Georgia Institute of Technology

The George W. Woodruff School of Mechanical Engineering
Nuclear & Radiological Engineering/Medical Physics Program

Ph.D. Qualifier Exam

Fall Semester 2010

_____ Your ID Code

Radiation Physics (Day 1)

Instructions

1. Use a separate page for each answer sheet (no front to back answers).
2. The question number should be shown on each answer sheet.
3. ANSWER 4 OF 6 QUESTIONS ONLY.
4. Staple your question sheet to your answer sheets and turn in.

NRE/MP Radiation Physics

Answer any 4 of the following 6 questions.

Q1. At t=0, there are exactly N_0 hypothetical radioactive nuclei. At t = T (exactly), N_T nuclei are left. The decay constant is calculated in terms of N_0, N_T and T.

a. Estimate the standard deviation of the calculated decay constant.
b. Estimate the optimal T that minimizes the standard deviation of the calculated decay constant.

Q2. If the Q value for the reaction $^3He(n,p)^3H$ is 0.764 MeV, what is the threshold energy for the reaction $^3H(p,n)^3He$?

Different from the reaction $^3He(n,p)^3H$, the cross section of the reaction $^3H(p,n)^3He$ is largely affected by the Coulomb force. Estimate the Coulomb barrier for the reaction $^3H(p,n)^3He$, assuming the equivalent hard-sphere radius of the proton is 1.05 fm.

Q3. Consider the 3 component decay chain $X_1 \xrightarrow{\lambda_1} X_2 \xrightarrow{\lambda_2} X_3$.

a. Derive an expression for the amount and the activities of X_2 and X_3 at any time t as a function of decay constants. Assume at time t=0, only N_1^0 amount of X_1 is present.
b. When will these radionuclides be in secular equilibrium? You may state the condition for secular equilibrium in terms of decay constants.

Q4. The isotope ^{18}F is a radionuclide used in medical diagnoses of tumors and, although usually produced by the $^{18}O(p,n)^{18}F$ reaction, it can also be produced by irradiating lithium carbonate (Li_2CO_3) with neutrons. The neutrons interact with ^6Li to produce tritons (nuclei of ^3H) which in turn interact with the oxygen to produce ^{18}F.

a. What are the two nuclear reactions?
b. Calculate the Q-value for each reaction
c. Calculate the threshold energy for each reaction
d. Can thermal neutrons be used to create ^{18}F?

Q5. Calculate the maximum energy that a 10-MeV electron can possibly transfer to an atomic electron? In your calculation, please show the energy conservation and momentum conservation equations for the interacting electrons.

Q6. In an Inverse-Compton Scattering experiment (shown in the figure below), a 10-MeV electron beam and a 3-eV laser beam are brought head-to-head toward each other. What will be the energy of the photons scattered into the 60° direction?