Exam 2
C&PE 211
Monday October 29, 2012
Closed Book - Closed Notes

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Name:

1. Please do not turn the page until you are instructed to do so.
2. Please write your name in the space provided and if you separate the pages, put your initials on all of the pages.
3. Please read each question carefully and work those that you know first. Do not spend too much time on one problem. If you get stuck move on to the next question. Partial credit is given so working through a problem as much as you can is to your benefit.
4. Do all of the work on the sheets provided. Write clearly and organized. If I cannot read your writing or follow the solution, no credit will be given.
5. Only a small amount of credit is given for the answer to the problem. The majority of the credit is given for the formulas and the work you use to solve the problem. If you do not show all of your work you will not receive full credit for the problem.
6. Cheating on this exam will result in a no credit for the exam. Two instances of cheating will result in failure of the course.
7. If a box is provided please put your answers in the box. If a box is not provided, please box your final answers. All work will be checked, but the answer in the box will be considered to be the final answer.

Please remember:
Don't panic! Panicking can cause silly errors.
Good Luck!

"So, Foster! That's how you want it, huh? ...
Then take this!"

1. (11 points total - no partial credit for each part) On the following Pxy diagram for acetone and benzene.

b) (1 point) Label the region of vapor (V)

c) (1 point) Label the region of liquid (L)

d) (1 point) Label the region of two-phase equilibrium (V+L)

e) (1 point) Label the bubble point

f) (1 point) Label the dew point

g) (2 points) An equimolar feed of acetone and benzene at 25°C is allowed to come to equilibrium at 160 mm Hg. What is the mole fraction of acetone in the vapor and the liquid phases?

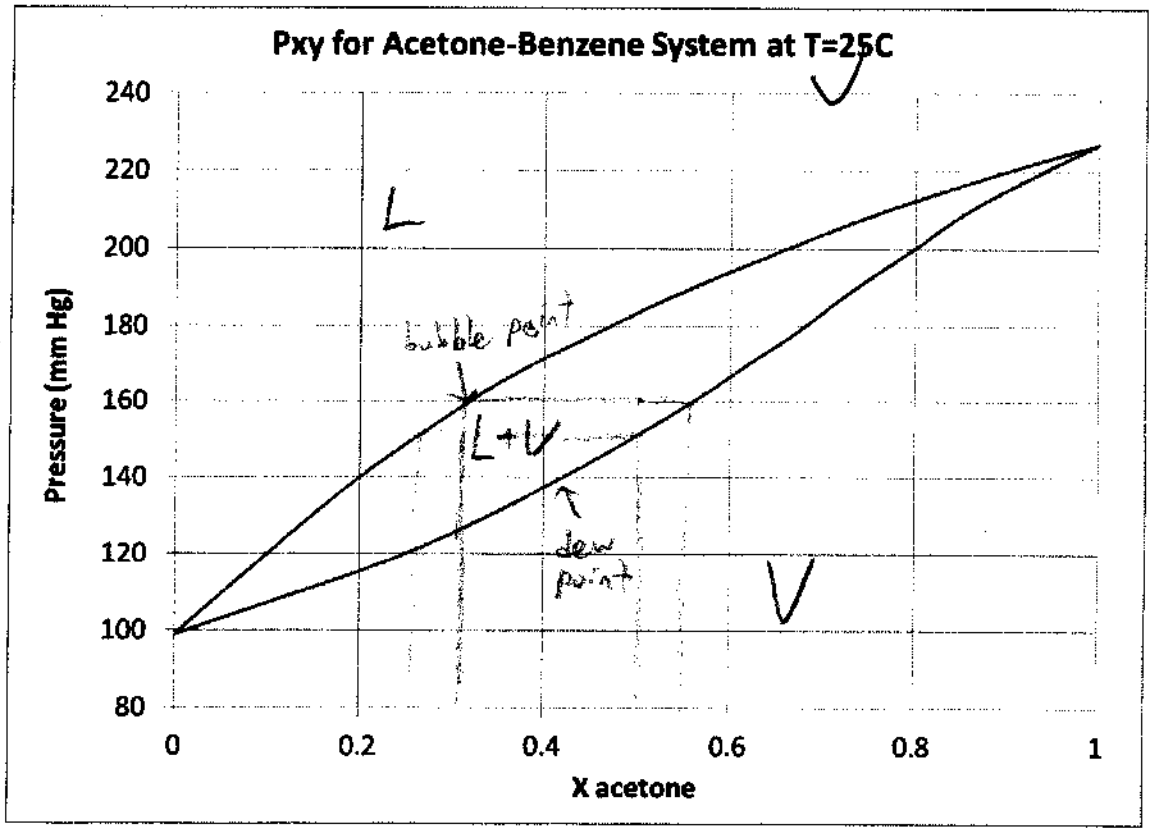
Ya = 0.55	Xa = 0.3

h) (2 points) What would be the dew point pressure of the equimolar feed of acetone and benzene at 25°C?

~~Bubble~~ dew point pressure = 150 mm Hg

i) (2 points) What would be the mole fraction of acetone in the liquid phase at the dew point you found in part h?

Mole fraction of acetone in liquid phase at dew point = 0.25

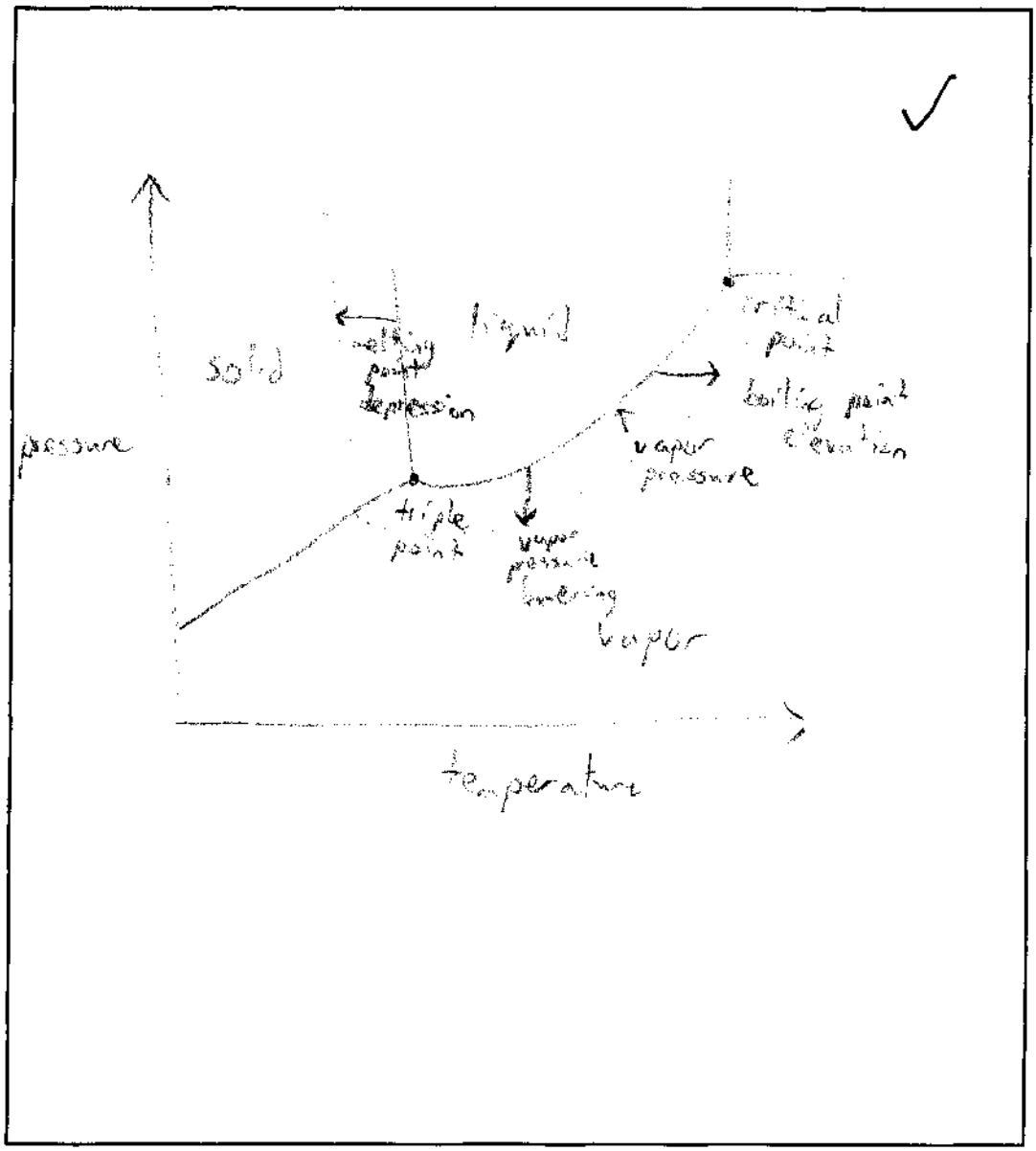


2. (11 points total, no partial credit for each part)

11/

In the space below, show an example of a typical pure solvent phase diagram with **temperature on the x axis** and **pressure on the y axis.**

a. (3 points) Identify the regions of solid, vapor, and liquid.
b. (2 points) Identify the critical point and triple point
c. (2 points) Identify which line corresponds to the vapor pressure
d. (2 points) Using the same graph, show what happens to the phase-equilibrium curves when you have a solution. Use a dashed line to indicate the solution phase-equilibrium line.
e. (2 points) Using the graph show the colligative properties of vapor pressure lowering, boiling point elevation, and melting point depression.



3. (3 points – no partial credit) Explain what an extensive variable is and give three specific examples.

3

Extensive variable - property which is dependant on the size of the system.

1) Mass
2) Volume
3) Pressure ✓
4) Moles of substance

4. (5 points – no partial credit for each part)

5

a. (3 points) If you have a mixture of ice, liquid water, and water vapor use the Gibbs phase rule to show how many degrees of freedom exist for that system.

b. (2 points) Explain why this answer makes sense or what is significant about the answer.

a. $C - P + 2 = \#\ DoF$ ✓

$1 - 3 + 2 = 0$

b. It means that there are 0 degrees of freedom in the system. This means we know everything about this system without any further information. Also note that this is the triple point. ✓

5. (20 points) An air stream containing 10% water vapor is being cooled isobarically at 1 atm. If the dew point temperature is found to be 53°C and you know the stream has 22°C of superheat.

20

a. Determine the temperature of the stream entering the unit and the relative humidity of the stream entering the unit.
b. If the mole fraction of the water in the vapor leaving the condenser is 0.04, find the operating temperature of the condenser.

Temperature of feed = 75°C

Relative humidity of feed = 26.3% ✓

Operating temperature of the condenser = 29.2 °C

relative humidity $= \frac{p_i}{p^*} = X$

$p^*(75\,^\circ C) = 10^{7.96681 - \frac{1668.210}{75 + 228}} = 289.1787$ mm Hg

$p_i = 0.1 \cdot 760 = 76$ mm Hg

$\frac{76}{289.1787} = 26.3\%$

$X_i P^* = y_i P$

$P^* = 0.04 \cdot 760$ mm Hg $= 30.4$ mm Hg

$\log(30.4) = 8.10765 - \frac{1750.286}{T + 235}$

$T = 29.2$ °C

25

6. (25 points) A process stream flowing at 35kmol/h contains 15 mole% hydrogen and the remainder 1-butene. The stream pressure is 10 atm absolute, the temperature is 50°C and the velocity of the fluid is 150 m/min.
   a. Determine the diameter (in cm) of the pipe transporting the fluid in the process assuming that 10 atm is too high of a pressure to be considered ideal.
   b. Would be the diameter of the pipe but larger, smaller, or the same if you had assumed the gas was ideal and why? You do not need to do the calculations but you must justify your answer.

a. Diameter of the pipe (cm) = 10.7 cm

b. larger, as a $z=1$ would yield higher volume flow rate & therefore a larger pipe.

✓

$T_c = 0.85 \cdot 419.6 + 0.15(33.3+8) = 362.855\ K$

$P_c = 0.85 \cdot 39.7 + 0.15(2.8+8) = 36.865\ atm$

$T_R = \frac{323.15}{362.855} = 0.89$

$P_R = \frac{10}{36.865} = 0.27$ $\Big\}$ $z = 0.87$

$z = \frac{PV}{nRT}$

$0.87 = \frac{10 \cdot V}{35000 \cdot 0.08206 \cdot 323.15}$ $\quad V = 80,726.36\ \frac{L}{h} = 1.3457\ \frac{m^3}{min}$

$\frac{1.3457\ \frac{m^3}{min}}{150\ \frac{m}{min}} = 0.00897\ m^2 = \pi r^2$

$d = 10.7\ cm$

25/

7. (25 points) A mixture of 40% isobutane and 60% n-pentane is sent to a flash unit where a liquid and a vapor stream are produced. The unit is operating at 49°C and the streams leaving the unit can be considered to be in equilibrium. If the liquid stream leaving the flash unit is 25 mole% isobutane, find the pressure of the flash unit, the composition of the vapor stream leaving the unit, and the total vapor to liquid ratio (V/L).

Pressure of flash unit (mm of Hg) = 2111.151 mmHg

Composition of vapor stream leaving flash:

isobutane (mole %) = 58.9% ✓

n-pentane (mole %) = 41.1%

Total vapor to liquid ratio (V/L) = 0.79

$x_i P_i^* = y_i P$ isobutane $P_i^*(49) = 10^{6.7966 - 882.817/(44+241.9}$

n-pentane $P_i^*(49) = 10^{6.8447 - 1060.793/(44+231.54}$

isobutane $.25 \cdot 4972 = y_i \cdot P = P_i = 1243.129$ mmHg

n-pentane $.75 \cdot 1157.362 = y_i P = P_i = 868.023$ mmHg

$\Sigma P_i = P = 2111.151$ mmHg

isobutane $\frac{P_i}{P} = y_i = 0.5888$

n-pentane $\frac{P_i}{P} = y_i = 0.4112$

$z_i F = x_i L + y_i V \qquad F = L + V$

$\frac{z_i F}{L} = x_i + y_i \frac{V}{L}$

$\frac{0.4(L+V)}{L} = 0.25 + 0.589 \frac{V}{L}$ $\qquad .4 + 0.4\frac{V}{L} = 0.25 + 0.589\frac{V}{L}$

$\frac{V}{L} = 0.7935$

Extra credit (5 points -- no partial credit)

The following is a ternary diagram of the liquid-liquid equilibrium for acetone (A), water (W) and methyl-isobutyl-ketone (MIK) at 25 °C and 1 atm in mass fraction (W_i).

a) Draw a point with a circle around it to indicate where on the ternary diagram you would be if you made a mixture in the proportions of 30% acetone, 43 % water and 27% MIK.

b) IF you let the mixture sit and come to equilibrium, determine if you would have 1 phase or 2 phases for the mixture above and if you had two phases determine the composition of each phase.

How many phases?

2 liquid phases

If more than one phase, what is composition of each phase?

Phase 1: 7% water
37% acetone
56% MIK

Phase 2: 72% water
25% acetone
3% MIK ✓