Midterm Exam. April 1, 2005

Open book.

1. Starting with the $2p_x$ atomic orbital of each atom of a homonuclear molecule,
(i) sketch the molecular orbitals (MO) formed from $2p_x(A) \pm 2p_x(B)$ for (a) large internuclear distance, (b) near the equilibrium distance and (c) the united atom limit.
(ii) Mark the nodal plane(s) of each MO (just show on the graphs of part (i)).
(iii) Indicate which MO has lower orbital energy.
(iv) Indicate the corresponding atomic orbital in the united-atom limit, i.e., the ℓ and m.
(20 pts)

2. Explain in simple words the idea behind
(i) frequency comb for measuring the carrier phase
(ii) saturation spectroscopy.
(15 pts)

3. (i) Calculate the ratio of the number of molecular hydrogen (H_2) with odd integers of rotational quantum number as compared to the number with even integers of rotational quantum number. The temperature is T.
(ii) If the molecules are D_2, what will the ratio be?
(20pts)

4. **Simple estimates involving lasers:** (5 pts each, 45 total)
(a) What is the Ponderomotive energy for 800nm Ti-Sapphire laser at peak intensity of 3.5×10^{16} W/cm^2?
(b) If you want to use the returning electron energy to excite a nucleus by the same Ti-Sapphire laser, what is the peak laser intensity you would need? Assume that the excitation energy of the nucleus is 500 keV.
(c) Sketch the maximum excursion length(s) of electrons that return to the atomic ion core with kinetic energy from 1.5 to 3.17 U_P. Use the simple 1D model as in exercise #4. Just use some scaled length units.
(d) Sketch the molecular orbital π_u. Based on the molecular ADK model, sketch the alignment dependence of the tunneling ionization rate.
(e) An attosecond pulse has FWHM of 0.1 fs with mean photon energy of 95 eV. What is the width of this pulse in the energy domain, in eV? Assume that the pulse is not chirped.
(f) What does it mean that a pulse is chirped? In the energy domain measurement if two pulses have the same width, which pulse has smaller width in the time domain? The one with chirp or the one without?
(g) Explain simply the Lewenstein model.
(h) Use Fig. 3 from the handout by Max Sayler, calculate the total kinetic energies for the dissociation of H_2 from the vibrational level v=0, and 2, and from v=6 and 8. Use laser peak intensity at 10^{13} W/cm^2.
(i) For D_2 molecules what would be the answer to (h)?