Final Exam (PY 413, Spring 2007)

1. (10pts) Electrolysis of $NaCl$ is the reaction $NaCl \rightarrow Na + \frac{1}{2}Cl_2$. The reaction uses liquid $NaCl$ and produces Cl_2 gas and liquid Na.

   (a) How much electrical energy is required to split 1 mole of $NaCl$? How much of that energy leaves/enters as heat, and how much work is done by the atmosphere? Draw a diagram that shows the direction of energy flow for W_{el}, W_{mech}, Q.

   (b) The reaction at the anode is $Cl^- \rightarrow e^- + \frac{1}{2}Cl_2$. What is the minimum voltage required to operate a $NaCl$ electrolysis cell?

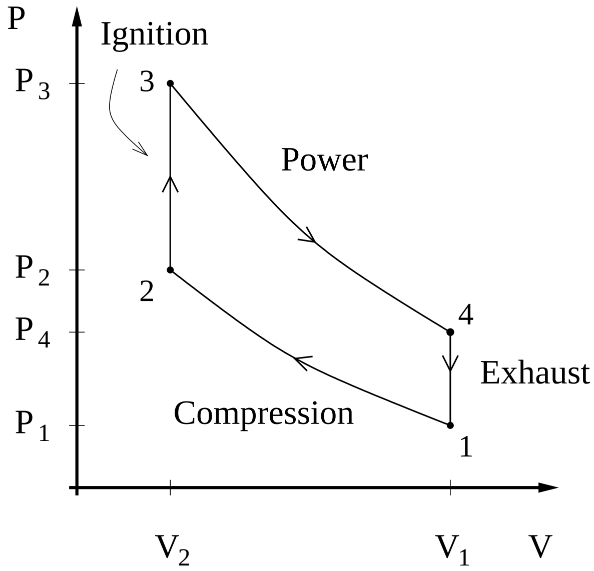
   The enthalpy and Gibbs free energy of formation for one mole of sodium chloride are $\Delta H = -411.15$ kJ and $\Delta G = -384.14$ kJ. You can treat Cl_2 as an ideal gas.

2. (10pts) Consider a paramagnet composed of N elementary spins. Every spin has three possible orientations $\uparrow, \rightarrow, \downarrow$. The corresponding energies are $E_\uparrow = -\mu B, E_\rightarrow = 0, E_\downarrow = +\mu B$. Take $\mu B = 1/40$ eV and $T = 293$ K.

   (a) What is the probability that a given spin is in the $\uparrow$ state?

   (b) Compute the entropy of a paramagnet consisting of N_A (one mole) of spins.

3. (10pts) The figure shows the PV diagram for a hypothetical engine. In the following we shall assume that the working substance is an ideal diatomic ($f = 5$) gas and that the power and compression strokes are isothermal.



(a) Compute Q and W for the four steps indicated in the figure. Express your result in terms of V_i and T_i.

(b) Compute the efficiency of the engine. Show that it is smaller than the Carnot result. What is the efficiency for a compression ratio $V_1/V_2 = 10$ and $T_1 = 293$ K, $T_3 = 1500$ K?

4. (10pts) Water molecules vibrate at a characteristic frequency $f = 4.8 \cdot 10^{13}$ Hz. We shall assume that the vibrational energy levels are $E_n = hfn$, where h is Planck's constant and $n = 0, 1, 2, \ldots$.

(a) Determine the vibrational partition function of one water molecule as a function of T. Also compute the free energy and entropy.

(b) What is the vibrational contribution to the entropy of one mole of water at 700^oC?