The Richard Stockton College of New Jersey
Chemistry Program, School of Natural Sciences and Mathematics
PO Box 195, Pomoma, NJ

CHEM 3410: Physical Chemistry I — Fall 2008

Exam 2

November 7, 2008

12:45–2 PM

Name: ____

Read all of the following information before starting the exam:

- This is a closed book exam. You are permitted an aid sheet consisting of two sides of a 8.5" x 11" piece of paper. **Your aid sheet must be turned in with your exam.**
- Show all work, clearly and in order, if you want to get full credit. I reserve the right to take off points if I cannot see how you arrived at your answer (even if your final answer is correct).
- Please keep your written answers brief; be clear and to the point. I will take points off for rambling and for incorrect or irrelevant statements.
- Justify your answers. Clearly state any assumptions you make.
- Circle or otherwise indicate your final answers.
- You have 75 minutes to complete the exam. There are a total of 67 points on the exam, so budget your time accordingly.
- For problems involving calculations, set up your calculations first and then do the computation if time permits.
- Be sure to read all the questions first. You do not have to complete the problems in any particular order.
- Good luck!

Use of wireless communication devices at any time during the exam is strictly prohibited.

Question	Score	Total
1		16
2		18
3		17
4		16
Total		67

1. (*16* points) Consider two possible processes for the vaporization of one mole of H_2O at 95°C and 1 atm.

A. The H_2O is the only substance in the container which is kept at constant pressure and temperature giving the process:

$$H_2O\ (l,\ 95°C, 1\ atm) \rightarrow H_2O\ (g,\ 95°C, 1\ atm)$$

B. One mole of He is present in the container along with one mole of H_2O. The container is kept at constant pressure and temperature. The $H_2O(l)$ and He(g) are initially not mixed since one is a liquid and the other is a gas. But after vaporizing, the $H_2O(g)$ then mixes with the He(g) in the container, giving the total process:

$$H_2O\ (l,\ 95°C, 1\ atm) + He\ (g,\ 95°C, 1\ atm) \rightarrow (H_2O + He)_{mixed}\ (g,\ 95°C, 1\ atm)$$

You can assume that He(g) and $H_2O(g)$ are ideal gases.

The following data may be useful:

The equilibrium boiling temperature of water is 100°C at 1 atm.

$\Delta H_{vap} = 40,525$ J/mol

$\Delta S_{vap} = 108.6$ J/molK

Assume that both the enthalpy of vaporization and the entropy of vaporization are independent of temperature in the range of 95°C to 100°C.

(a) Find ΔG for process **A**. Is this process spontaneous? (*4*)

(b) What are ΔS_{mixing} and ΔG_{mixing} for mixing one mole of He(g) with one mole $H_2O(g)$ at a constant pressure of 1 atm and a constant temperature of 95°C? (*4*)

(c) What is ΔG for the complete process **B**. Is this process spontaneous? (*4*)

(d) Predict whether $\Delta S_{universe}$ for process **B** will be positive, negative, or equal to zero. Briefly explain your choice. [*Bonus +4 if you calculate* $\Delta S_{universe}$ *for process* **B**] (*4*)

2. (*18* points) The gas phase dissociation of molecule A is given by:

$$A(g) \rightleftharpoons B(g) + C(g)$$

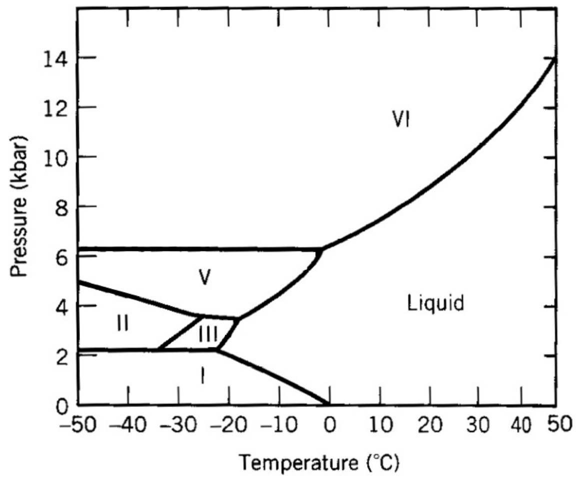
Initially pure A is placed in a container.

(a) At 80°C and 1 bar, the fraction α of "A" that is dissociated is 0.4. (If n moles of A are initially placed in the container, then αn moles will have dissociated leaving $n - \alpha n$ moles of A at equilibrium). Calculate the equilibrium constant K_p and the standard free energy change ΔG° for the dissociation of A at 80°C. (***6***)

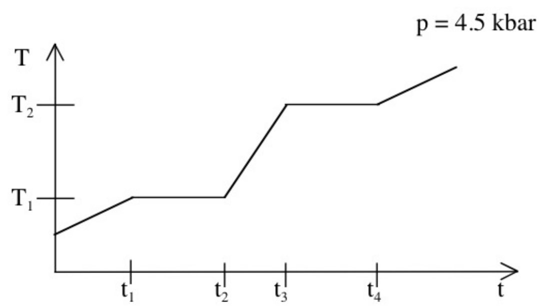
(b) Calculate the pressure at which the fraction α that is dissociated is 0.9 at 80°C. (***6***)

(c) At 320°C, $K_p = 1.076$. Calculate the standard heat of reaction ΔH° for the dissociation of "A" if ΔH° is assumed to be independent of temperature.
[If you were unable to do part (a), then use (incorrectly) $K_p(80°C) = 0.30$]. (***6***)

3. (*17* points) Unary phase diagrams, such as the one for water shown below,



are often constructed from data obtained using a constant pressure calorimeter. A carefully measured number of moles of the compound is placed in the calorimeter. Heat is added to the calorimeter at a constant rate and T is measured vs. time, t. A T vs. t plot for H_2O at $P = 4.5$ kbar might look like the sketch below:



(a) What is happening at T_1 and T_2? (*3*)

(b) Based on the above phase diagram for H_2O, what are the approximate values of T_1 and T_2? (*3*)

(c) If P is decreased from $P = 4.5$ kbar to $P = 4.0$ kbar, how will the temperatures of the horizontal regions of the T vs. t plot change? What do these changes tell you about the sign of ΔV for the II $\rightarrow$ V and V $\rightarrow$ liquid phase transitions?

(*4*)

(d) Sketch a similar heating curve for a pressure of 2.5 kbar. Indicate any relevant transformation temperatures on the sketch.

(*4*)

(e) Why do the non-horizontal portions of the heating curve have different slopes? (*3*)

4. (*16* points) Please identify each of the following statements as true or false. Give a brief justification for each answer.

   (a) The mixing of ideal gases is spontaneous at high temperatures but non-spontaenous at low temperatures. (*4*)

   (b) The entropy of a *system* is always maximized at equilibrium. (*4*)

   (c) The chemical potential of 12 grams of ice at 0°C and 1 atm is equal to the chemical potential of 12 grams of liquid water at 0°C and 1 atm. (*4*)

   (d) Increasing the pressure on a gas-phase reaction will always shift equilibrium towards the products. (*4*)

Potentially useful information

R = 0.0821 L·atm/mol·K = 8.314 J/mol·K

$PV = nRT$ for an ideal gas

$\Delta G = \Delta H - T\Delta S$

The Periodic Table of the Elements

1 **H** Hydrogen 1.00794																	2 **He** Helium 4.003
3 **Li** Lithium 6.941	4 **Be** Beryllium 9.012182											5 **B** Boron 10.811	6 **C** Carbon 12.0107	7 **N** Nitrogen 14.00674	8 **O** Oxygen 15.9994	9 **F** Fluorine 18.9984032	10 **Ne** Neon 20.1797
11 **Na** Sodium 22.989770	12 **Mg** Magnesium 24.3050											13 **Al** Aluminum 26.981538	14 **Si** Silicon 28.0855	15 **P** Phosphorus 30.973761	16 **S** Sulfur 32.066	17 **Cl** Chlorine 35.4527	18 **Ar** Argon 39.948
19 **K** Potassium 39.0983	20 **Ca** Calcium 40.078	21 **Sc** Scandium 44.955910	22 **Ti** Titanium 47.867	23 **V** Vanadium 50.9415	24 **Cr** Chromium 51.9961	25 **Mn** Manganese 54.938049	26 **Fe** Iron 55.845	27 **Co** Cobalt 58.933200	28 **Ni** Nickel 58.6934	29 **Cu** Copper 63.546	30 **Zn** Zinc 65.39	31 **Ga** Gallium 69.723	32 **Ge** Germanium 72.61	33 **As** Arsenic 74.92160	34 **Se** Selenium 78.96	35 **Br** Bromine 79.904	36 **Kr** Krypton 83.80
37 **Rb** Rubidium 85.4678	38 **Sr** Strontium 87.62	39 **Y** Yttrium 88.90585	40 **Zr** Zirconium 91.224	41 **Nb** Niobium 92.90638	42 **Mo** Molybdenum 95.94	43 **Tc** Technetium (98)	44 **Ru** Ruthenium 101.07	45 **Rh** Rhodium 102.90550	46 **Pd** Palladium 106.42	47 **Ag** Silver 107.8682	48 **Cd** Cadmium 112.411	49 **In** Indium 114.818	50 **Sn** Tin 118.710	51 **Sb** Antimony 121.760	52 **Te** Tellurium 127.60	53 **I** Iodine 126.90447	54 **Xe** Xenon 131.29
55 **Cs** Cesium 132.90545	56 **Ba** Barium 137.327	57 **La** Lanthanum 138.9055	72 **Hf** Hafnium 178.49	73 **Ta** Tantalum 180.9479	74 **W** Tungsten 183.84	75 **Re** Rhenium 186.207	76 **Os** Osmium 190.23	77 **Ir** Iridium 192.217	78 **Pt** Platinum 195.078	79 **Au** Gold 196.96655	80 **Hg** Mercury 200.59	81 **Tl** Thallium 204.3833	82 **Pb** Lead 207.2	83 **Bi** Bismuth 208.98038	84 **Po** Polonium (209)	85 **At** Astatine (210)	86 **Rn** Radon (222)
87 **Fr** Francium (223)	88 **Ra** Radium (226)	89 **Ac** Actinium (227)	104 **Rf** Rutherfordium (261)	105 **Db** Dubnium (262)	106 **Sg** Seaborgium (263)	107 **Bh** Bohrium (262)	108 **Hs** Hassium (265)	109 **Mt** Meitnerium (266)	110 (269)	111 (272)	112 (277)	113	114				
				58 **Ce** Cerium 140.116	59 **Pr** Praseodymium 140.90765	60 **Nd** Neodymium 144.24	61 **Pm** Promethium (145)	62 **Sm** Samarium 150.36	63 **Eu** Europium 151.964	64 **Gd** Gadolinium 157.25	65 **Tb** Terbium 158.92534	66 **Dy** Dysprosium 162.50	67 **Ho** Holmium 164.93032	68 **Er** Erbium 167.26	69 **Tm** Thulium 168.93421	70 **Yb** Ytterbium 173.04	71 **Lu** Lutetium 174.967
				90 **Th** Thorium 232.0381	91 **Pa** Protactinium 231.03588	92 **U** Uranium 238.0289	93 **Np** Neptunium (237)	94 **Pu** Plutonium (244)	95 **Am** Americium (243)	96 **Cm** Curium (247)	97 **Bk** Berkelium (247)	98 **Cf** Californium (251)	99 **Es** Einsteinium (252)	100 **Fm** Fermium (257)	101 **Md** Mendelevium (258)	102 **No** Nobelium (259)	103 **Lr** Lawrencium (262)