Physics 135-3, Quiz #6 **Solution Key**

1) The rare element Hypotheticalium (Hy) has energy levels which are exactly like those of hydrogen, except that the n = 2 level in Hy is metastable, and thus Hy can be used to make a laser. **1a) (5 points)** What minimum excitation energy would you need to produce lasing in the Hy? In other words, what minimum energy is needed to create a population inversion?

Solution
Since the n = 2 level is metastable, it is almost impossible to excite it. Therefore, one must excite electrons into the level just *above* it, and allow them to fall to n = 2. The energy jump from the ground state will be given by: $\Delta E = -13.6\text{ eV}/3^2 - (-13.6\text{ eV})/1^2 =$ 12.09 volts.

1b) (5 points) At what wavelength will the Hypotheticalium lase?

Solution
The lasing transition will be n = 2 to n = 1, or $E = -13.6\text{ eV}/2^2 - (-13.6\text{ eV})/1^2 = 10.2$ eV. This corresponds to $\lambda = 1240/10.2 =$ 122 nm.

2) (10 points) The proton has a mass of 1.00728 u. The neutron has a mass of 1.00866 u. Gold ($^{197}Au_{79}$) has a mass of 196.96657 u. If I wanted to smash a gold atom into a cloud of separate protons and neutrons by hitting it with a single photon, how energetic would the photon need to be? (u = 931.494 MeV)

Solution
Gold has 79 protons and 197 – 79 = 118 neutrons. The mass of these as free particles is (79)(1.00728) + (118)(1.00866) = 198.597 u. The difference in mass between these particles and the ones in the gold is 198.597 – 196.96657 = 1.63043 u, which means that an atom-smashing photon would need to supply this much energy (at least) to create the extra mass. We have E = (1.63043)(931.494) = 1518.736 MeV.