22.01 Introduction to Ionizing Radiation
Fall 2003
Problem Set #1

Due Date: September 15, 2003

Show all work. Provide units on all answers.

1. Calculate the energy produced by the following fusion reaction:

$$ {}^{2}_{1}H + {}^{3}_{1}H \rightarrow {}^{4}_{2}He + {}^{1}_{0}n $$

2. Using the result from 1) above, how much deuterium (${}^{2}_{1}H$) and tritium (${}^{3}_{1}H$) would be required to run a 100 megawatt power plant for 1 year?

3. In his famous scattering experiment, Rutherford used 7.69 MeV collimated alpha particles from a ^{214}Po source directed at a thin gold foil.
   a. What is the minimum distance to which an alpha particle could approach a gold nucleus?
   b. How much energy would an alpha particle need to "just touch" a gold nucleus in the target foil?

4. ${}^{239}_{94}Pu$ decays by alpha emission to ${}^{235}_{92}U$
   a) Calculate the Q value for this reaction.
   b) What are the recoil energies of the alpha particle and the daughter nucleus?
   c) What is the velocity of the alpha particle?

5. Calculate the average binding energy per nucleon for the nuclide ${}^{42}_{19}K$.

6. a) Calculate the radius of the n=2 electron orbit in the Bohr hydrogen atom.
   b) What is the orbital velocity of this electron?

7. Fluorescence is the photon emission that occurs when atomic electrons from higher shells drop to fill inner shell vacancies. This phenomenon is also referred to as "characteristic radiation" because the photon energies are characteristic of the particular element involved. A K-shell vacancy filled by an L-shell electron emits a photon called a K_α photon. A K-shell vacancy filled by an M-shell electron emits a photon called a K_β photon, etc.
   a. Calculate the electron binding energies of the K, L and M shells of titanium.
   b. What are the energies of the K_α and K_β characteristic photons of titanium?
   c. What are the wavelengths of these K_α and K_β characteristic photons?