PHYS 2380 - Assignment 2

Due February 17, 2017

February 8, 2017

Note: an electron volt (eV) is equivalent to 1.60×10^{-19} J. It may also be convenient to use the combination $hc = 1240$ eV·nm.

1

An atom in an excited state will, on the average, undergo a transition to a state of lower energy in about 10^{-8} seconds. If the electron in a doubly ionized lithium atom (Li^{+2}, which is hydrogen-like) is placed in the $n = 4$ state, about how many revolutions around the nucleus does it make before undergoing a transition to a lower energy state?

This is question 4-18 in Tipler & Llewellyn.

2

Suppose the scale of a hydrogen nucleus is 10^{-15} m. Now suppose we constrain an electron to be somewhere within this region. Calculate the uncertainty in the electrons momentum. Using the most conservative estimate, calculate the resulting kinetic energy of the electron. If this energy is substantially greater than the rest energy of the electron,

$$E_0 = m_e c^2, \tag{1}$$

then do the calculation using the relativistic energy. Convert the energy into electron volts (eV) and compare to the ionization energy of the hydrogen atom in the ground state. Is it possible to confine an electron inside an atomic nucleus?

3

An interesting question was asked in class: why didn't Rutherford notice any diffraction effects in his α particle scattering experiments?

The most energetic α particles Rutherford had access to were the products of nuclear decay, and had maximum kinetic energy 7.7 MeV. When these particles were scattered off of aluminum foil, they were energetic enough to probe the aluminum nuclei and show a deviation from the Rutherford scattering law. This allowed Rutherford to estimate the size of the aluminum nucleus.

The mass of an α particle is $m_\alpha = 6.64 \times 10^{-27}$ kg. Or, if you prefer, rest energy of $E_0 = 3727$ MeV, from equation 1 with m_α in place of m_e.

a.) Let's idealize the foil target to be perfectly thin, made of a single atom thick sheet. The atomic spacing of atoms in aluminum foil is about 5 nM. Calculate the de Broglie wavelength of an α particle with kinetic energy of 7.7 MeV and compare it to this value.

b.) What energy does an α particle need in order to have a de Broglie wavelength of 5 nm?

c.) Is it surprising Rutherford did not see any diffraction effects?

4

Suppose a hydrogen atom in its ground state absorbs a 20 eV photon. Does this electron ionize the hydrogen atom? If so, what is the speed of the liberated electron?

5

A hydrogen atom is excited from the ground state ($n = 1$) to the third excited state ($n = 4$).

a.) Calculate the energy absorbed by the atom in eV.

b.) Calculate and display on an energy-level diagram the different photon energies that could be emitted as the electron returns to its ground state.

c.) Estimate the recoil speed of the H atom if it makes the transition from $n = 4$ to $n = 1$ in a single step.