CHM 3400 – Fundamentals of Physical Chemistry
Second Hour Exam

There are five problems on the exam. Do all of the problems. Show your work

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R = 0.08206 L•atm/mole•K	$N_A = 6.022 \times 10^{23}$
R = 0.08314 L•bar/mole•K	1 L•atm = 101.3 J
R = 8.314 J/mole•K	1 atm = 1.013 bar = 1.013×10^5 N/m^2
F = 96485. C/mol	1 atm = 760 torr
(1 volt)•(1 Coulomb) = 1 Joule	

Two phase diagrams are given below. The one on the left is for a pure chemical substance, (substance C), and is used in problem 1. The one on the right is for a mixture of two volatile liquids (A and B), and is used in problem 2.

1. (18 points) This question deals with pure chemical substance C, whose phase diagram is the left side diagram below.

a) For pure substance C give the temperature corresponding to i.) the normal melting point for the substance, ii.) the normal boiling point for the substance, and iii.) the normal sublimation point for the substance. If one or more of these points does not exist, briefly explain why the point does not exist.

b) Points A and B on the phase diagram for pure substance C have the following location

A: p = 1.71 atm, T = 120.0 °C B: p = 4.54 atm, T = 140.0 °C

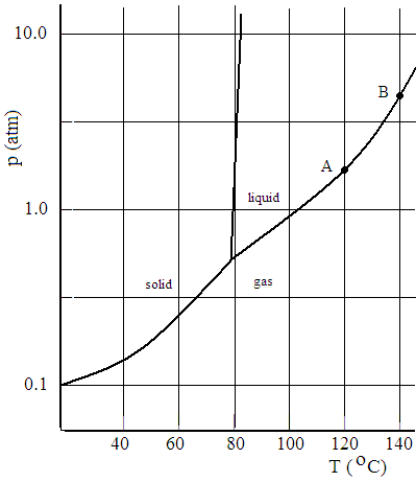
Based on this data find ΔH_{vap}, the enthalpy of vaporization for substance C.

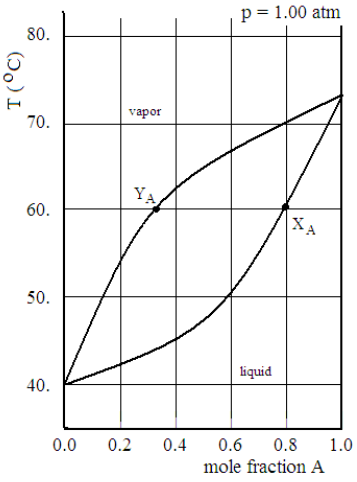
2. (20 points) This question deals with the mixture of volatile liquids A and B, whose phase diagram is the right side diagram below. Note that at T = 60. °C the mole fractions of A in the liquid and vapor phases are $X_A = 0.795$ and $Y_A = 0.330$

a) What are $T_A°$ and $T_B°$, the normal boiling point temperatures for liquids A and B?

b) For a closed system with $Z_A = 0.60$ and T = 60. °C which will be larger - the total number of moles of liquid in the system, or the total number of moles of vapor in the system? Briefly justify your answer.

c) Assuming that A and B form an ideal solution, find the value for p_A*, the vapor pressure of pure A, at T = 60.0 °C? Give your answer in units of atm.





3. (14 points) A common method for providing nourishment to someone following surgery is the use of a 5% solution of glucose in water, injected intravenously directly into the blood stream. Such a solution contains 5.00 g glucose (M = 180.2 g/mol) per 100.0 mL solution. Since the solution is approximately isotonic (same osmotic pressure) with blood plasma, use of a solution at this concentration of glucose does no damage to red blood cells or other cells in the blood stream.

Find the osmotic pressure of a 5% glucose solution in water at T = 37. °C. Give your final answer in units of atm.

Standard half-cell reduction potentials for several substances are given below (at T = 25.0 °C) and may be of use in doing problem 4.

Reaction	E° (v)	Reaction	E° (v)
$Cu^{2+}(aq) + 2\ e^- \rightarrow Cu(s)$	+ 0.34 v	$2\ H_2O(\ell) + 2\ e^- \rightarrow H_2(g) + 2\ OH^-(aq)$	- 0.83 v
$2\ H^+(aq) + 2\ e^- \rightarrow H_2(g)$	0.00 v		

4. (24 points) Consider the following galvanic cell

$$M(s) \mid M^{3+}(aq,\ a = 1.0 \times 10^{-4}) \parallel Cu^{2+}(aq,\ a = 0.050) \mid Cu(s) \qquad (4.1)$$

where M represents some unspecified rare earth metal, and the activities of M^{3+} and Cu^{2+} ions are as specified in the cell diagram. The cell potential for the given conditions for this galvanic cell, measured at T = 25.0 °C, is E_{cell} = 0.143 v.

a) What are the half-cell oxidation reaction, the half-cell reduction reaction, and the net cell reaction for the above galvanic cell?

b) What is the numerical value for ΔG_{cell}, the free energy change, for the above galvanic cell?

c) What is the value for $E°(M^{3+},M)$, the standard half-cell reduction potential at T = 25.0 °C, for the process

$$M^{3+}(aq) + 3\ e^- \rightarrow M(s) \qquad (4.2)$$

5. (24 points) Iron pentacarbonyl ($Fe(CO)_5$) is an inorganic compound used as the starting material in the preparation of additional inorganic iron compounds, many of which are themselves used in synthetic organic chemistry. It is prepared by the reaction

$$Fe(s) + 5\ CO(g) \leftrightarrows Fe(CO)_5(g) \qquad (5.1)$$

The reaction is slow at room temperature, and so is normally carried out at high temperature and pressure. Because of this, the equilibrium properties of the compound must be inferred from thermochemical data.

a) Give the expression for the equilibrium constant for the above reaction in terms of reactant and product activities.

b) Give the expression for the equilibrium constant for the above reaction assuming ideal behavior of the reactants and products.

Using the data given below (at T = 298. K), find the following:

c) The numerical value for the equilibrium constant at T = 298. K.

d) The numerical value for the equilibrium constant at T = 500. K.

Substance	$\Delta H°_f$ (kJ/mol)	$\Delta G°_f$ (kJ/mol)	S°(J/mol·K)
CO(g)	- 110.53	- 137.17	197.67
Fe(s)	0.0	0.0	27.28
$Fe(CO)_5(g)$	- 733.9	- 697.3	445.2