Physics 330, Spring 2009
HW#3 25 points

Problems from Tipler and Llewellyn:

1. **4.6 (5 points)** A gold foil of thickness 2.0 μm is used in a Rutherford experiment to scatter α particles with energy 7.0 MeV. (a) What fraction of the particles will be scattered at angles greater than 90°? (b) What fraction will be scattered at angles between 45° and 75°? (c) Use N_A,ρ, and M for gold to compute the approximate radius of a gold atom. (For gold, ρ=19.3 g/cm^3 and M=197 g/mol.)

2. **4.14 (5 points)** Show that Equation 4-19 for the radius of the first Bohr orbit and Equation 4-20 for the magnitude of the lowest energy for the hydrogen atom can be written as

$$a_0 = \frac{hc}{\alpha mc^2} = \frac{\lambda_c}{2\pi\alpha}$$

$$E_1 = \frac{1}{2}\alpha^2 mc^2$$

   where $\lambda_c = h/mc$ is the Compton wavelength of the electron and $\alpha = ke^2/hc$ is the fine-structure constant. Use these expressions to check the numerical values of the constants a_0 and E_1.

3. **4.20 (5 points)** In the lithium atom ($Z = 3$) two electrons are in the n=1 orbit and the third is in the $n = 2$ orbit. (Only two are allowed in the $n = 1$ orbit because of the exclusion principle, which will be discussed in Chapter 7.) The interaction of the inner electrons with the outer one can be approximated by writing the energy of the outer electron as

$$E = -Z'^2(E_1/n^2)$$

   where $E_1 = 13.6$ eV, $n = 2$, and Z' is the effective nuclear charge, which is less than 3 because of the screening effect of the two inner electrons. Using the measured ionization energy of 5.39 eV, calculate Z'.

4. **4.32 (5 points)** (a) Compute the energy of an electron in the $n = 1$ (K shell) of tungsten, using $Z - 1$ for the effective nuclear charge. (b) The experimental result for this energy is 69.5 keV. Assume that the effective nuclear charge is $Z - \sigma$, where σ is called the screening constant, and calculate σ from the experimental result.

5. **4.36 (5 points)** The transition from the first excited state to the ground state in potassium results in the emission of a photon with $\lambda = 770$ nm. If potassium vapor is used in a Franck-Hertz experiment, at what voltage would you expect to see the first decrease in current?