Name(s): PHY-222 (Fall 2018), 10/09/18

Homework Assignment #4

(*Due Date*: Wed, 10/17, 04:10 pm, in class; Show all your work for full/partial credit)

4.1 *Rutherford Scattering* (cf. Probs. 4.8+9 in textbook) *(4 pts.)*
A beam of α particles of $10\,MeV$ kinetic energy is directed on a thin silver foil (Ag nuclei have a charge of $Z_{\rm Ag}$=47.)

(a) If the rate of scattered α's at a 20° angle is 200 per minute, what is the rate at (i) 10° (ii) 90° (iv) 170°?

(b) When increasing the energy of the α incomong particles, at what scattering angles will deviations from the Rutherford formula occur first?

(c) Deviations from the Rutherford formula are found to appear for α-particle energies of $25\,MeV$; estimate the radius (in fm) of the silver nucleus.

(d) If the original silver foil is replaced by a lead foil (with a thickness giving the same number of atoms along the beam direction; $Z_{\rm Pb}$=82), what is the rate of scattered α's under 90° for $10\,MeV$ incoming energy?

4.2 *Electronic Transition Radiation* (cf. Prob. 4.11 in textbook) *(1.5 pts.)*
Consider the following three transitions between electronic orbits in a He^+ atom characterized by their initial (n_i) and final (n_f) quantum numbers as follows:
(i) n_i=1 and n_f=2 (ii) n_i=5 and n_f=2 (iii) n_i=3 and n_f=∞.
Calculate the energies (in eV, incl. the correct sign) of the absorbed/emitted photons in these transitions, and order them according to increasing wavelength (in nm).

4.3 *Bohr Model of the Atom* (cf. Probs. 4.17+23+24 in textbook) *(4.5 pts.)*
Use Bohr's theory of the atom to address the (otherwise unrelated) questions below.

(a) Use angular momentum quantization and the virial theorem ($K_e = \frac{1}{2}m_e v_e^2 = \frac{1}{2}|U_e|$) to derive the expression for the Bohr Radius, and calculate the ground-state radii (in $\mathring{A}$) of the He^+ and Be^{3+} atoms.

(b) For a hydrogen atom in its first excited state, calculate the potential and kinetic energies (in eV) of the electron, as well as its angular momentum (in $eV nm/c$), linear momentum (in eV/c) and speed (in units of c as well as m/s).

(c) A hydrogen atom decays from its first excited (n=2) to the ground state. Calculate the momentum of the emitted photon (in eV/c), and use this to estimate the momentum (in eV/c) and kinetic energy (in eV) of the recoiling proton. (*hint*: use momentum conservation and $E = p^2/2M$ for the recoiling proton)