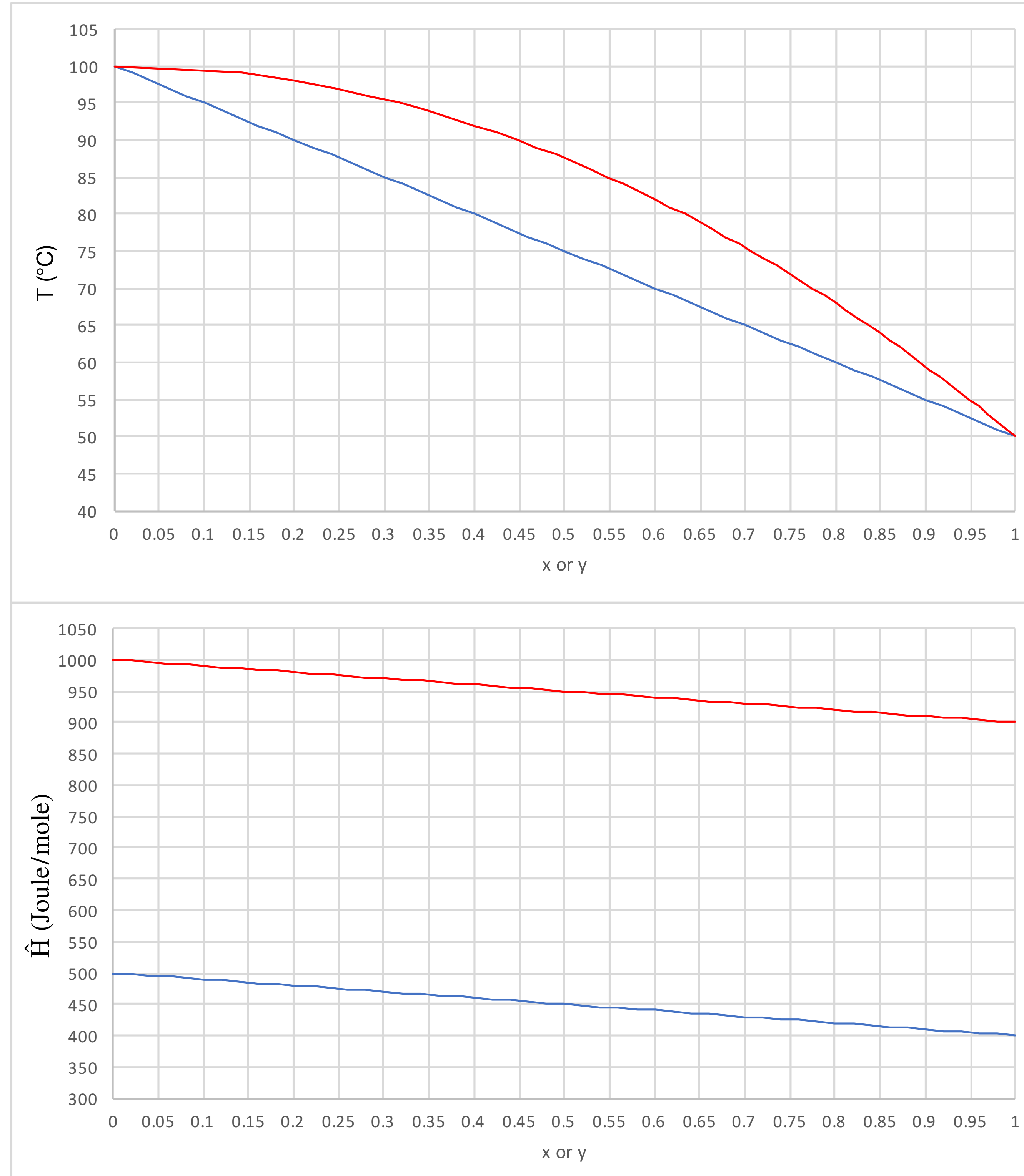
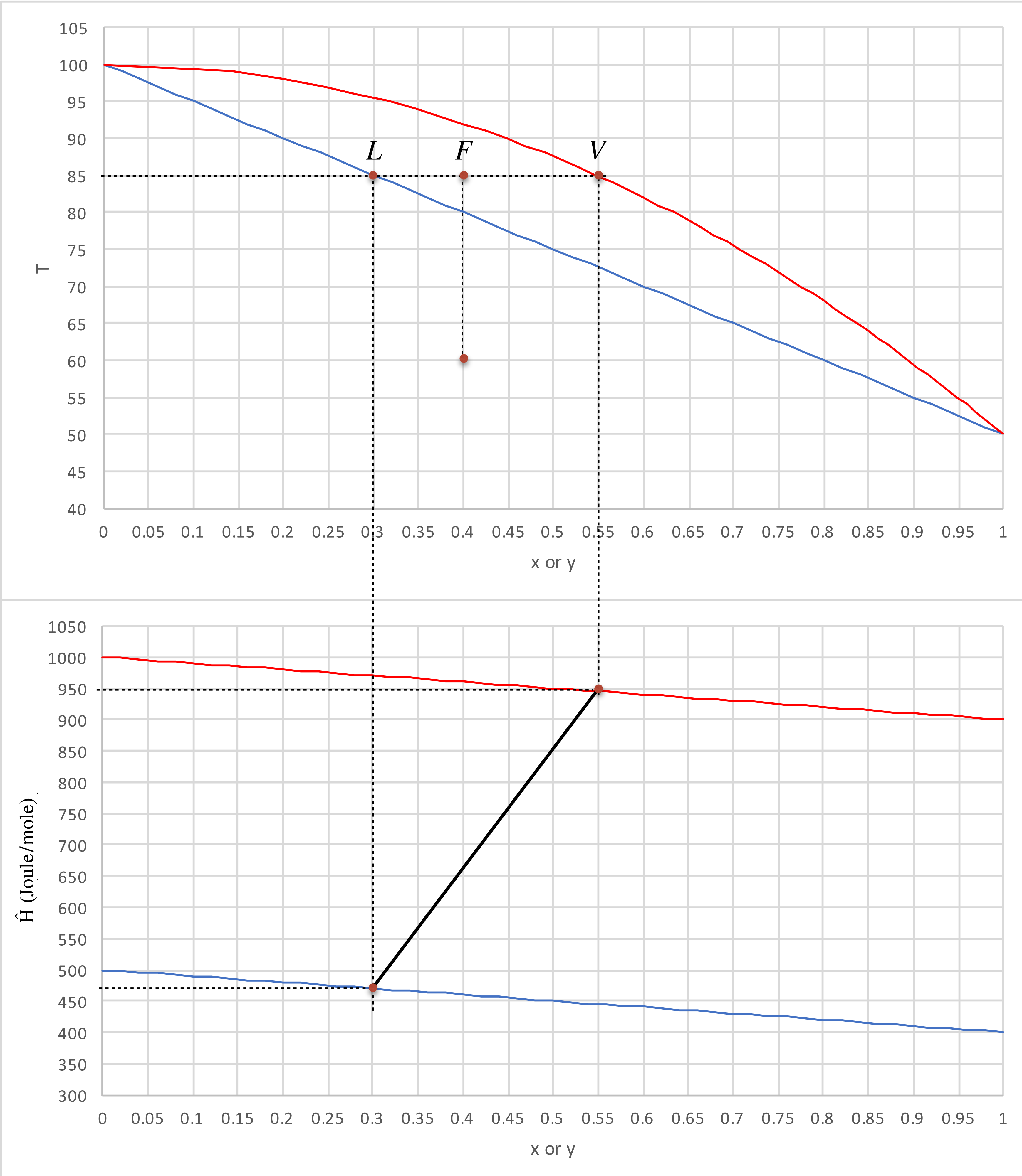
Exercise problem 1

You are an engineer working in a biofuel fermentation plant.

Immediately after fermentation and initial processing, you obtain 40% biofuel in water at 60 ^{o}C.

You decided to increase the concentration of 100 moles biofuel (liquid) at 60 ^{o}C by heating it in a closed vessel at 85 ^{o}C. Describe the resulting composition, actual amounts of liquid and vapor phases and enthalpies (per mole as well as total).





$x_1 = 0.3$
$y_1 = 0.55$

H_L = 470 Joule/mole
H_V = 950 Joule/mole

$$\frac{\text{amount of liquid}}{\text{total amount}} = \frac{FV}{LV} = \frac{3}{5}$$

$$\text{amount of liquid} = \frac{3}{5} * 100 = 60 \text{ moles}$$

$$\text{amount of vapor} = 100 - 60 = 40 \text{ moles}$$

$$\text{liquid enthalpy} = 60 * 470 = 28200 \text{ Joules}$$

$$\text{vapor enthalpy} = 40 * 950 = 38000 \text{ Joules}$$

Exercise problem 2: Understanding limitation of flash drum

A flash drum operating is separating an ethanol-propanol mixture. The feed contains z_1 = 0.4 ethanol with a flow rate of F. Assume equilibrium relationship $y_1 = k_1 x_1$

Ideally, you will want all ethanol in vapor (ethanol is more volatile) and all propanol in liquid phase (its is less volatile). However, that is not possible with a single flash drum. To maximize separation, you want to maximize concentration of ethanol in vapor and minimize ethanol concentration in liquid

(a) What is maximum possible composition of ethanol in vapor, y_1.

(b) What is the minimum possible composition of ethanol in liquid, x_1.

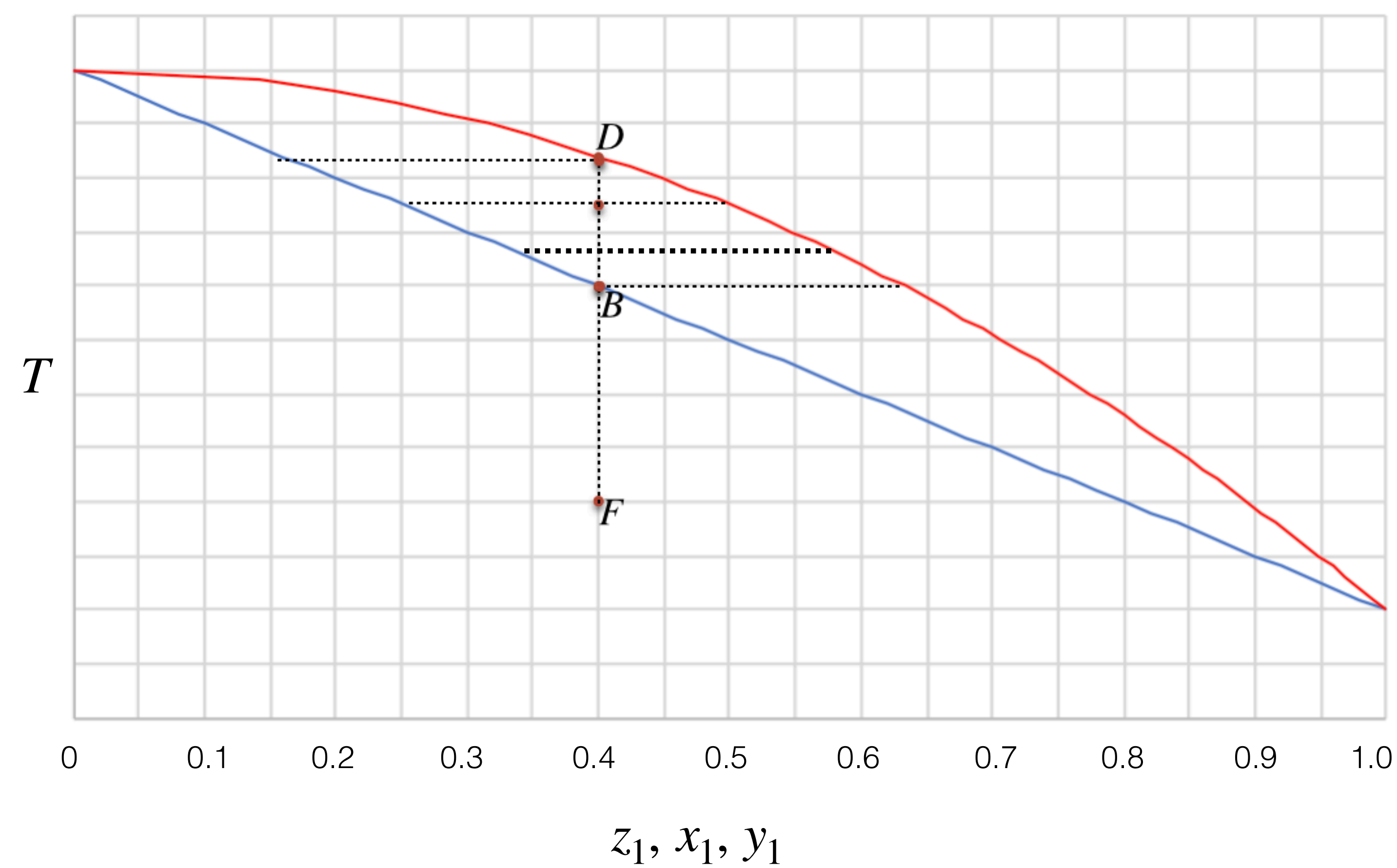
(c) What would be composition of liquid and vapor streams if V/F = 0.2

Maximum ethanol concentration in vapor is when V = 0; L= F
Point B in plot

$$y_{1,max} = \frac{k_1 z_1}{\frac{L}{F} + k_1 \frac{V}{F}} = k_1 z_1$$

Minimum ethanol concentration in liquid is when L = 0; V= F
Point D in plot

$$x_{1,min} = \frac{z_1}{\frac{L}{F} + k_1 \frac{V}{F}} = \frac{z_1}{k_1}$$



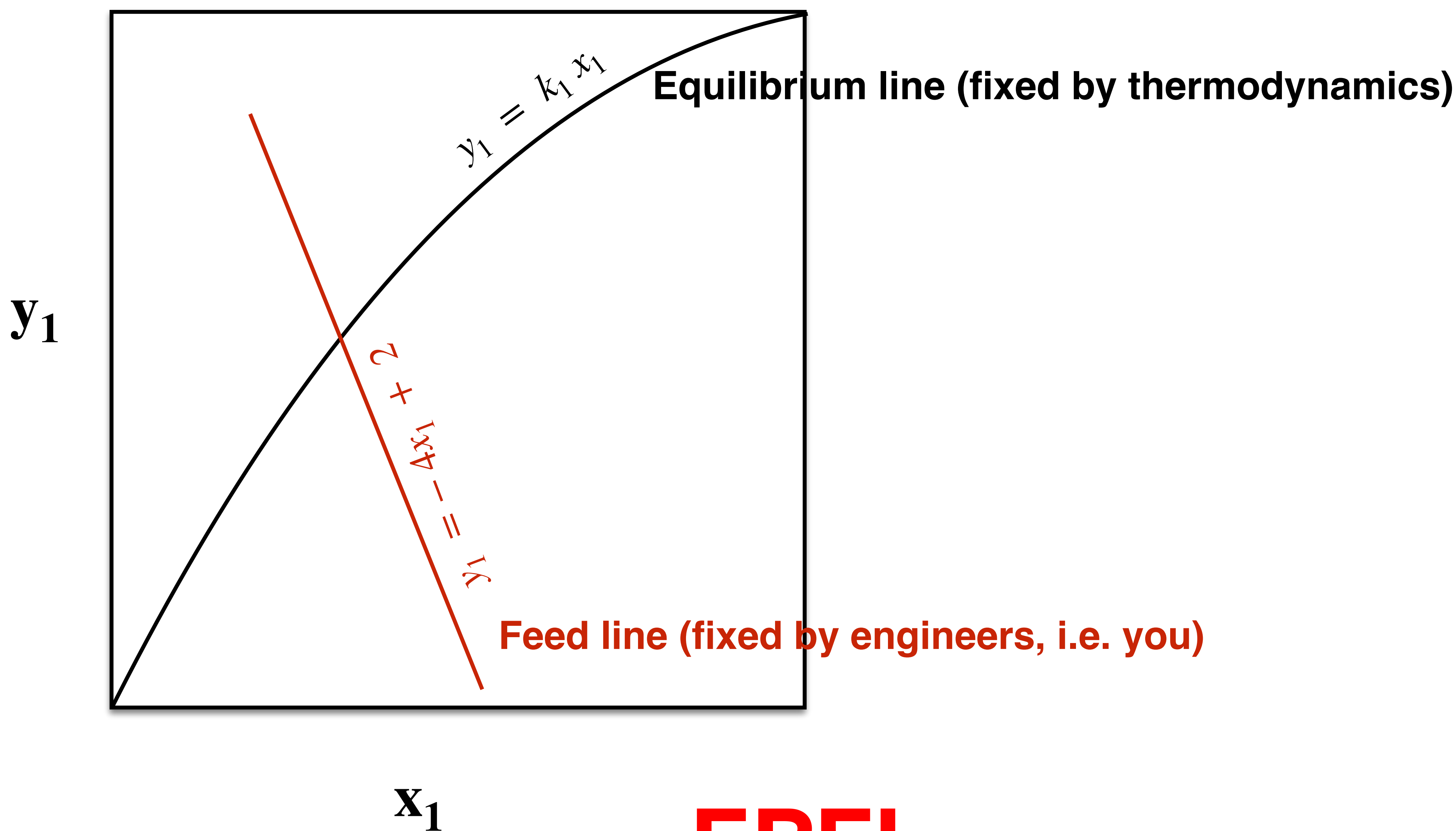
Problem

(c) What would be composition of liquid and vapor streams if V/F = 0.2, z_1 = 0.4.

$$Fz_1 = Lx_1 + Vy_1 \quad \Rightarrow z_1 = \frac{L}{F}x_1 + \frac{V}{F}y_1 \quad \Rightarrow 0.4 = 0.8x_1 + 0.2y_1$$

$$\Rightarrow y_1 = -4x_1 + 2$$

McCabe-Thiele plot



EPFL

Exercise problem 3:

Consider a mixture of two component liquid mixture (ideal solution; heat of mixing is zero). They are separated in flash column at the following condition.

$$\mathrm{T_{ref}} = \mathrm{T_F} = 25\mathrm{C};\quad \mathrm{T} = 75\mathrm{C} \qquad x_1 = 0.2,\ y_1 = 0.6 \qquad \mathrm{F} = 100\ \mathrm{mole/hr} \qquad \frac{V}{F} = 0.2$$

$$\mathrm{C_{P,1,L}} = 100\ \mathrm{J/mol/K} \qquad \mathrm{C_{P,1,V}} = 80\ \mathrm{J/mol/K} \qquad \mathrm{h_{1,latent}} = 1000\ \mathrm{J/mol}$$

$$\mathrm{C_{P,2,L}} = 50\ \mathrm{J/mol/K} \qquad \mathrm{C_{P,2,V}} = 100\ \mathrm{J/mol/K} \qquad \mathrm{h_{2,latent}} = 1500\ \mathrm{J/mol}$$

Find $\mathrm{h_F, h_L, h_V,\ and\ Q}$

$$\mathrm{h_F} = \Sigma \mathrm{z_i h_{iF}},\ \text{where } \mathrm{h_{i,F}} = \mathrm{C_{P,i,L}(T_F - T_{ref})}$$ Liquid feed

$$\mathrm{h_{i,F}} = \mathrm{h_{i,latent}} + \mathrm{C_{P,i,V}(T_F - T_{ref})}$$ Vapor feed

$$\mathrm{h_L} = \Sigma \mathrm{x_i h_{iL}},\ \text{where } \mathrm{h_{i,L}} = \mathrm{C_{P,i,L}(T - T_{ref})}$$

$$\mathrm{h_V} = \Sigma \mathrm{y_i h_{iV}},\ \text{where } \mathrm{h_{i,V}} = \mathrm{h_{i,latent}} + \mathrm{C_{P,i,V}(T - T_{ref})}$$

EPFL

h_F, h_L, h_V, and Q

$T_{ref} = T_F = 25C; \quad T = 75C$

$x_1 = 0.2, \; y_1 = 0.6$

$F = 100 \text{ mole/hr}$

$\frac{V}{F} = 0.2$

$C_{P,1,L} = 100 \text{ J/mol/K}$ $\quad C_{P,1,V} = 80 \text{ J/mol/K}$ $\quad h_{1,latent} = 1000 \text{ J/mol}$

$C_{P,2,L} = 50 \text{ J/mol/K}$ $\quad C_{P,2,V} = 100 \text{ J/mol/K}$ $\quad h_{2,latent} = 1500 \text{ J/mol}$

$h_F = 0$

$h_L = \Sigma x_i h_{iL}$, where $h_{i,L} = C_{P,i,L}(T - T_{ref})$

$h_{1,L} = 100(75-25) = 5000 \text{ J/mol}$ $\qquad h_{2,L} = 50(75-25) = 2500 \text{ J/mol}$

$$h_L = 0.2 * 5000 + 0.8 * 2500 = 3000 \text{ J/mol}$$

$h_V = \Sigma y_i h_{iV}$, where $h_{i,V} = C_{P,i,V}(T - T_{ref}) + h_{i,latent}$

$h_{1,V} = 80(75-25) + 1000 = 5000 \text{ J/mol}$ $\qquad h_{2,V} = 100(75-25) + 1500 = 6500 \text{ J/mol}$

$$h_V = 0.6 * 5000 + 0.4 * 6500 = 5600 \text{ J/mol}$$

$Q = Lh_L + Vh_V - Fh_F = 80 * 3000 + 20 * 5600 - 0 = 352000$ Jolue/hr; heat is added

Obvious from problem