PRELIM 2

VERSION: DELTA-2

NAME:

1. Prelim 2 has *two* problems and is worth a total of 50 points.
2. You may use your course notes (on the computer, iPad, etc., or paper) or other course materials, e.g., discussion problems, to formulate your solutions.
3. Do not consult with any other person regarding the prelim (except the TAs or JV), or use *any form of electronic communication* to discuss the prelim questions. Violation of this policy will result in a ZERO for the prelim.
4. Do not consult the interwebs to search for the prelim questions/solutions. Violation of this policy will result in a ZERO for the prelim.
5. Show your work and state all assumptions or simplifications.
6. Good luck!

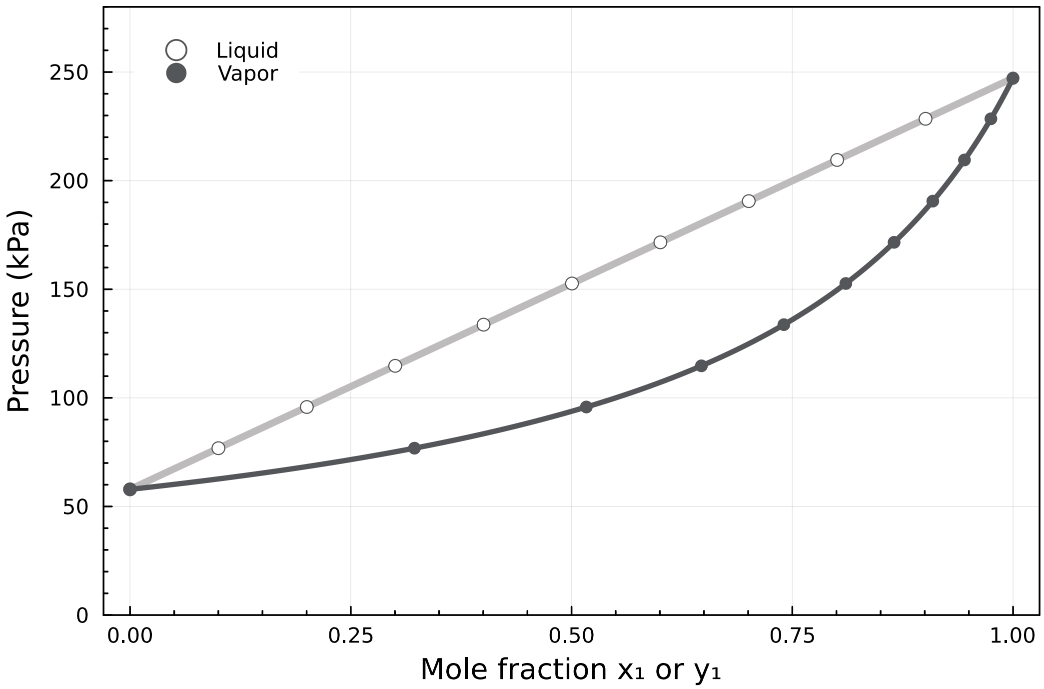

Figure 1: Pressure (kPa) versus composition (x_1 or y_1) for a binary mixture of Acetone(1)/Water(2) computed assuming ideal liquid and vapor phases.

1. (25 points) Cornell Inc. was hired to design a flash separation process for a binary ($\mathcal{M}$ = 2) mixture of Acetone(1)/Water(2). The engineering team has been asked to do initial design calculations using an ideal Pxy diagram (Fig. 1).

   Let the saturation pressure of component i be described by the Antoine equation:

$$\ln\left(P_i^{sat}\right) = A_i - \frac{B_i}{C_i + T} \tag{1}$$

   where P_i^{sat} has units of kPa and the temperature T has units of $^{\circ}C$. The Antoine parameters are given by:

   Table 1: Antoine parameters for the Acetone/Water flash problem.

Species	A	B	C
Acetone	14.31	2756.22	228.06
Water	16.39	3885.7	230.17

   Assumptions: (i) the Flash drum operates at steady-state; (ii) vapor-liquid equilibrium occurs everywhere inside the drum at some (T,P); (iii) treat both the vapor and liquid phases as ideal; (iv) the Flash drum is well-mixed; (v) a single liquid feed (stream 1) enters, and a vapor (stream 2) and liquid (stream 3) exit the drum; (vi) R = 8.314$\times$10^{-2} L bar K^{-1} mol^{-1}.

a) (3 points) What temperature T (°C) is the Flash drum operating at? (place your estimated temperature in Table 2).

b) (20 points) Graphically estimate the exit composition and compute the missing values in Table 2 assuming the Flash drum operates at P = 150 kPa with an input feed rate of $\dot{F}$ = 10 mol/t and z_1 = 0.64.

c) (2 points) Check your graphical composition estimates by computing the residual ϵ from the pressure expression:

$$\epsilon \equiv x_1 P_1^{sat} + x_2 P_2^{sat} - P \tag{2}$$

If abs$(\epsilon) > 5\%$, then recompute your values for part b (and update your values in Table 2).

Table 2: State table for the Pxy flash problem.

Stream	State	T (°C)	$\dot{n}_{s,T}$ (mol/t)	x_1 or y_1	x_2 or y_2	P (kPa)
1	L	N/A	10	0.64	0.36	N/A
2	V					
3	L					

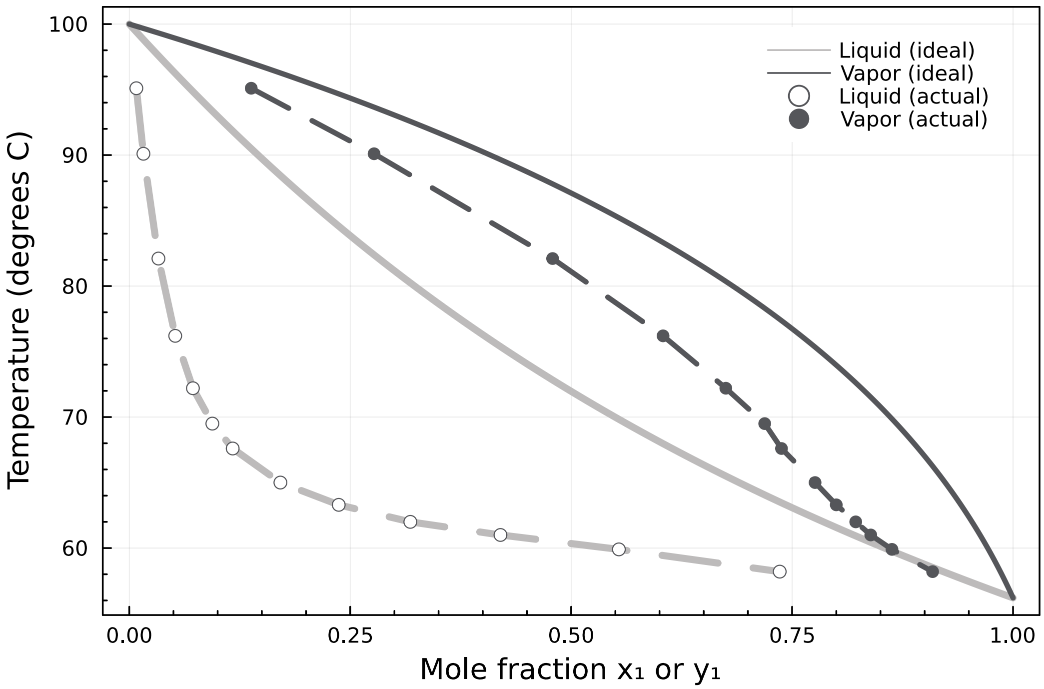

Figure 2: Temperature ($^{\circ}C$) versus composition (x_1 or y_1) for a binary mixture of Acetone(1)/Water(2) computed assuming ideal liquid and vapor phases (solid lines) and measured experimentally (dashed lines).

2. (25 points) Cornell Inc. was hired to design a flash separation process for a binary ($\mathcal{M}$ = 2) mixture of Acetone(1)/Water(2). The engineering team performed initial design calculations assuming an ideal liquid and vapor phase, a drum temperature of T = 70°C and z_1 = 0.64 (Fig. 2).

   Let the saturation pressure of component i be described by the Antoine equation:

$$\ln\left(P_i^{sat}\right) = A_i - \frac{B_i}{C_i + T} \tag{3}$$

   where P_i^{sat} has units of kPa and the temperature T has units of $^{\circ}C$. The Antoine parameters are given by:

   Table 3: Antoine parameters for the Acetone/Water flash problem.

Species	A	B	C
Acetone	14.31	2756.22	228.06
Water	16.39	3885.7	230.17

   Assumptions: (i) the Flash drum operates at steady-state; (ii) vapor-liquid equilibrium occurs everywhere inside the drum at some (T,P); (iii) treat both the vapor and liquid phases as ideal (unless using experimental data); (iv) the Flash drum is well-mixed; (v) a single liquid feed (stream 1) enters, and a vapor (stream 2) and liquid (stream 3) exit the drum; (vi) R = 8.314 L kPa K^{-1} mol^{-1}.

a) (2 points) Using the ideal data, what pressure is the Flash drum operating at? (place your estimated pressure value in Table 4).

b) (12 points) Estimate the missing values in Table 4 assuming an ideal system, with an input feed rate of $\dot{F}$ = 10 mol/t and composition z_1 = 0.64.

c) (10 points) When presenting your design, the client revealed the actual Pxy behavior for this mixture (Fig. 2, dashed lines). Recompute the missing values in Table 5 for the actual system.

Table 4: Ideal state table for the Acetone/Water Txy flash problem.

Stream	State	P (kPa)	$\dot{n}_{s,T}$ (mol/t)	x_1 or y_1	x_2 or y_2	T ($^\circ$C)
1	L	N/A	10	0.64	0.36	N/A
2	V					70.0
3	L		7.1	0.55		70.0

Table 5: Actual state table for the Acetone/Water Txy flash problem.

Stream	State	$\dot{n}_{s,T}$ (mol/t)	x_1 or y_1	x_2 or y_2	T (°C)
1	L	10	0.64	0.36	N/A
2	V		0.72		70.0
3	L				70.0