Physics 408 Problem Set 7 Due Thurs, Oct 21 at beginning of class

1) Callen 6.2.3

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3) A manufacturing plant is designed to take in air at 20°C and produce pure nitrogen gas and pure oxygen gas, also at 20°C, with the air source and the final gases both at 1 atm pressure. Assume that the gases are produced at 790 m^3 per hour (nitrogen) and 210 m^3 per hour (oxygen): these are in the same proportion as percentages in air, since for this problem we are neglecting small amounts of other gases.
a) Find the minimum power needed to run this plant.
b) Find the change of chemical potentials of each of the gases in this process, by first determining the change in the Gibbs free energy.

4) Consider a crystalline solid which has a specific heat $C = 0$ for temperatures below a "turn-on" temperature T_A, and then has a constant C per atom at T_A and above. (This is somewhat unrealistic but it roughly captures the behavior of real materials, for example an Einstein solid has constant-C in the classical limit, but C drops exponentially to zero below the Einstein temperature.) For this solid the internal energy is U_A at $T = 0$.
a) Find the internal energy as a function of T for this system.
b) Find the Helmholtz free energy vs. T for this system, and make a realistic sketch showing how this function behaves vs. T.
c) Suppose this material can transform to a different crystal structure B, which has a similar thermal behavior, however with a turn-on temperature T_B which is so large that its specific heat remains zero at temperatures of interest. Its $T = 0$ internal energy is U_B (with $U_B < U_A$). As described in class there can be a phase change depending on which system has the lowest free energy, and for this case where the volume does not change the Helmholtz free energy is the relevant quantity. Suppose specifically that the transformation takes place at $T = 2T_A$; solve for $U_A - U_B$, in terms of T_A and C.
d) Find the enthalpy change for this solid (N atoms) during the phase transformation, for the conditions given in part (c).

5) Suppose you have a cylinder of a monatomic ideal gas (total of N molecules). The initial temperature of the system is T_o, and volume V_o.
a) Using the maximum work theorem, determine the minimum work that would be required from a reversible work source to change the volume of the gas to $V_o/3$, with final temperature T_o, if a single heat reservoir is available at a temperature of $T_o/2$.
b) Make a sketch in a P-V diagram of the processes involved.
c) Suppose that instead of a reversible work source, the work source available only works in one direction, corresponding to work that adds energy to the gas. Assume that the one-way work source remains lossless, so that all of its work expenditure is transferred to the gas. Find the minimum work that could be done using this source to make the same change in state with the same heat reservoir as in part (a).
d) Determine the extra entropy generated by process (c), relative to the process you obtained for parts (a-b).