

22.01 Introduction to Ionizing Radiation
Fall 2003
Problem Set #3

Due Date: Wednesday, October 1, 2003

Show all work. Provide units on all answers.

1. Which can transfer more energy to an electron in a single collision – a proton or an alpha particle? Explain.
2. A proton and an alpha particle with the same velocity are incident on a water target. Which will penetrate to a greater depth? Explain.
3. Astatine –211 is an alpha-emitting isotope that is used in radiation therapy by attaching it to a monoclonal antibody. The energy of the ^{211}At alpha particle is 6.87 MeV.
 - (a) What is the stopping power ($-dE/dx$) of water for the ^{211}At alpha?
 - (b) What is the range in water?
4. Consider two particles: a 1.2 MeV proton and a 30.5 MeV alpha particle.
 - (a) Calculate the stopping powers ($-dE/dx$) of water for both particles.
 - (b) What are the ranges of these particles in water?
 - (c) Calculate the maximum energy transferred by each in a collision with an orbital electron (assume that the electron is free and at rest).
 - (d) What are the ranges in water of these delta ray electrons?
5. Consider two particles: 10 MeV protons and 8400 MeV iron nuclei ($^{56}_{26}\text{Fe}$). You are a NASA engineer faced with shielding astronauts from these particles. Compare water, aluminum and lead.
 - (a) Calculate the velocities of the two particles.
 - (b) Calculate the stopping power of water, aluminum and lead for these two particles.
 - (c) Calculate the ranges of the protons and the iron particles in water, aluminum and lead.
6. Estimate the kinetic energy at which the collisional and radiative stopping powers are equal for electrons in
 - (a) Be
 - (b) Cu
 - (c) Pb

7. A small 1.85 GBq ^{198}Au (maximum beta particle energy 0.961 MeV) is enclosed in a lead shield, just thick enough to stop all the beta particles.

- (a) Estimate the bremsstrahlung fluence at a point 50 cm away.
- (b) How thick would the shield be if it were made of Lucite (a low-Z material with density = 1.19 g cm^{-3})?
- (c) What would the bremsstrahlung fluence be at a point 50 cm away from the source enclosed in Lucite?

8. Calculate the range in cm of the maximum energy beta ray from ^{90}Y (2.8 MeV) in bone of density 1.9 g cm^{-3} , and in air of density $1.3 \times 10^{-3} \text{ g cm}^{-3}$.

9. An electron emerges normally from a 4-mm-thick Lucite slab (density 1.19 g cm^{-3}) with an energy of 1.62 MeV. What was its energy when it entered the slab?

10. You have at your disposal an accelerator capable of accelerating any ion up to a maximum energy of 400 MeV per nucleon. You want to do a cell irradiation experiment with $^{12}_6\text{C}$ and $^{56}_{26}\text{Fe}$ ions **both having the same stopping power** ($-\text{dE}/\text{dx}$). You can pick any stopping power you want, but both ions must be able to penetrate the cell target, i.e., have a range of > 20 micrometers in water. Is this experiment possible? Why or why not?