

**22.01 “Introduction to Ionizing Radiation”  
Fall 2006  
Problem Set #1**

***Due Date: September 19, 2006***

Show all work. Provide units on all answers.

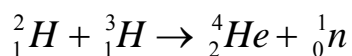
Problems in Turner:

Chapter 2: Problems 2.4, 2.14, 2.56

Chapter 3: Problems 3.3, 3.4

Also:

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



2. In his famous scattering experiment, Rutherford used 7.69 MeV collimated alpha particles from a  ${}^{214}\text{Po}$  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?
3.  ${}^{239}_{94}\text{Pu}$  decays by alpha emission to  ${}^{235}_{92}\text{U}$ 
  - 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?
4. A nuclear scientist attempts to perform experiments on the stable nuclide  ${}^{56}_{26}\text{Fe}$ .  
Determine the energy (in MeV) required to:
  - a) remove a single neutron,
  - b) remove a single proton,
  - c) completely dismantle the nucleus into its individual components,
  - d) fission it symmetrically into two identical lighter nuclides  ${}^{28}_{13}\text{Al}$ .[The exact masses of the  ${}^{56}_{26}\text{Fe}$  and  ${}^{28}_{13}\text{Al}$  atoms are 55.934942 amu and 27.981910 amu, respectively.]
5.
  - a) What photon energy (eV) is required to excite the hydrogen electron in the innermost (ground state) Bohr orbit into the first excited state orbit?
  - b) What is the orbital velocity of this excited electron?

6. 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  $K_{\alpha}$  photon. A K-shell vacancy filled by an M-shell electron emits a photon called a  $K_{\beta}$  photon, etc.
- Calculate the electron binding energies of the K, L and M shells of titanium.
  - What are the energies of the  $K_{\alpha}$  and  $K_{\beta}$  characteristic photons of titanium?
  - What are the wavelengths of these  $K_{\alpha}$  and  $K_{\beta}$  characteristic photons?