Quiz 1.

1. Assume that the nucleus of the proton is a sphere of uniformly distributed charge. Take the radius of the sphere to be 1 fm=10^{-13} cm. We will consider the **ground state** of atomic hydrogen and the ground state of the muonic hydrogen where the electron has been replaced by muon (mass of muon is 206 times larger than the electron).
(i) Explain why the probability of finding the muon inside the nucleus is much larger.
(ii) Calculate the probability of finding the electron and the muon, respectively, inside the nucleus.
(You can estimate the answer. If not, tell me how you will do the calculation.)

2. Use the Bohr model of atomic hydrogen to calculate the orbiting period of an electron in the excited state with principal quantum number n. What is the orbiting period for n=1, express your answer in femtoseconds. What is the period for n=25, 100, respectively?

3. Evaluate the spin-orbit interaction of the 3d state of atomic hydrogen. Consider the mass of the proton to be infinite. Express everything in your derivation in atomic units, but express the final answers in units of cm^{-1}.
Hints: radial wavefunction, p159; some expectation values of radial wavefunctions, p.165.

4. High precision spectroscopy can be used to measure the radius of the nucleus. In the Oct 1, 2004 issue of Phys. Rev. Lett. 93, 142503 (2004), it was reported that the size of the so-called halo nucleus ^{6}He has been determined. The experimentalists measured the energy separation between two levels of an atom consisting of ^{6}He, as compared to one made of the normal ^{4}He nucleus. The nuclear spins of both nuclei are zero. Identify in "words" the sources that contribute to the difference in the level separation between the two isotopes.

Physics 850 QUIZ II

November 17, 2004 (10:30-11:20am)

1. "Guess" the configurations, the terms (L,S) and the J of the ground state of O^{2+}, F^{2+} and Ne^{2+} ions. Note that the neutral atoms of these elements have 8,9 and 10 electrons, respectively. Explain the basis of your guess briefly. (**21 pts**)

2. (a) The $1s^2\ ^1S$ ground state and $1s2s\ ^1S$ excited state of He has an energy separation of about 20 eV. Estimate the energy difference between the same two states for Ne^{8+}.

(b) The $1s2s\ ^1S$ and $1s2s\ ^3S$ states of He have an energy separation of 0.8 eV. What would be the energy separation between these two states for Ne^{8+}.

(Think about the scaling of the source that is responsible for their separations.) (**18pts**)

3. Work out the possible terms (L and S) for $1s2s2p^2$. (**20pts**)

4. (a) Based on the model for the oxygen atom on problem 19 from your homework, calculate the total binding energy of the ground state of oxygen. Express your results in eV's.

(b) How much energy would it take to knock out one of the 1s electrons?

(c) Suppose that this 1s hole is subsequently filled by one of the 2p electrons, with the ejection of another 2p electron (the Auger transition) into the continuum. What is the energy of this ejected electron that you will observe? (**27pts**)

5. In problem 21 from your homework, you were asked to derive the cross section near a resonance for the s-wave scattering. If it is a p-wave scattering, would you still get the Fano resonance profile? Explain concisely.

In a scattering, if the potential scattering part is such that the phase shift from the s-wave is $\pi/2$, and all the other phase shifts are zero, while the resonance is a p-wave resonance, sketch the expected total cross section vs energy near the resonance. (**14 pts**)

*(Extra credit question: What do you expect for the differential cross sections?Write down the mathematical expression and explain**.** **10 pints**)*

AMO-I Final Examination

C. D. Lin December 13, 2004
Open Book, 20 points for each problem.

1. The atomic structure of NeIII has the $2s^2 2p^4$ configuration.

(a) Write down the possible L and S from this configuration and indicate their relative energy level positions, neglecting the spin-orbit interaction.

(b) Again neglect spin-orbit interaction, what is the radiative mode for each transition from the excited state to the ground state?

(c) The "next" excited configuration would be $2s^2 2p^3 3s$. There are many possible L and S states from this configuration. Identify them all.

(d) What is the radiative transition mode (E1, M1, E2, …) of the lowest state from the $2s^2 2p^3 3s$ configuration to the ground state.

2. (a) The 2p3d ^1P state of He can decay by autoionization (or Auger decay). Write down the configuration of the final state and indicate the orbital angular momentum and the approximate energy of the continuum electron.

(b) This state can also decay by dipole-allowed radiative transitions to singly excited states. Indicate what is the most likely final state that it can decay to.

(c) Answer part (b) again if the initial state is 2p3d ^3D.

3. Recall how we estimated the radiative lifetime of a Rydberg state like the np state of H. We will consider the Be atom here. The ground state is $1s^2 2s^2\ ^1S$. The singly excited states are $1s^2 2smp\ ^1P$ ($m \geq 2$), for example. Now consider doubly excited states of Be like $1s^2 2p\, nd\ ^1P$ for n>10.

(a) The $1s^2 2p\, nd\ ^1P$ for n>10 states can decay by autoionization. Show that this rate decreases like $1/n^3$.

(b) The $1s^2 2p\, nd\ ^1P$ state can decay radiatively to the singly excited states of Be. For a given n, explain what is the most likely final state. How does the radiative rates vary with n? Still goes like $1/n^3$? Why?

4. (a) For a particle of spin ½ like an electron, the two particles can couple to S=0 and S=1. Indicate how many of the coupled states are symmetric under the exchange of the two particles and how many of them are antisymmetric. (This has been done many times in the class.)

(b) Now generalize this to a particle of spin 1. What are the possible total S from two such particles? Indicate the number of symmetric vs antisymmetric states under the exchange of the two particles. (I did not discuss this one in the class but you should be able to generalize the method of part (a) to get the anwer.)

5. (a) For atomic hydrogen the 2s and 2p states are degenerate. In a small static electric field, how many levels are they splitted into? Consider terms up to first order in the electric field only.

(b) Now consider the 3s and 3p states of Li. They are not degenerate. How these levels will be splitted in a static electric field-- again, consider to first order in the electric field only.

(c) Repeat (a) and (b) but for a static magnetic field.