Josh Whitehead

Q1: (30 Points): A ternary phase diagram of species A, B and C is shown below.

(1) (5 points) If a mixture contains 20 wt% A, 60 wt% B, 20 wt% C, does this mixture form a ~~single-phase or two-~~phase system? Circle the right answer.

A: Single-phase B: two-phase

(5 points) What is the degree-of-freedom for this mixture?

DOF= $\boxed{4}$

$C - \Pi + 2$

$3 - 1 + 2$

(2) (10 points) If a mixture (different from the one in (1)) forms a two-phase system and the mass fraction of A in A-rich phase is 89 wt%. Write down the compositions of B and C in A-rich (I) phase and C-rich (II) phase in the table below.

A-rich phase		C-rich phase	
x^{I}_{B} (wt%)	7	x^{II}_{B} (wt%)	30
x^{I}_{C} (wt%)	4	x^{II}_{C} (wt%)	56

(3) (10 points) If a two-phase system (same composition as (2)) has m_A kg A and m_B kg B in the overall system. Write down enough equations you need to calculate the amount of C (m_C kg) and explain how you would solve for m_C. (You don't need to solve these equations)

~~If each phase has 1 kg~~

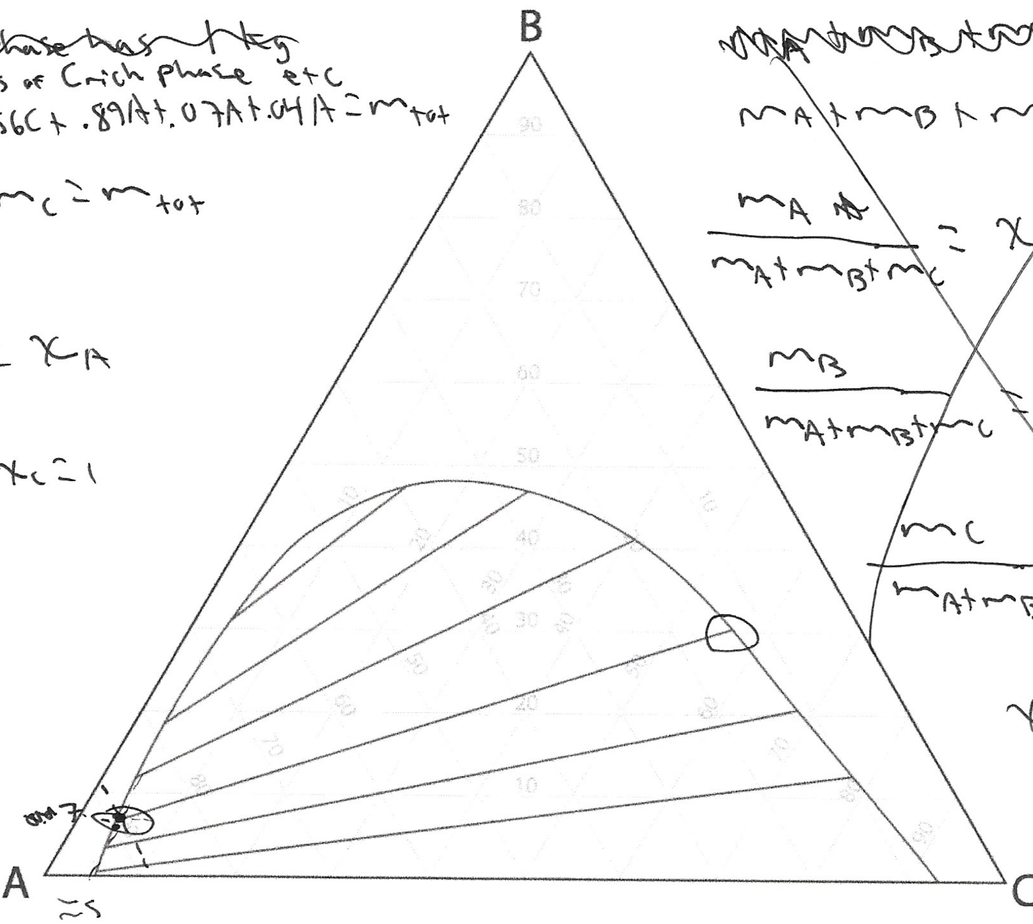
C = mass of C rich phase etc

$.14C + .3C + .56C + .89A + .07A + .04A = m_{tot}$

$m_A + m_B + m_C = m_{tot}$

$\frac{m_A}{m_A + m_B + m_C} = x_A$

$x_A + x_B + x_C = 1$



~~$m_A + m_B + m_C = 100$~~

~~$m_A + m_B + m_C = 100$ kg~~

~~$\frac{m_A}{m_A + m_B + m_C} = x_A$~~

~~$\frac{m_B}{m_A + m_B + m_C} = x_B$~~

~~$\frac{m_C}{m_A + m_B + m_C} = x_C$~~

~~$x_A + x_B + x_C = 1$~~

$\frac{m_A}{m_A + m_B + m_C} + \frac{m_B}{m_A + m_B + m_C} + \frac{m_C}{m_A + m_B + m_C} = 1$ — Solve for m_C

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Q2: (30 points) A mixture of cyclohexane (C) and toluene (T) is separated in a flash separator at a temperature of 60 ˚C. The mixture contains 40 mol% of C and 60 mol% of T. The table below listed the vapor pressure for pure C and T at 60 ˚C.

	Cyclohexane	Toluene
P*(T = 60 ˚C) in kPa	51.8	18.5

(1) (15 points) What are the minimum and maximum pressures that the flash separator can operate at? You must write out all equations and the values of variables substituted into the equations to get full credits.

P_{Min} = 24.9 kPa $\qquad$ P_{Max} = 31.8 kPa

(2) (15 points) What is the molar fraction of C in the liquid (x_c) and vapor phase (y_c), if the separator operates at 28 kPa? You must write out all equations and the values of variables substituted into the equations to get full credits.

x_c= 0.285 $\qquad$ y_c = 0.527

1) $P_{dew} = \frac{1}{\sum y_i / P_i^*} = \frac{1}{\frac{0.4}{51.8} + \frac{0.6}{18.5}} = 24.9 \text{ kPa}$

$P_{bub} = \sum x_i P_i^* = 0.4(51.8) + 0.6(18.5) = 31.82$

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2) $28 = P = x_c P_c^* + x_T P_T^* = x_c P_c^* + (1-x_c) P_T^* = x_c P_c^* + P_T^* - x_c P_T^* = 28$

$28 - P_T^* = x_c P_c^* - x_c P_T^* \rightarrow 28 - P_T^* = x_c (P_c^* - P_T^*)$

$\therefore x_c = \frac{28 - P_T^*}{P_c^* - P_T^*} = \frac{28 - 18.5}{51.8 - 18.5} = 0.285$

$y_c = \frac{x_c P_c^*}{P} = \frac{0.285 \cdot 51.8}{28} = 0.527$

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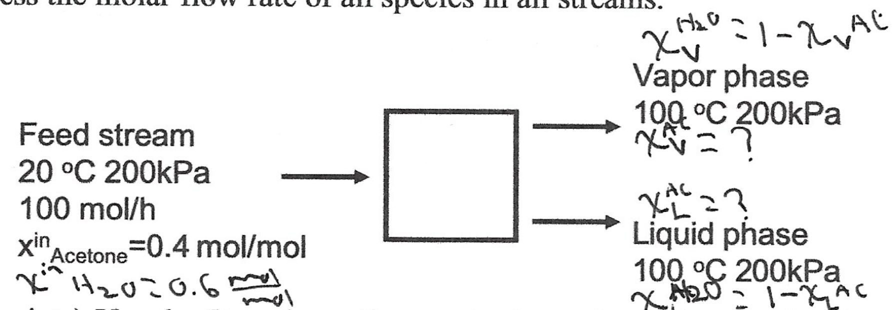
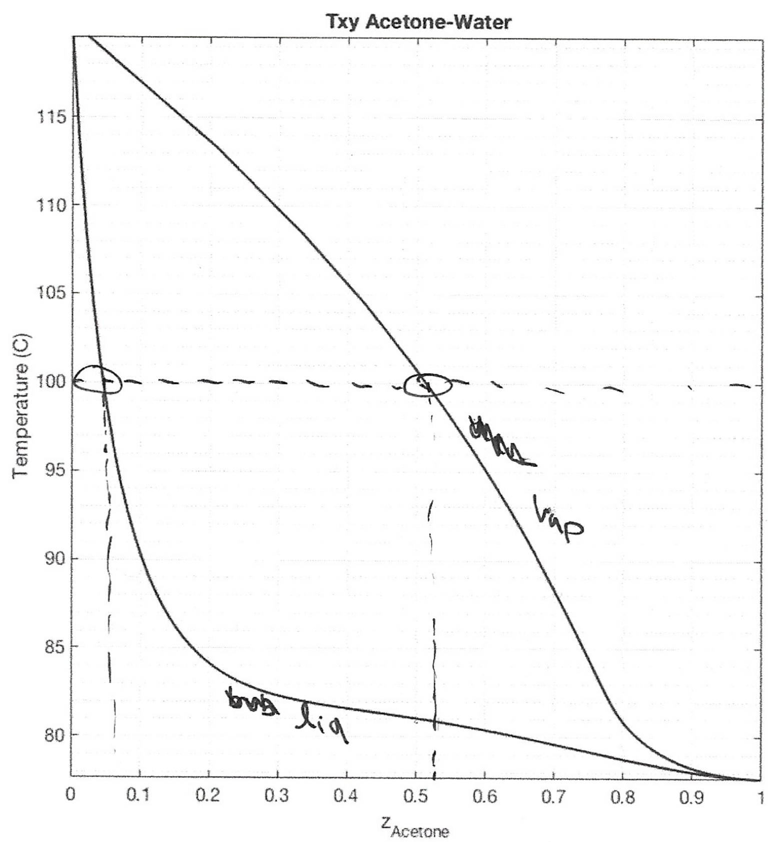
Q3: (40 points) Below is a Txy phase diagram for an acetone-water mixture at 200 kPa. The feed has 40 mol% liquid acetone and balance liquid water at 20 °C and 200 kPa. The feed molar flow rate is 100 mol/h. The separator operates at 100 °C. The output streams are at 200 kPa and 100 °C.

(1) (5 points) Fully label the flow chart, using sufficient unknown variables so you can express the molar flow rate of all species in all streams.



(2) (10 points) Use the Txy phase diagram to determine the molar fraction of acetone in the vapor (y_A) and liquid phase (x_A).

x_A= 0.05 y_A = 0.51



(3) (10 points) Write out the energy balance equation to calculate the rate of heat ($\dot{Q}$ kJ/s) transferred to this system. (please express the terms in the equation using the symbols in the enthalpy table below.)

(4) (15 points) Use inlet condition as reference states, write out the equations you would use for calculating $\hat{H}_{in,A(l)}$ $\hat{H}_{out,A(l)}$ $\hat{H}_{out,A(v)}$. The normal boiling point of acetone is 56 °C. Ignore the effect of pressure on liquid enthalpy and assume ideal gases. You don't

3) $Q + \cancel{W_s} = \cancel{E_p} + \cancel{E_k} + \Delta H \rightarrow Q = \Delta H$

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have to actually calculate the H values (Do not assume constant heat capacities. You must indicate correct species, state of aggregation to get full credits). Assume you are given the heat capacities of acetone in liquid and vapor phases as a function of temperature and the standard heat of vaporization of acetone. Use the symbols below.

Heat capacities: $C_{P,species,l\ or\ g}$; Standard heat of vaporization $\Delta H^{o}_{v,species}$

Inlet-outlet Enthalpy Table

(References: liquid water and acetone at 20 ˚C and 200 kPa)

	$\dot{n}_{in}$ (mol/h)	$\hat{H}_{in}$ (kJ/mol)	$\dot{n}_{out}$ (mol/h)	$\hat{H}_{out}$ (kJ/mol)
Acetone (v)	0	-	$\dot{n}_{out,A(v)}$	$\hat{H}_{out,A(v)}$
Acetone (l)	$\dot{n}_{inA(l)}$	$\hat{H}_{in,A(l)}$	$\dot{n}_{out,A(l)}$	$\hat{H}_{out,A(l)}$
Water (v)	0	-	$\dot{n}_{out,W(v)}$	$\hat{H}_{out,W(v)}$
Water (l)	$\dot{n}_{in,W(l)}$	$\hat{H}_{in,W(l)}$	$\dot{n}_{out,W(l)}$	$\hat{H}_{out,W(l)}$

4) Reference

$$\boxed{\hat{H}_{in,A(l)} = 0}$$

$$\boxed{\hat{H}_{out,A(l)} = \int_{20}^{100} C_{P,Ac,l}\, dT}$$

$$\text{Ac liq } 20^\circ \xrightarrow{\Delta H_a} \text{Ac liq } 100^\circ$$

~~Ac liq 56° —ΔH°v,Ac→ Ac~~

$$\begin{array}{ccc} \text{Ac liq } 20^\circ & \longrightarrow & \text{Ac vap } 100^\circ \\ \downarrow & & \uparrow \\ \text{Ac liq } 56^\circ & \xrightarrow{\Delta H^{o}_{v,Ac}} & \text{Ac vap } 56^\circ \end{array}$$

$$\boxed{\hat{H}_{out,A(v)} = \int_{20}^{56} C_{P,Ac,l} + \Delta H^{o}_{v,Ac} + \int_{56}^{100} C_{P,Ac,V}}$$