

Interactions, Measurements, Theory of Radiation

Fall 2005

1. (15 min.) Consider thermal neutrons in an infinite medium at room temperature. Answer the following questions:

a) (5 min.) As you know, the neutron is not a stable particle. A free neutron decays with a half-life of 11.7 minutes. What are the reaction products of free neutron decay?

b) (10 min.) Determine the relative probability that a 2200 m/s neutron will undergo decay before being absorbed in the infinite medium of regular water ($\Sigma_a = 0.02220 \text{ cm}^{-1}$). Repeat your calculations assuming heavy water as the medium ($\Sigma_a = 0.0000442 \text{ cm}^{-1}$). Discuss your results.

2. (15 min.)

a) (5 min.) Give the definition and units of the microscopic cross section.

b) Assume a medium of constant number density, N , with σ_f and σ_t the microscopic fission and microscopic total cross section, respectively:

(5 min.) What is the probability that a particle starting at $x=0$ and moving along the x -axis will make a collision between x and $x+dx$?

(5 min.) What is the relative probability that a collision results in fission?

3. (10 min.) Consider the discrete sampling procedure to determine that a simulated collision results in fission, capture, elastic scattering, or inelastic scattering. Explain how the discrete sampling procedure works. To illustrate your answer, assume a random number generator that provides random numbers uniformly distributed between 0 and 1.

4. (15 min.) A 5-MeV proton is absorbed by $^{28}_{14}\text{Si}$. Find the excitation energy of the compound nucleus. The mass of a proton is 1.007276 amu.

<u>Nuclide</u>	<u>Atomic Mass (amu)</u>
$^{28}_{14}\text{Si}$	27.976927
$^{29}_{14}\text{Si}$	28.976494
$^{29}_{15}\text{P}$	28.981803

5. (10 min.) In the MeV range of photon energies prove that μ/p is approximately constant for all elements except H.

6. (15 min.) Consider how you might calibrate a thin (10^{-5} meter thick) plastic scintillator for eventual use in gamma ray dose measurements. The objective is to measure the number of photons produced by the scintillator per unit energy deposited. To accomplish the calibration you need a radiation source that will deposit the same amount of energy in the thin scintillator each time there is an interaction, and will produce light output that is relevant to that expected for the gamma ray dosimetry measurements. Explain why each of the following radiation sources will not work for this calibration.

- a) ^{137}Cs gamma rays
- b) ^3H beta particles
- c) Collimated ^{131}I beta particles
- d) Collimated ^{244}Cm alpha particles

7. (20 min.) A mono-energetic, uni-directional beam of neutrons is incident on a slab of material. The beam is perpendicular to the face of the slab, the neutrons in the beam have energy 500 keV, and 10^6 n/s enter the slab from the beam. We know the following about the slab:

$$\begin{aligned} \text{thickness} &= 2.5 \text{ cm}, \\ \Sigma_t(E) &= [0.1 + (1 \text{ MeV} - E)/(10 \text{ MeV})] \text{ cm}^{-1}, \\ \Sigma_a(E) &\approx 0 \text{ for } E > 100 \text{ eV}, \\ \Sigma_s(E' \rightarrow E) &= \begin{cases} \frac{\Sigma_s(E')}{E'}, & E < E' \\ 0, & E > E' \end{cases} \end{aligned}$$

a) (10 min.) At what rate [n/s] do neutrons make it all the way through the slab without interacting with the slab material? That is, at what rate do uncollided neutrons exit from the slab?

b) (5 min.) At what rate [n/s] do uncollided neutrons scatter in the slab? That is, how many neutrons per second are having their very first scattering collisions in the slab?

c) (5 min.) Consider the neutrons that are having their first scattering collisions in the slab. They enter the collision with energy 500 keV. What fraction of these neutrons emerge from the scattering collision with energies less than 100 keV?

8. (5 min.) Sketch a typical β^- particle energy spectrum and indicate how this spectrum can be used to indicate the Q -value of the decay.

9. (15 min.) A 1 gram sample of 90% enriched ^{134}Xe (density = 5.89 g/liter) is irradiated in a 2200 m/s neutron flux of $1 \times 10^{13} \text{ n/cm}^2\text{-s}$ for 8.0 hours. What is the ^{135}Xe activity at the end of irradiation? See attached figure.

