Physics 780.04 Winter Quarter 2007
Dr. Herbst 14 February

MIDTERM EXAMINATION (100 POINTS)
IN CLASS

1. (20 points) Consider a spectral transition between two non-degenerate states separated by 1000 cm^{-1}. The Einstein A coefficient for the transition is 1 s^{-1}. In absorption, the spectral line is broadened by pressure broadening with a FWHM $\Delta\nu$ of 100 MHz. Determine the absorption coefficient (cm^{-1}) at resonance and calculate the fraction of incident radiation that traverses 1-cm and 1-m cells at this wave number. The concentration of molecules in the lower state is 10^{15} cm^{-3}.

2. (15 points) The electron affinity of atomic hydrogen is 0.76 eV. This statement means that the negative ion H^- has its ground state 0.76 eV below that of H(1s) + e. Find the shielding that each electron must exert upon the other in H^- so that the simple independent electron model reproduces the experimental electron affinity.

3. (30 points) Consider the diatomic molecule B_2, which possesses 10 electrons.
   (a) (15 points) Determine the ordered term symbols and number of bonds of the lowest configuration. Do not forget the g and u subscripts. Hint: B_2 has an internuclear distance similar to that of C_2.
   (b) (15 points) Determine and order the term symbols in the Russell-Saunders limit for the ground configuration of atomic boron. Use this information to obtain those terms that arise from the separated atoms and correlate with the ground configuration terms of B_2. You may assume (not quite correctly) that each term produced from separate atoms has both a *u* and a *g* variety. Neglect +/- symmetry. Draw a diagram.

4. (15 points) Present formulae for the low-temperature concentration ratio of rigid D_2 molecules (i_D=1) in their *J*=1 state to those in their *J*=0 state if the molecule is *normal* (ortho and para do not interconvert) and if the molecule is in thermodynamic equilibrium. You may assume that only the *J*=0 and *J*=1 states are populated appreciably.

5. (20 points) Derive the formula for the R-branch transition wave numbers $\nu_R(J)$ for vibrational-rotational transitions of a diatomic molecule in terms of ν_0, the origin, and $B_{v'}$ and $B_{v''}$, the effective rotational constants for the upper and lower vibrational levels. Neglect centrifugal distortion. Above what value of *J*, if any, will the R-branch lines start to decrease in frequency?