Problems for chapter 11, due April 16, 2012

1. ***Diamagnetic susceptibility of atomic hydrogen.*** The wave function of the hydrogen atom in its ground state (1s) is $\psi = (\pi a_0^3)^{-1/2} \exp(-r/a_0)$, where $a_0 = \hbar^2/me^2 = 0.529 \times 10^{-8}$ cm. The charge density is $\rho(x, y, z) = -e|\psi|^2$, according to the statistical interpretation of the wave function. Show that for this state $\langle r^2 \rangle = 3a_0^2$, and calculate the molar diamagnetic susceptibility of atomic hydrogen (-2.36×10^{-6} cm^3/mole).

2. ***Hund rules.*** Apply the Hund rules to find the ground state (the basic level in the notation of Table 1) of (a) Eu^{++}, in the configuration $4f^7\,5s^2p^6$; (b) Yb^{3+}; (c) Tb^{3+}. The results for (b) and (c) are in Table 1, but you should give the separate steps in applying the rules.

3. ***Triplet excited states.*** Some organic molecules have a triplet ($S = 1$) excited state at an energy $k_B\Delta$ above a singlet ($S = 0$) ground state. (a) Find an expression for the magnetic moment $\langle \mu \rangle$ in a field B. (b) Show that the susceptibility for $T \gg \Delta$ is approximately independent of Δ. (c) With the help of a diagram of energy levels versus field and a rough sketch of entropy versus field, explain how this system might be cooled by isentropic magnetization (not demagnetization).

8. ***Paramagnetism of S = 1 system.*** (a) Find the magnetization as a function of magnetic field and temperature for a system of spins with $S = 1$, moment μ, and concentration n. (b) Show that in the limit $\mu B \ll kT$ the result is $M \cong (2n\mu^2/3kT)B$.