NAME: _____

COURSE 3.20: THERMODYNAMICS OF MATERIALS

90 Minute Exam, Nov 22, 2002

PROBLEM 1 (20 POINTS) _____

PROBLEM 2 (20 POINTS) _____

PROBLEM 3 (25 POINTS) _____

PROBLEM 4 (15 POINTS) _____

PROBLEM 5 (20 POINTS) _____

TOTAL (100 POINTS) _____

You can either write your answer on the question sheets or use separate pages. In each case make sure your answer is neatly marked.

1) It is now possible to attach the endpoints of a single polymer of length l and impose a constant force f on the ends of the polymer. Experimentally, it has been found that the elongation (l-l_o) of a particular polymer (where l_o is the equilibrium length of the polymer at f=0) is proportional to the applied force on the ends, i.e. (l-l_o)=αf. Assume that a polymer satisfying this relation is held at constant force f.

a) Write an expression for the appropriate partition function for this polymer at constant temperature T and force f (leave the expression as a sum over states).

b) Derive an expression for $\overline{l^2} - \bar{l}^2$ of the polymer at constant T and f and express your result in terms of parameters given in this problem.

2) Conceptual questions, be brief in your answers, write relevant equations if it improves clarity.

a) Give a statistical mechanical interpretation of the second law of thermodynamics for a spontaneous change of state in an isolated system.

b) Give a statistical mechanical interpretation of the third law of thermodynamics.

3) M arsenic atoms are adsorbed on a surface with M sites. Each arsenic atom vibrates in a parabolic potential on each site. The arsenic atoms do not interact with each other when adsorbed. The characteristic vibrational frequency for each adsorbed arsenic atom is ν. (The adsorbed atoms vibrate independently of each other).

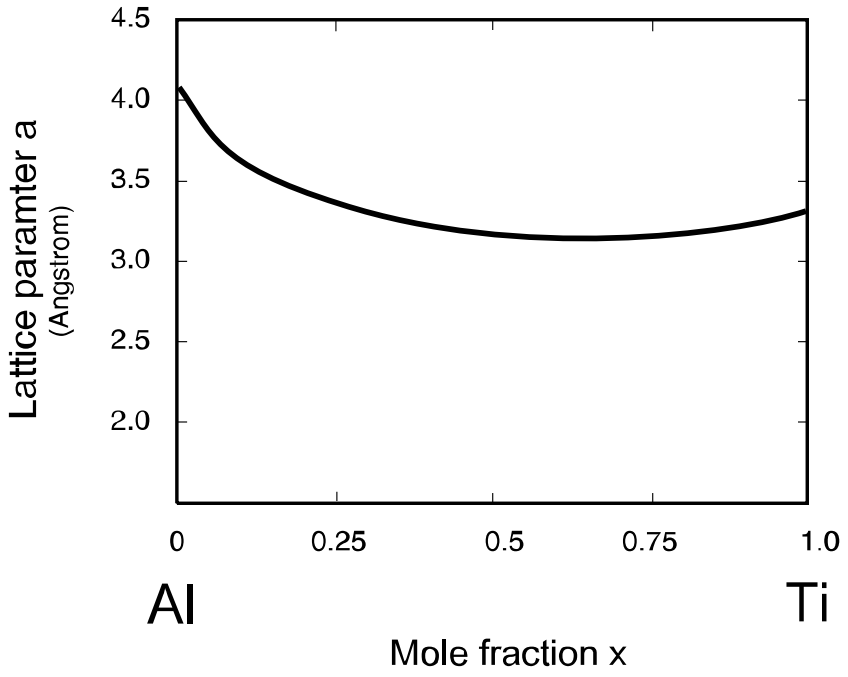
a) Solve for an expression of the partition function of the system of M arsenic atoms in terms of ν (for fixed temperature).

Now assume that there are only $N < M$ arsenic atoms adsorbed over the M surface sites. Each arsenic atom still vibrates independently in a parabolic potential with frequency ν.

b) Solve for an expression of the partition function in terms of ν.

c) The system of adsorbed arsenic atoms is in equilibrium with a gas of arsenic atoms. The gas phase has a constant arsenic chemical potential μ. Solve for an expression for the average number of arsenic atoms adsorbed over the M sites in equilibrium with the gas phase at constant temperature.

4) Given is a plot of the cubic lattice parameter *a* for fcc binary alloy Al-Ti as a function of the mole fraction *x* (at 360 C). Estimate the partial molar **volume** of Ti in the binary Al-Ti alloy at x=0.25.



5) Consider an idealization of a crystal which has N lattice sites and the same number of interstitial positions (places between the lattice points where atoms can reside).

a) Derive the number of configurational micro-states for this system when n atoms have gone to interstitial sites leaving n vacancies behind.

b) Assume that the vacancies and interstitial atoms do not interact. Calculate the entropy and express it in terms of the interstitial concentration x=n/N.

c) Assume now that the interstitial atoms are energetically attracted to the vacant sites. Will the entropy increase, stay the same or decrease from the value determined in part b ?