Practice problems for Midterm #2
(The actual midterm could contain questions similar to these, but not so many of them. This is just intended to be extra practice and not a representative exam.)

Question 1:

a) Show that $\left.\frac{\partial S}{\partial T}\right|_P = \frac{C_P}{T}$, with C_p defined as $C_p \equiv \left.\frac{\partial H}{\partial T}\right|_P$.

b) Using part a and the appropriate Maxwell Relation, show that: $dS = \frac{C_P}{T}dT - \beta V dP$

c) Starting with the definition of the Helmholz free energy, show that for an ideal gas: $P = T\left(\frac{\partial S}{\partial V}\right)_T$

d) Show that $\left(\frac{\partial C_P}{\partial P}\right)_T = -T\left(\frac{\partial^2 V}{\partial T^2}\right)_p$

Question 2:

Consider two small interacting systems. System A is a paramagnet consisting of 20 elementary dipoles each of which can store either 0 or 1 units of energy. System B is an Einstein solid consisting of 4 elementary oscillators each of which can store any number of units of energy of the same size as those for system A.

PARAMAGNET 20 dipoles	EINSTEIN SOLID 4 oscillators

If the two systems share 2 units of energy, what is the most likely division of energy between the two systems?

Question 3:

Even an "evacuated" box is filled with a photon gas due to the electromagnetic radiation that is thermally emitted by the interior walls. A **photon gas** is a gas-like collection of photons, which has many of the same properties of a conventional gas like hydrogen or neon - including pressure, temperature, and entropy. At thermal equilibrium the entropy S of a photon gas can be shown (using quantum mechanics) to depend *only* on its energy U and the volume V of its container.

$S(U,V) = aU^{3/4}V^{1/4}$ where a is a constant.

Use the expression for S(U,V) to find both the temperature and pressure of the photon gas as a function of both U and V (and possibly a).

Question 4:

An object with constant pressure heat capacity C_P and temperature T_1 is brought in contact with a thermal reservoir with constant temperature T_2 *(different from* T_1) until the object reaches equilibrium (at constant pressure). What is the total change in entropy for this process (including both the object and reservoir) ?

Question 5:

Adsorption is the process of particles sticking to the surface of a solid (rather than getting absorbed inside of it). To model adsorption, consider a surface that consists of M >> 1 discrete sites; each site has two possible states: vacant (with energy $\varepsilon = 0$), or bound to a single atom (with energy ε_o). If N >> 1 atoms are bound (with M >> N), find expressions for the following parameters of the system of adsorbed atoms:
(a) The energy, U(N, εo).
(b) The multiplicity, Ω(M, N).
(c) The temperature T(M,N).

Question 6:

Suppose that you want to know how much heat it would take to boil water at 473 K and 1atm pressure, rather than 373 K. At T = 373 K, ΔHvap = 40.7 kJ mol^{-1} is the enthalpy of vaporization. Assuming that the heat capacities of the liquid ($Cp,$liquid = 75 J K^{-1} mol^{-1}) and the vapor ($Cp,$vapor = 3.5 J K^{-1} mol^{-1}) are constant over this temperature range, calculate the enthalpy of vaporization at 473 K (for 1 mole).