1 (a) From Gibbs phase equilibria

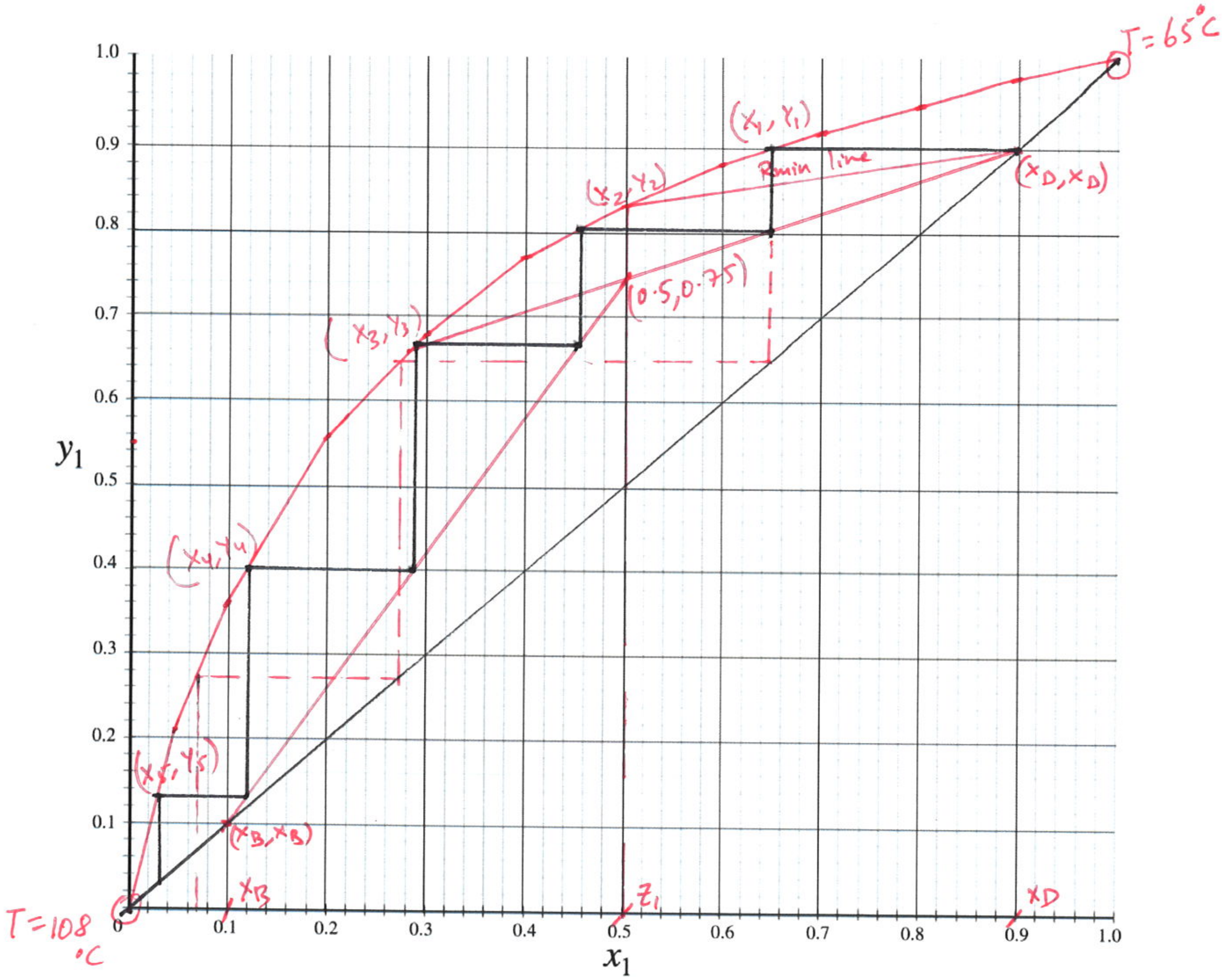
degree of freedom = 2 - 2 + 2 = 2

(b) $\alpha_{12} = \frac{k_1}{k_2} = 5 \Rightarrow \frac{k_2}{k_1} = 1/5 = 0.2$

(c) See the diagram in the attached page based on the following

$$y_1 = \frac{\alpha_{12} x_1}{(1 - x_1 + \alpha_{12} x_1)}$$

x_1	y_1
0	0
0.05	0.21
0.1	0.36
0.2	0.56
0.3	0.68
0.4	0.77
0.5	0.83
0.6	0.88
0.7	0.92
0.8	0.95
0.9	0.98
1	1



(1) The boiling points are marked in red.

(e)-(g) fractional recovery of component 1 in distillate = 90%.

$\Rightarrow \quad 0.9 = \dfrac{D x_D}{F z} \quad \Rightarrow D x_D = (Fz)\,0.9$

$= 100 \times 0.5 \times 0.9$

$= 45$ mol/h

$\Rightarrow \quad 0.1 = \dfrac{B x_B}{F z} \quad \Rightarrow \quad B x_B = (Fz)\,0.1$

$= 5$ mol/h

$x_B = 0.1 \quad \Rightarrow \quad B = 50$ mol/h

$D = 100 - 50 = 50$ mol/h

$x_D = \dfrac{45}{50} = 0.9$

(h) For saturated ~~vapor~~ liquid feed, feed quality = 1

(i) Minimum reflux ratio line is drawn on the graph paper

$$\text{slope of line} = \frac{R_{min}}{R_{min}+1} = \left(\frac{0.9-0.83}{0.9-0.5}\right) = \frac{0.07}{0.4}$$

$$\Rightarrow 0.4R_{min} = 0.07R_{min} + 0.07$$

$$\Rightarrow R_{min} = \frac{0.07}{0.33} = 0.21$$

(j) $R = 3R_{min} = 3 \times 0.21 = 0.63$

(k) operating line for the rectifying section

$$y = \frac{R}{R+1}x + \frac{x_D}{R+1}$$

$$\Rightarrow y = 0.39x + 0.55$$

(l) For stripping section, we have to draw the operating line for rectifying section and then connect the line from (x_B, x_B) to the intersection at the feed line (see graph)

Both lines intersect at $(0.5, 0.75)$

$$\text{so operating line slope} = \left(\frac{0.75-0.1}{0.5-0.1}\right) = \frac{0.65}{0.4} = 1.625$$

$$y = 1.625x + c$$

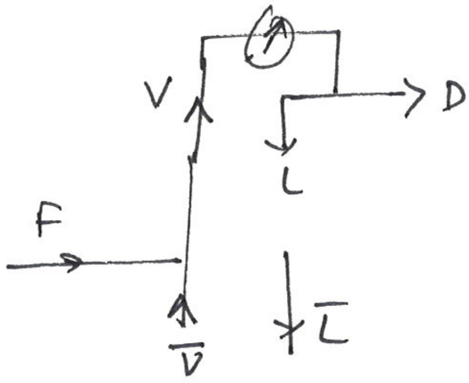
$$c = y - 1.625x = 0.1 - 1.625(0.1) = -0.0625$$

$$\Rightarrow y = 1.625x - 0.0625$$

(m) $R = \frac{L}{D} \Rightarrow L = RD = 0.63 \times 50 = 31.5$ mol/h

$V = L + D = 50 + 31.5 = 81.5$ mol/h

(n) $\bar{L} = F + L$
(saturated liquid feed)



$\Rightarrow \bar{L} = 100 + 31.5 = 131.5$ mol/h

$\bar{V} = V$ (no change in feed tray)

$= 81.5$ mol/h

(o) Boilup ratio $= V_B = \frac{\bar{V}}{B} = \frac{81.5}{50} = 1.63$

(p) From operating eqn, $y = \frac{V_B + 1}{V_B} - \frac{x_B}{V_B}$

$\Rightarrow 0.0625 = \frac{0.1}{V_B} \Rightarrow V_B = 1.6$

So the two calculations are very close.

q. Calculation of trays based on graphical diagram

There a total of 5 equilibrium stages.

r. Above feed tray we ~~▬~~ have only 1 tray

s. composition for (x_1, y_1) is $(0.65, 0.9)$

$x_1 = 0.65,\ y_1 = 0.9$

t) Minimum number of trays $= 3$

2 a) Compositions are marked in the diagram

b) Outlet composition of E_1

$\simeq$ 65% solvent, 28% Acetic acid, 7% water

(c) Outlet flow rate of extract stream can be obtained by lever rule.

Flow rate of M = 200 kg/h

$\Rightarrow$ Flow rate of $E_1 \simeq \left(\frac{70}{93}\right)_{\text{measured by ruler}} \times 200 \simeq 150$ kg/h

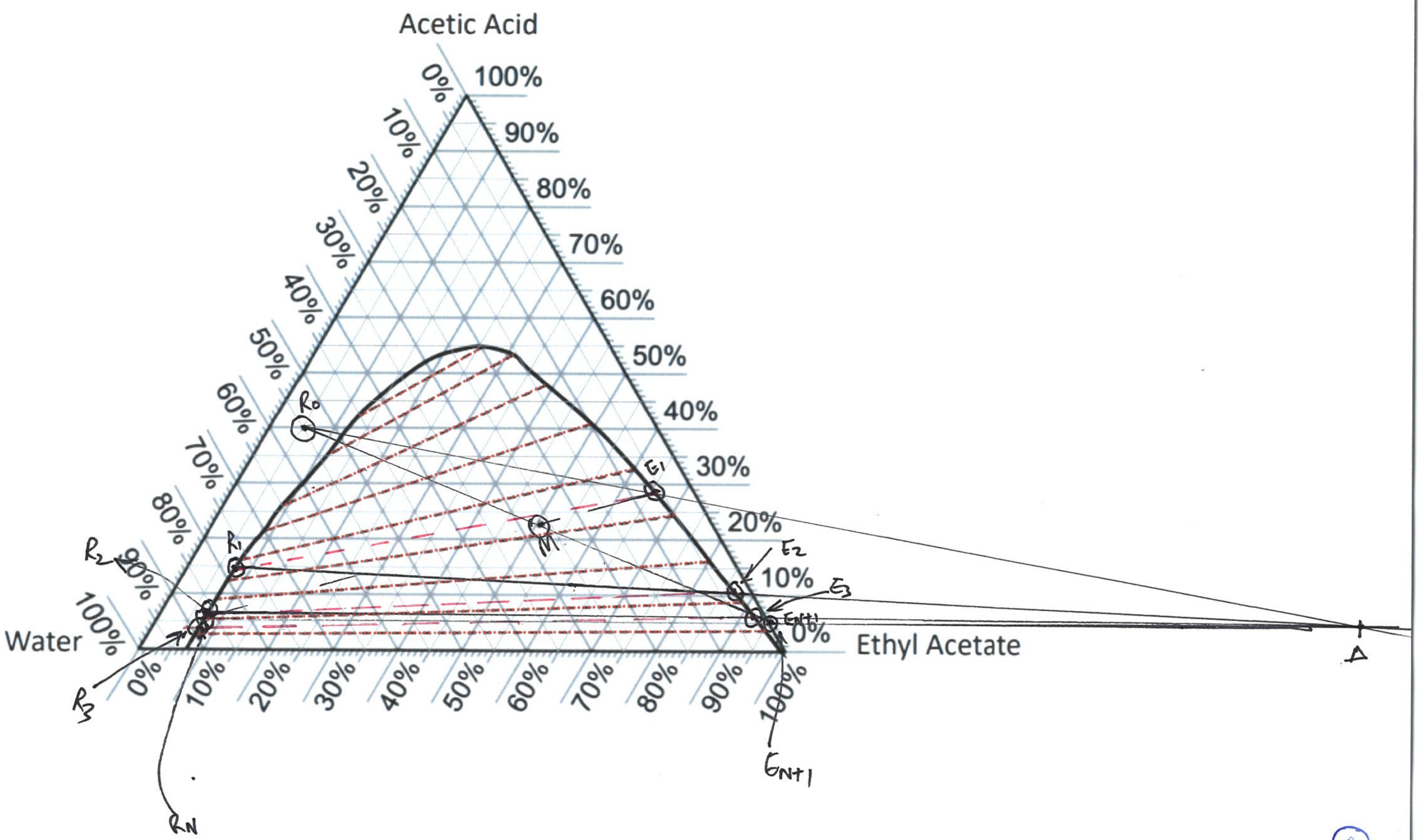
(d) R_1 is obtained using tie line from E_1

15% Acetic acid, 78% water, 7% solvent

(e) Flow rate of Δ can be obtained using lever rule with E_1 becoming mixture of Δ and R_0

$$\text{Flow rate} = 150\Big|_{E_1} \times \left(\frac{7.2}{21.9}\right)_{\text{ruler}} \simeq 49 \text{ kg/h}$$

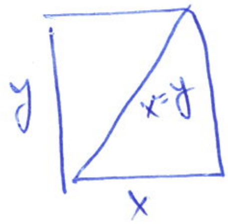
(f) Number of equilibrium stages ~ 3 (see diagram)



Acetic Acid
Water
Ethyl Acetate
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
R0
R1
R2
R3
RN
E1
E2
E3
EN+1
GN+1
M
Δ

6

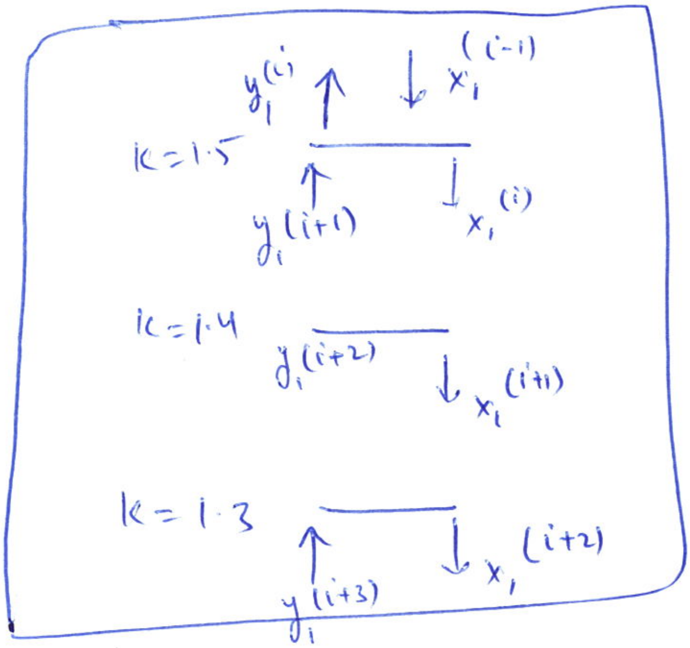
③ For this, $x = y$ line in operating line



$$y_1^{(j)} = x_1^{(j-1)} \Rightarrow y_1^{(j)} = \frac{y_1^{(j-1)}}{K_{j-1}}$$

equilibrium relation

$$\Rightarrow y_1^{(i+1)} = \frac{y_1^{(i)}}{1.5}$$



$$\Rightarrow y_1^{(i+2)} = \frac{y_1^{(i+1)}}{1.4}$$

$$\Rightarrow y_1^{(i+3)} = \frac{y_1^{(i+2)}}{1.3}$$

$$\Rightarrow y_1^{(i+3)} = \frac{y_1^{(i)}}{1.5 \times 1.4 \times 1.3} = \frac{x_1^{(i-1)}}{1.5 \times 1.4 \times 1.3} = \frac{0.9}{1.5 \times 1.4 \times 1.3}$$

$$= 0.33$$