temperature? Label this point 'a' on the TXY diagram.

~85 (using lever rule)

c. Find Rmin.

$y_{int} = .42 = \frac{.75}{1+R_m}$ $R_m = .786$ $R = 1.18$

d. Draw the top operating line on the XY diagram and write down its equation.

$y_{int} = \frac{.75}{2.18} = .344$

$L = 38 \times 1.18 = 44.8$

$V = 38 + 44.8 = 82.8$

e. Draw the q-line on the XY diagram.

V:L = 1

slope = -1

$y = \frac{44.8}{82.8}x + \frac{38}{82.8}0.75$

f. Draw the bottom operating line on the XY diagram and write down its equation.

Connect as shown ~~$\bar{V} = V - 82.8$ $\bar{L} = L + F$~~

$\bar{V} = V - 50 = 32.8$ $\bar{L} = L + 50 = 94.8$

g. Use the McCabe-Thiele method to find the number of stages required.

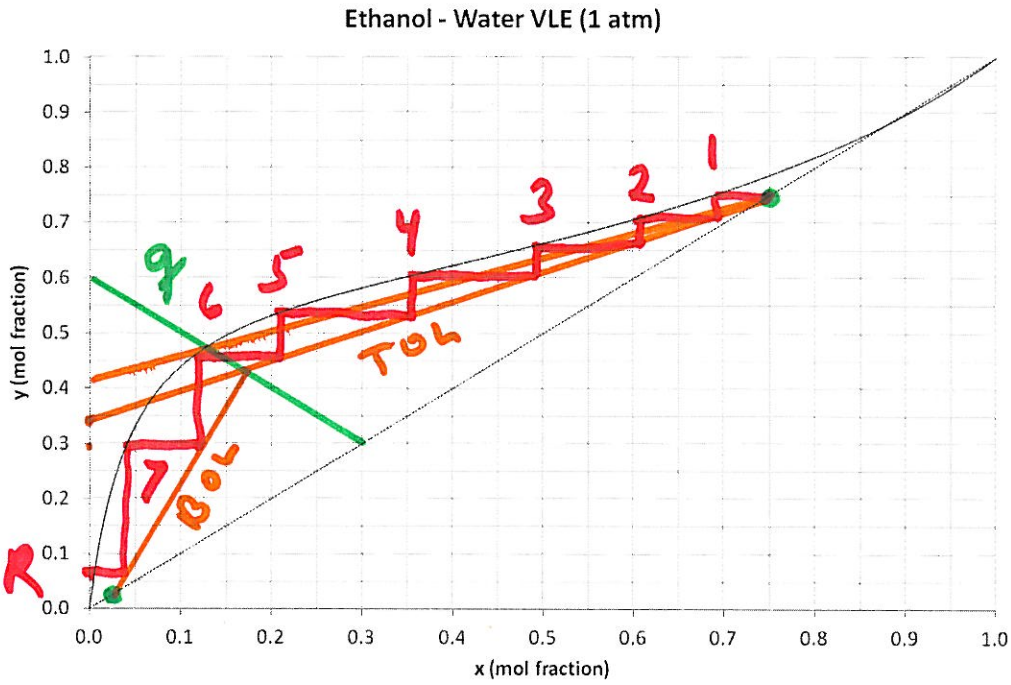
7+R

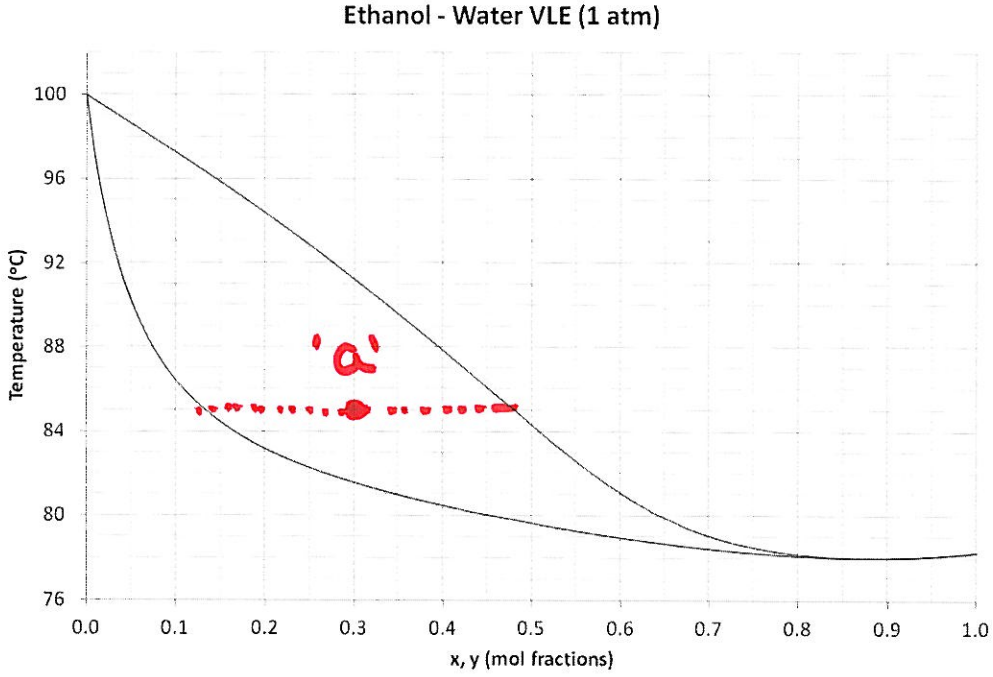
$y = \frac{94.8}{32.8}x - \frac{62}{32.8}0.025$

h. Indicate the optimum feed tray.

6 see graph

(note - gridlines washed out - just do your best)


Ethanol - Water VLE (1 atm)
y (mol fraction)
x (mol fraction)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
1
2
3
4
5
6
7
R
TOL
BOL


Ethanol - Water VLE (1 atm)
Temperature (°C)
x, y (mol fractions)
100
96
92
88
84
80
76
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
'a'

3a. 100 kmol/h of a saturated liquid mixture of 30 mol% ethanol in water is distilled continuously using open steam at 1 atm introduced directly to the bottom plate. The column has a total condenser and no reboiler. 20 kmol/h of a saturated liquid distillate is produced at 80 mol% ethanol. A saturated liquid side stream is taken from the optimum tray at 10 kmol/h and 50 mol% ethanol. The reflux ratio is 3.

a. Make a sketch of the system below the XY diagram on the facing page, labeling the given information.

b. Use material balances to find the steam flow rate and the bottoms flow rate and composition.

$F + S_T = D + B + S \qquad S_T = 80$

$B = 3 \times 20 + 100 - 10 = 150$

$x_B = (100 \times .3 - 10 \times .5 - 20 \times .8)/150 = .06$

c. Draw the q-lines for the feed and side product on the XY diagram.

Both are sat liq so vertical lines.

d. Draw the top operating line on the XY diagram.

$y_{int} = \frac{.8}{4} = .2$

e. Draw the middle operating line on the XY diagram.

$\frac{L'}{V'} = \frac{60-10}{80} = \frac{5}{8}$

f. Draw the bottom operating line on the XY diagram.

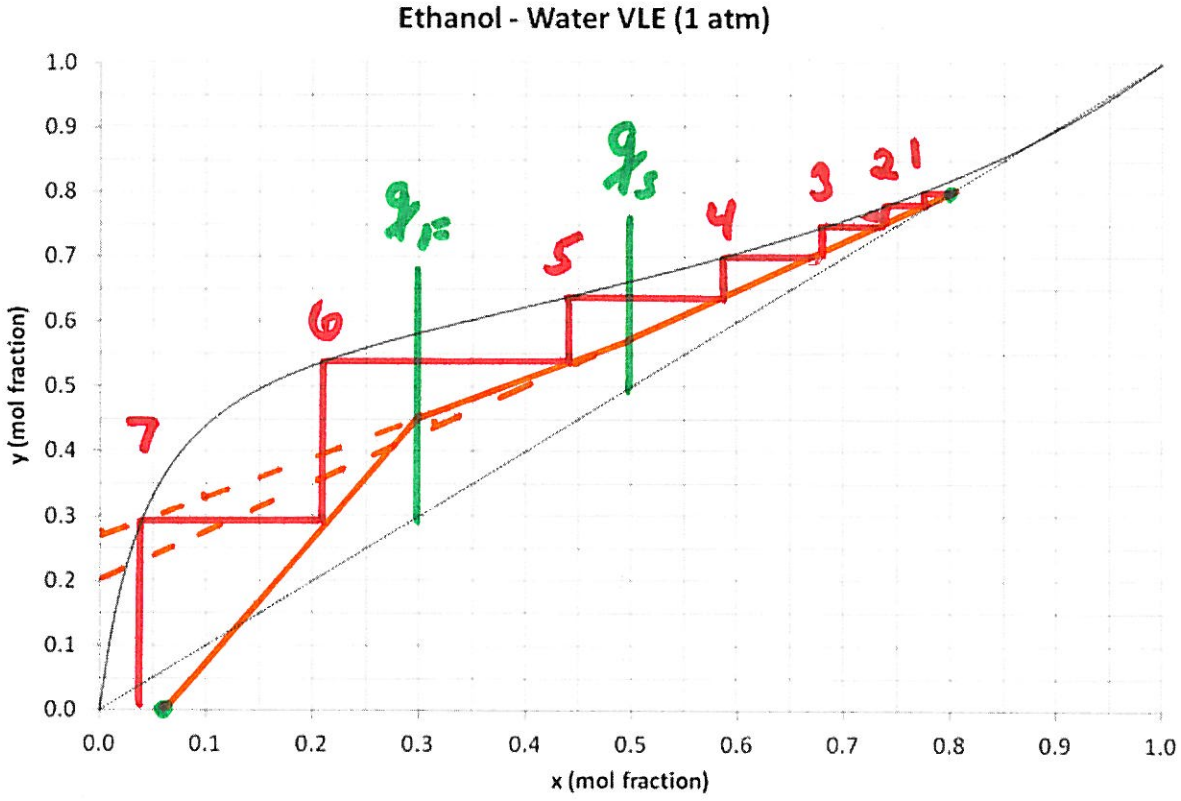
just connect as shown.
this line will have slope $\frac{150}{80}$

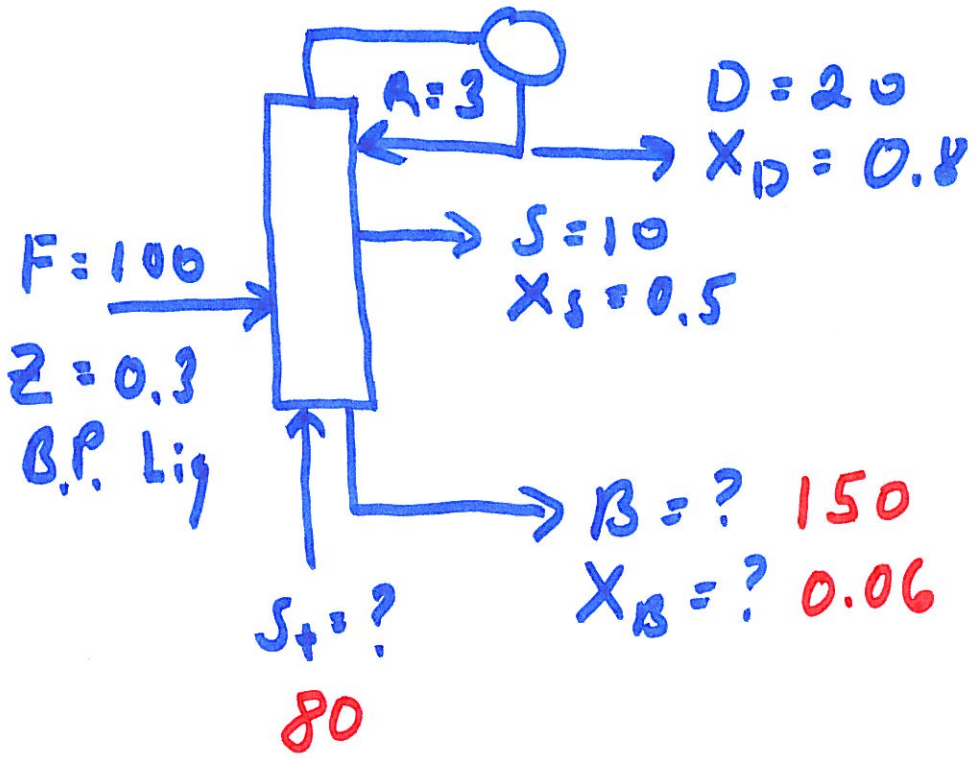
g. Use the McCabe-Thiele method to find the required number of stages.

7 stages (no reboiler)

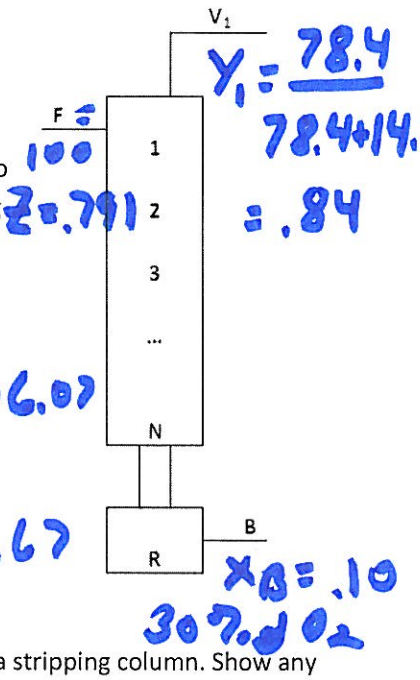
h. Indicate the optimum feed and side product stages.

side from 5
feed to 6


Ethanol - Water VLE (1 atm)
y (mol fraction)
x (mol fraction)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1.0
7
6
5
4
3
2
1


R = 3
D = 20
$X_D$ = 0.8
F = 100
Z = 0.3
B.P. Liq
S = 10
$X_S$ = 0.5
B = ? 150
$X_B$ = ? 0.06
$S_t$ = ?
80

3b. 100 moles/s of saturated liquid air at 1 atm is fed to the top of a stripping column equipped with a partial reboiler. This is simply the bottom section of a normal distillation tower so there is nothing above the feed stage other than vapor product leaving. Consider air to be 20.9% $O_2$ and 79.1% $N_2$. The liquid product from the partial reboiler contains 30% of the $O_2$ (note: this is not the mole fraction) fed to the column and has a composition of 10% $N_2$. XY and TXY diagrams are on the facing page.




$y_1 = \frac{78.4}{78.4+14.8} = .84$

F = 100, z = .791

a. Use material balances to determine the concentrations and flow rates of the bottoms and vapor products.

$B_{O_2} = .3 \times 20.9 = 6.07$

$\frac{B_{N_2}}{6.07 + B_{N_2}} = .1 \quad B_{N_2} = .67$

$V_{1,O_2} = 20.9 - 6.07 = 14.8$

$V_{1,N_2} = 79.1 - .67 = 78.4$

$x_B = .10$

307.4 $O_2$

b. Draw the operating line on the XY graph. Note there is no "top operating line" in a stripping column. Show any calculations here.

Start at $x_B = .1$

$L = 100$

$V = 78.4 + 14.8 = 93.2$

$\frac{L}{V} = 1.07 \begin{cases} \frac{y - .1}{.9 - .1} = 1.07 \\ y = .956 \\ (\text{int } x = .9 \text{ here}) \end{cases}$

c. Use the McCabe-Thiele method to find the number of theoretical stages required, including the partial reboiler. Number the stages from 1 (top/feed stage) to the bottom.

2 stages + R

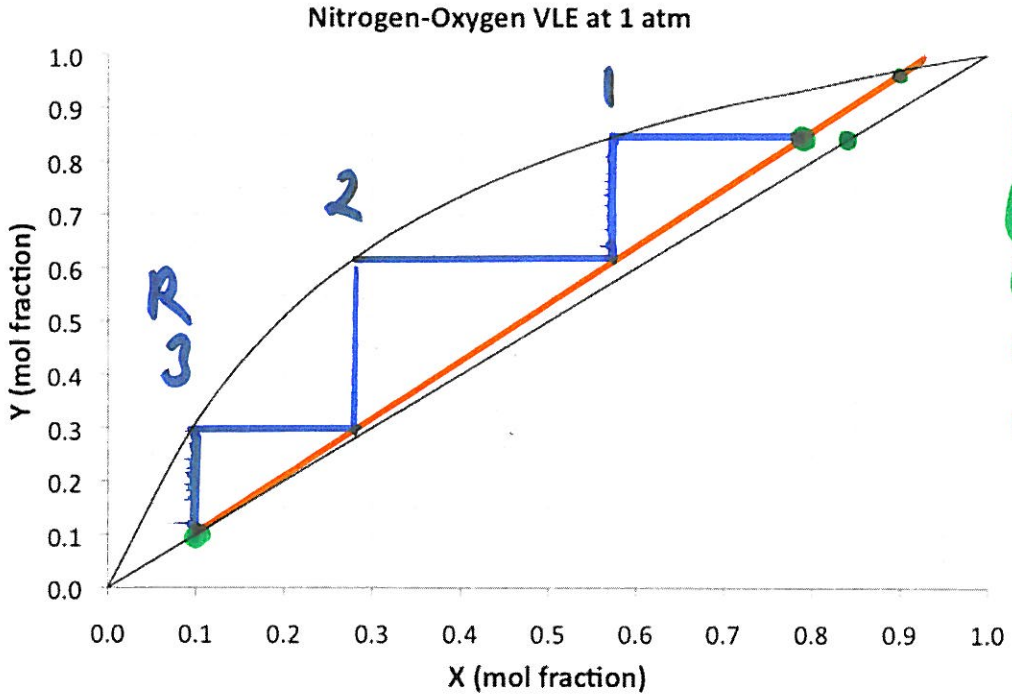
d. Identify the temperature of the feed, bottoms, and vapor product (F, B, and V1). Indicate these points on the TXY diagram.

F 79 (K)

$V_1$ 81 (K)

B 87.5 (K)

Note these are really cold!




Note $(\bar{z}, y_1)$ is on op line as expected