Physics 390: Homework 2

For full credit, show all your working.

1. Problem 4-49 in Tipler & Llewellyn. Note in part (d) that "Rutherford cross section" refers not to the cross section in the first part of the question but to Rutherford's original cross section from page 154 and Equation 4-3.

2. What will be the distance of closest approach R to a gold nucleus for α particles with energies (a) 4.5 MeV, (b) 7.7 MeV, and (c) 10.0 MeV?

3. **Reduced mass correction:** The first spectral line in the Balmer series for hydrogen is emitted when an electron hops from the energy level with quantum number $n_i = 3$ to the one with quantum number $n_f = 2$ in the hydrogen atom.

   (a) If we assume that the nucleus of the atom has infinite mass, what is the wavelength λ of this spectral line in nm to three significant figures? Is the line visible? If so, what color is it?

   (b) What is the wavelength (also to three figures) if we include the "reduced mass" correction for the finite mass of the nucleus, bearing in mind that a proton has 1836 times the mass of the electron?

   (c) Suppose the reduced mass μ changes by a small amount $\Delta\mu$. Show that the wavelength changes by a corresponding amount $\Delta\lambda$ that satisfies

   $$\frac{\Delta\lambda}{\lambda} = -\frac{\Delta\mu}{\mu}.$$

   (d) Hence find the wavelength shift in the first Balmer line between hydrogen (whose nucleus contains just a single proton) and deuterium (whose nucleus contains a proton and a neutron, the neutron having the same mass as the proton).

   It was precisely this small wavelength shift that led to the first discovery of deuterium in 1931.

4. Problem 4-51 in Tipler & Llewellyn.