NAME:____________________________

COURSE 3.20: THERMODYNAMICS OF MATERIALS

90 minute EXAM, Oct 10, 2003

PROBLEM 1 (15 POINTS)____________

PROBLEM 2 (25 POINTS)____________

PROBLEM 3 (20 POINTS)____________

PROBLEM 4 (20 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 clearly marked.

A neat answer is the sign of a clear mind

Question 1

The Helmholtz free energy ($F = U - TS$) of a system of atoms (each of which carries a magnetic moment) is found to depend on the magnetic moment of the system as:

$F(M) = A\ (M/\mu - 1/2)^2$ where μ is a constant (the Bohr magneton), and F is the free energy per atom, and A is another constant with appropriate units. This relation holds at constant temperature.

Compute the relation between applied field H and M.

Question 2

Some researchers have considered to use phase transitions in a material as a way of rapidly absorbing mechanical energy (work). The idea is that under high enough pressure a substantial amount of work is done on a system when it transforms to a phase with smaller volume.

Some recent results on *Absorbium,* a previously unknown element, indicate that it might be desirable for such applications. At atmospheric pressure *Absorbium* undergoes an allotropic reversible phase transition from the α to the β form at $T_0 = 350K$. (The low temperature phase is α). The β form has a lower molar volume.

a) Argue that for temperatures below $T_0 = 350K$ the α phase can be transformed to β by the application of pressure. How do you know ?

b) Find the amount of work absorbed by the α to β transition when it is induced by pressure at T = 300K.

c) In some cases (e.g. when the transition is completed very quickly) it is more realistic to think of the transition as occurring adiabatically (isentropically). What is the work absorbed from the environment when the transition is induced by pressure at 300 K, but occurs adiabatically .

Assume that only reversible processes take place in the material (e.g. no plastic deformation or defect creation). Both phases may be considered incompressible (though there is a volume change when the system transforms from α to β.

DATA:

for the transition from α *to* β *at 350K*: ΔH = 1 kJ/mol ; Δ□ = 1 cc/mol

Clearly state any assumptions you make

Question 3

a) Find the three equations of state for a system with the fundamental equation:

$$U = A\, S^3 / (NV)$$

In this equation, S is the entropy, N is the number of moles in the system, and V is the volume. A is a constant.

b) Show that the equations of state are *intensive*.

Question 4

Air is enclosed in a spherical soap bubble of radius *r*. The soap film does not let air molecules through. The pressure outside the bubble is p_o. Using the conditions of equilibrium, it is possible to show that the air pressure inside the bubble is $p_i = p_o + 2\sigma/r$, where *r* is the radius of the film, and σ is the interfacial energy between the air and soap film. (σ is the conjugate variable to the surface area of the bubble (A)).

What is the heat capacity of a collection of bubbles under constant outside pressure (per mole of gas ? Write in terms of properties of the gas and the interface (C_p, C_V, σ, etc.)

Air can be treated as an ideal gas for this problem.

Problem 5: Short questions

a) The only way to transfer heat from high temperature to low temperature is by an irreversible process.

CORRECT___________ NOT CORRECT_________

b) If the thermal expansion is negative, the constant pressure heat capacity is smaller than the constant volume heat capacity.

CORRECT___________ NOT CORRECT_________

c) Enthalpy is a conserved quantity

CORRECT___________ NOT CORRECT_________

d) In an adiabatic expansion of a material the temperature always goes down.

CORRECT___________ NOT CORRECT_________

e) The entropy of a system can decrease

CORRECT___________ NOT CORRECT_________