Name:
Recitation Instructor:

5.60/20.110/2772J
Fall 2005
Exam II
November 2, 2005

You have 50 minutes for this exam.

WRITE YOUR NAME ON EVERY PAGE

CLOSED BOOK
2 pages of notes allowed

1 (35 points)		
2 (45 points)		
3 (25 points)		
total (100 points)		

$k = 1.38 \times 10^{-23}$ J/K

R= 8.314 J K^{-1} mol^{-1}, R=0.08314 L bar K^{-1} mol^{-1}, T(K)=t(°C)+273.15

760 Torr = 1atm = 1.013 bar

Please show all work. When possible do not erase or cross out “false starts” on problems.

Name:

1. (35 points) Consider the reaction

$$A(g) + B(g) = C(g) + D(g)$$

The equilibrium constant for the reaction of the gas A with the gas B into the two gases C and D at 300 K is $K_p(300K)=2.49$, and at 350 K it is $K_p(350K)= 3.0$. Assume that all four gases are ideal. Assume that the enthalpy of reaction is independent of temperature over the range considered.

a) (10 points) One mole of gas A and 3 moles of gas B are placed in a closed 10 liter container at 300 K. What would be the pressure if no reaction took place.

b) (10 points) What is the enthalpy of reaction over the range considered?

Name:

c) (10 points) The reaction of the one mole of gas A and the 3 moles of gas B placed in the 10 liter container of part (a) is allowed to proceed to equilibrium. What is the partial pressure of each of the four gases at equilibrium at 300 K? What is the total pressure in the 10 liter container?

d) (5 points) After equilibrium is achieved, the volume of the container is decreased from 10 liters to 5 liters. Is the number of moles of the gas B in the container after equilibrium is reestablished higher, the same, or lower than it was at equilibrium when the volume of the container was 10 liters? Explain briefly (no credit without an explanation) [You can answer this question without having done part (c)].

Name:

2.) (45 points)
The energy levels of a molecule are $\varepsilon_i = 2(i-1)\varepsilon_0$ where i = 1,2,3. There are NO levels with i >3. The degeneracy of the i-th level is $g_i=i$.

a) (6 points) Sketch the energy level diagram for this molecule. Label each energy level with its index (i), draw the number of degenerate states that belong to each level (g_i), and label each energy level with its energy in units of ε_0.

b) (5 points) Write an algebraic expression for the partition function, q, of the system, as a function of T and ε_0.

Name:

c) (4 points) What is the numerical value of the partition function, q, at T = 0? At T=∞?

T=0: q=

T=∞: q=

d) (5 points) Calculate the numerical value of the partition function, q, at $T=2\varepsilon_0/k$.

Name:

e) (7 points) You measure experimental values of the fractional populations of levels 1 and 2, $p_1 = 0.73$ and $p_2 = 0.18$, at $T = 2\varepsilon_0/k$. Is the system in equilibrium?

f) (4 points) Calculate the fractional populations, p_1, p_2, and p_3, at $T = \varepsilon_0/k$. What is the numerical value of $\Sigma_i\, p_i$?

$p_1 =$

$p_2 =$

$p_3 =$

$\Sigma_i\, p_i =$

Name:

g) (7 points) What is the maximum possible value of entropy for this molecule?

Use $S = -k\sum_{i=1}^{3} p_i \ln p_i$ and leave your answer in units of k.

h) (7 points) For a system comprised of N = 100 indistinguishable molecules of the type described at the beginning of this question, calculate the Helmholtz free energy (A) at $T = 2\varepsilon_0/k$. Leave your answer in units of ε_0.

Name:

3.) (25 points)
A table of vapor/liquid and vapor/solid coexistence data for I_2 is the following:

T (°C)	vapor pressure (bar)
175.0	0.7866
150.0	0.4054
125.0	0.1923
113.78	0.1333
113.65	0.1007
100.00	0.05036
75.00	0.01336
38.70	1.333×10^{-3}
20.00	3.254×10^{-4}
1.00	6.373×10^{-5}

The T_{melt} of I_2 is 113.65°C.

a) (10 points) Calculate $\Delta\overline{H}_{fus}$, $\Delta\overline{H}_{sub}$ and $\Delta\overline{H}_{vap}$. Use the approximations that I_2 (gas) behaves as an ideal gas and its volume $V_{gas} >> V_{liquid}$ and $V_{gas} >> V_{solid}$, that the ΔH's are independent of temperature and pressure.

Name:

b) (7 points) Calculate the T_{boil} of I_2(liq) at p=1bar.

c) (8 points) Calculate $\Delta\overline{S}_{fus}$ and $\Delta\overline{S}_{vap}$. How does the value for $\Delta\overline{S}_{vap}$ that you obtained using the tabulated data compare to the value predicted by Trouton's rule, 88 J/mol K?

Name: