Exam 2
CHM 3400, Dr. Chatfield,

Read through the questions thoroughly, set up the answers carefully, show your work, and be neat. There are 5 questions; each is worth 20 points. Partial credit will be given when the instructor can follow your train of thought. Credit will not be given for answers without work or reasoning. If you have difficulty with a question, go on and return to it later. Check your work.

GOOD LUCK!

1. An aqueous solution of an unknown compound is prepared by dissolving 0.0500 g of the unknown in water so that the total volume of the solution is 100.0 mL. The osmotic pressure at 298 K is measured to be Π = 76.0 Torr. Determine the molar mass of the unkown.

$$[B] = \frac{\Pi}{RT} = \frac{76.0\ \text{Torr} \cdot \frac{1\ \text{atm}}{760\ \text{Torr}} \cdot \frac{1.01325\ \text{bar}}{\text{atm}}}{0.0831447\ \text{L-bar K}^{-1}\text{mol}^{-1} \cdot 298\text{K}}$$

$$= 0.004089\ \text{mol/L}$$

$$V = 0.100\ \text{L}$$

$$n = V[B] = 0.0004089\ \text{mol}$$

$$M = \frac{m}{n} = \frac{0.0500\text{g}}{0.0004089\ \text{mol}} = 122\ \text{g/mol}$$

2. Determine the boiling point of methanol in a rotovap in which the pressure is 0.500 bar. Given: The standard boiling point of methanol (i.e. T_b at p = 1 bar) is 337.2 K, and $\Delta_{vap}H^\circ = 35.27$ kJ mol^{-1}. (You may treat $\Delta_{vap}H^\circ = 35.27$ as constant.)

$$\ln \frac{p'}{p} = \frac{\Delta_{vap} H^\ominus}{R}\left(\frac{1}{T} - \frac{1}{T'}\right)$$

$$\frac{1}{T'} = \frac{1}{T} - \frac{R}{\Delta H^\ominus_{vap}} \ln \frac{p'}{p}$$

p' ← 0.5 bar

T ← 337.2 K

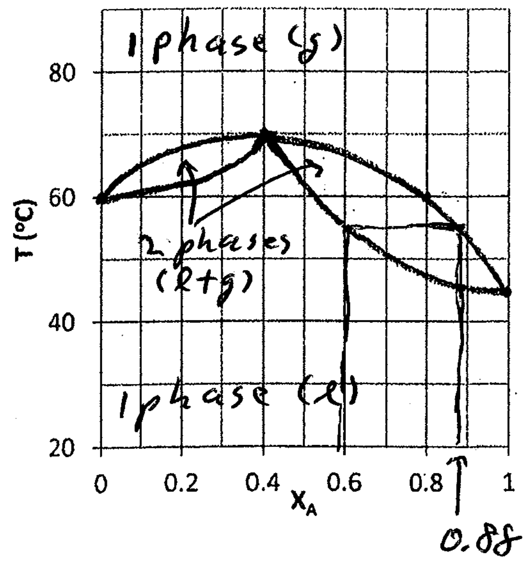
$\Delta H^\ominus_{vap}$ ← 35270 J mol^{-1}

p ← 1 bar

$$\frac{1}{T'} = 0.002966 + 0.00016 = 0.003129 \text{ K}^{-1}$$

$$T' = 319.6 \text{ K}$$

3. Below is a phase diagram for a binary liquid-gas mixture. Answer questions a-e; each is worth 4 points.



a. Label the 1-phase and 2-phase regions of the phase diagram.

b. If a mixture with composition $X_A = 0.6$ is heated, at what temperature will boiling begin, i.e. vapor begin to form (estimate from the plot)? 55 °C

c. For heating process described in (b), what will the composition of the vapor be (X_A = ?) when boiling just begins? $X_A = 0.88$

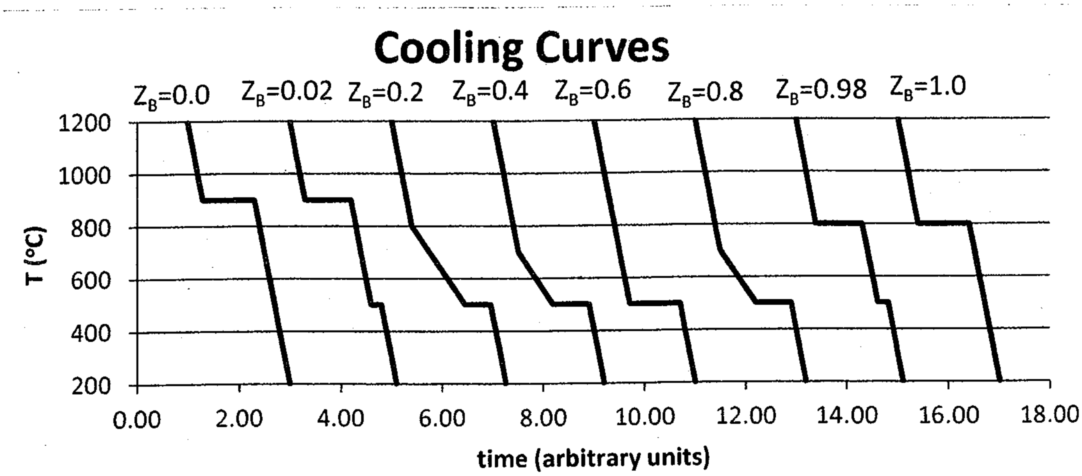
d. What is a mixture with composition $X_A = 0.4$ called? azeotrope

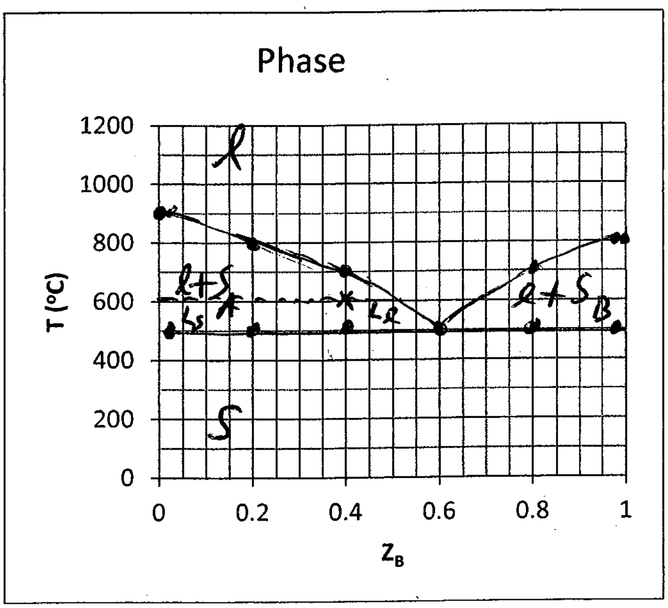
e. Is it possible to separate the components by distillation beginning with a mixture with composition $X_A = 0.4$? Why or why not?

No. Liquid and gas phases have same concentration as azeotropic mixture boils.

4. In class and on homework, we saw how to predict cooling curves from a given phase diagram. In this question, we turn the problem around, and see how a set of cooling curves can be used to construct a phase diagram. Below is a set of cooling curves obtained for a mixture of two metals, A and B. At the highest temperature, there is one phase and it is liquid. At the lowest temperature, the mixture is solid.

(a) From the cooling curves, construct the phase diagram on the graph provided.





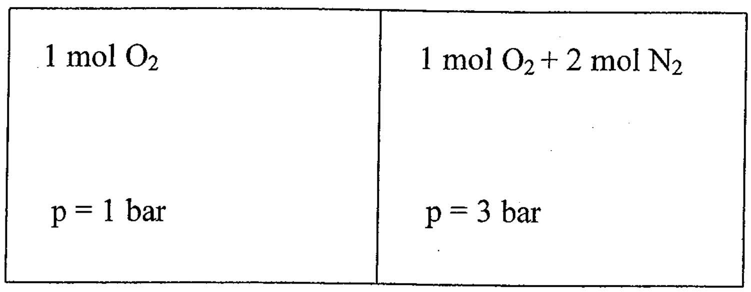
(b) Identify the eutectic composition (Z_B = ?) $Z_B = 0.6$

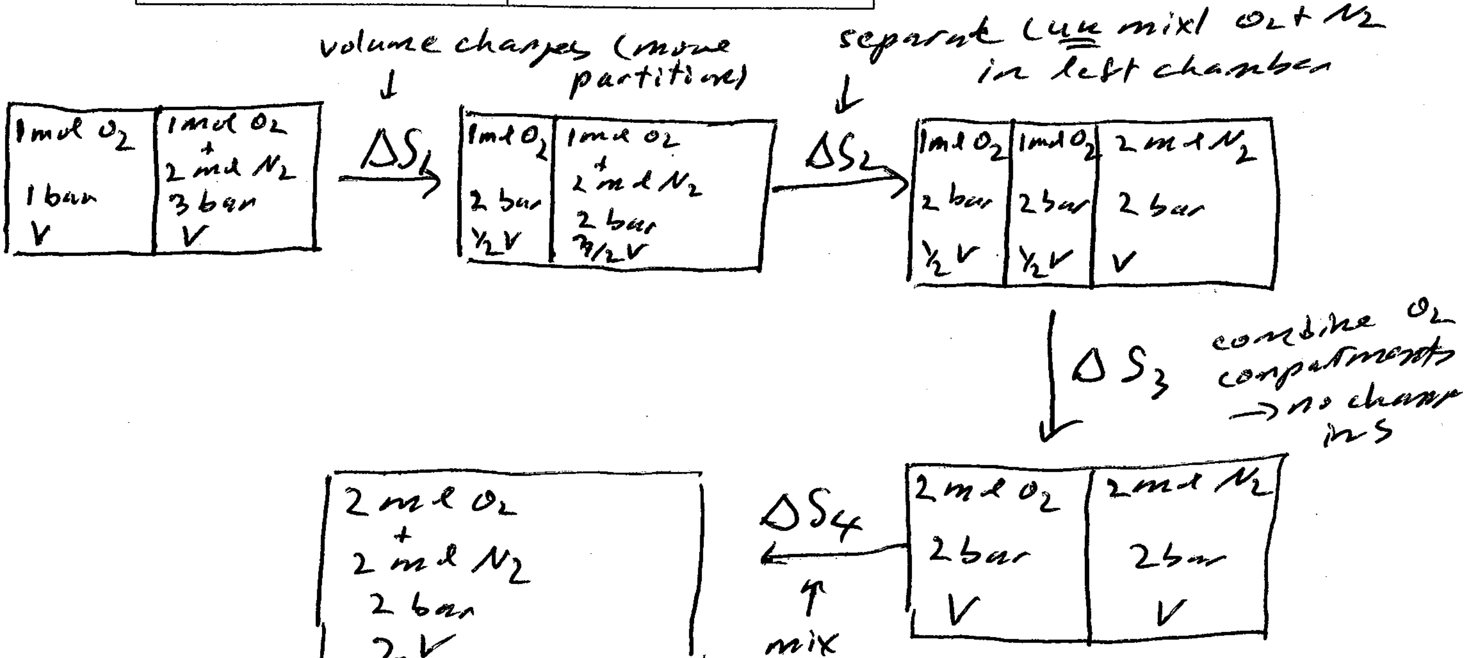
(c) When the overall composition (Z_B) is 0.4 and the temperature is 600 °C:
i. Determine the composition of the liquid (X_B) and solid (Y_B) phases present
ii. Determine the relative amount of the liquid and solid phases (n_l/n_s)

$$\frac{n_l}{n_s} = \frac{L_s}{L_l} = \frac{8}{2} = 4$$

Four times as much liquid as solid.

5. Consider a rigid container as sketched below. It is divided into two sections of equal volume by a partition. Initially, there is 1 mol O_2 on one side at 1 bar pressure, and a mixture of 1 mol O_2 and 2 mol N_2 on the other side at 3 bar pressure. At a particular time, the partition is removed. Calculate ΔS, the change in entropy after the partition is removed. You may treat the gases as perfect. Hint: construct a cycle, that is, a series of fictitious steps.





$$\Delta S_1 = \overset{1\text{ mol}}{n} R \ln \frac{\frac{1}{2}V}{V} + \overset{3\text{ mol}}{n} R \ln \frac{\frac{3}{2}V}{V} = -5.76 + \sout{0.11}\ 10.11 = 4.35\ \mathrm{J\,K^{-1}}$$

$$\Delta S_2 = +\overset{3\text{ mol}}{n} R \left(\tfrac{1}{3}\ln\tfrac{1}{3} + \tfrac{2}{3}\ln\tfrac{2}{3}\right) = -15.88\ \mathrm{J\,K^{-1}}$$

$$\Delta S_3 = 0$$

$$\Delta S_4 = -\overset{4\text{ mol}}{n} R \left(\tfrac{1}{2}\ln\tfrac{1}{2} + \tfrac{1}{2}\ln\tfrac{1}{2}\right) = 23.05\ \mathrm{J\,K^{-1}}$$

$$\Delta S = \sum_{i=1}^{4} \Delta S_i = 11.53\ \mathrm{J\,K^{-1}}$$

$\Delta S > 0$ as expected (no heat flow $\Rightarrow \Delta S_{sur} = 0$, $\Delta S_{tot} = \Delta S$)

Equations and constants for Exam 2, CHM 3400, Fall 2011

1 atm = 760 Torr = 1.01325 bar

R = 8.31451 J K^{-1} mol^{-1} = 0.0831451 L bar K^{-1} mol^{-1}

$\Pi = [B]RT$

$\Delta T_f = K_f b_B$

$\Delta T_b = K_b b_B$

$\Delta G = nRT(x_A \ln x_A + x_B \ln x_B)$

$\Delta S = -nR(x_A \ln x_A + x_B \ln x_B)$

$$\Delta S = nR \ln\left(\frac{V_f}{V_i}\right)$$

$$\ln \frac{p'}{p} = \frac{\Delta_{vap} H^O}{R}\left(\frac{1}{T} - \frac{1}{T'}\right)$$

$\Delta G = -S_m \Delta T$

$\Delta G = V \Delta p$

$\Delta_r G^O = -RT \ln K$

$\Delta H = C_p \Delta T$

$\Delta_r H(T') = \Delta_r H(T) + \Delta C_p \Delta T$

$$\Delta S = C_p \ln\left(\frac{T_f}{T_i}\right)$$

$dU = TdS - pdV$

$F = C - P + 2$

$p_A = x_A p_A^*$

$p_B = x_B K_B$

$G = n_A \mu_A + n_B \mu_B$

$\mu_A = \mu_A^O + RT \ln a_A$

$$\frac{n'}{n''} = \frac{l''}{l'}$$