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	

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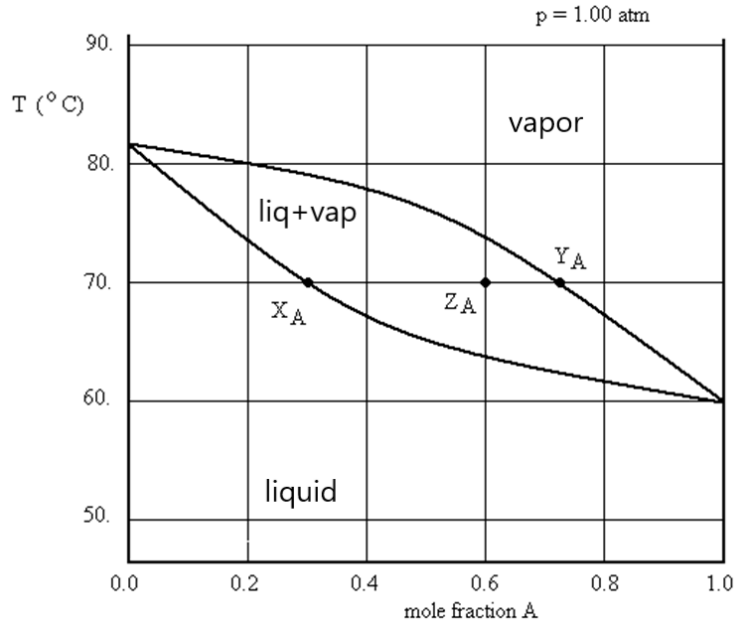
1. (24 points) A phase diagram for two volatile liquids A and B is given below, and may be used to answer the following questions. Note that in this problem p = 1.00 atm.

a) What are the values for $T_A°$ (normal boiling point of A) and $T_B°$ (normal boiling point of B).

b) Does the above solution form any azeotropes? If your answer is yes, give the location (temperature and mole fraction) of each azeotrope that forms.

c) A closed system contains a solution of A and B at low temperature, with n_A = 3.00 moles and n_B = 2.00 moles (and so Z_A = 0.600). The solution is slowly heated. At what temperature (in °C) will the solution first begin to boil.

d) We continue heating the solution until we reach a temperature T = 70.0 °C. At this point, X_A = 0.308 and Y_A = 0.724. How many moles of A are in the vapor phase at this temperature?



2. (16 points) The vapor pressure of pure water (H_2O, M = 18.02 g/mol) at T = 30.0 °C is 31.824 torr. When 1.084 g of a nonvolatile and nonionizing solute is dissolved in 200.0 g of water, the vapor pressure of the solution, again measured at 30.0 °C, is 0.037 torr lower than the vapor pressure of pure water at the same temperature. What is M, the molecular mass of the solute?

3. (24 points) Phosphine (PH_3) is the phosphorus analogue of ammonia (NH_3). It plays a role in the biochemical cycling of phosphorus in the biosphere. In the gas phase, phosphine exists in equilibrium with phosphorus (P_4) and hydrogen (H_2).

$$P_4(g) + 6\ H_2(g) \leftrightarrows 4\ PH_3(g) \qquad (3.1)$$

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

b) Find the numerical value for the equilibrium constant for the above reaction at T = 298. K.

c) Find the numerical value for the equilibrium constant for the above reaction at T = 400. K.

Thermochemical data of use in doing this problem are given below at T = 298. K.

Substance	$\Delta H°_f$ (kJ/mol)	$\Delta G°_f$ (kJ/mol)	S° (J/mol·K)
$H_2(g)$	0.0	0.0	130.68
$P_4(g)$	58.91	24.44	279.98
$PH_3(g)$	5.4	13.4	210.23

4. (16 points) Consider the following galvanic cell.

$$H_2(g) \mid H^+(aq) \parallel AgCl(s) \mid Ag(s) \qquad (4.1)$$

The balanced net cell reaction corresponding to this galvanic cell is

$$H_2(g) + 2\ AgCl(s) \rightarrow 2\ H^+(aq) + 2\ Cl^-(aq) + 2\ Ag(s) \qquad (4.2)$$

Data for the standard cell potential for the above galvanic cell have been obtained at several temperatures, and fit to the following formula

$$E°_{cell} = 0.2220\ v - (6.5 \times 10^{-4}\ v/K)\ (T - 298.\ K) \qquad (4.3)$$

Using eq 4.3, find $E°_{cell}$ and $\Delta G°_{rxn}$ for the above galvanic cell at T = 298.

5. (20 points) The gas phase reaction

$$2\ NO_2(g) + F_2(g) \rightarrow 2\ NO_2F(g) \qquad (5.1)$$

is an example of a second order heterogeneous reaction, with the rate of the reaction given by the expression

$$\text{Rate} = -\frac{d[F_2]}{dt} = k[NO_2][F_2] \qquad (5.2)$$

where k = 38. L/mol·s at T = 27. °C

In a particular experiment (at T = 27. °C) the initial concentrations of reactants are $[NO_2]_0 = 2.0 \times 10^{-4}$ mol/L and $[F_2]_0 = 5.0 \times 10^{-5}$ mol/L. No NO_2F is initially present in the system.

a) What is R_0, the initial rate of reaction, for the above conditions.

b) What will be the rate of reaction in this experiment when the concentration of NO_2F in the system reaches the value $[NO_2F] = 3.0 \times 10^{-5}$ mol/L?