**Georgia Institute of Technology**

The George W. Woodruff School of Mechanical Engineering

Nuclear & Radiological Engineering/Medical Physics Program

Ph.D. Qualifier Exam

Fall Semester 2017

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Your ID Code

**MP Radiation Physics & Detection**

**(Day 1)**

Instructions

1. Use a separate page for each answer sheet using only one side of the paper. DO NOT write on the BACK of the answer sheet.
2. The question number and your ID Code should be shown clearly on each answer sheet
3. **ANSWER 2 OF 3 Questions in each section; you will have answers for 2**

**Radiation Physics questions and 2 Detection questions**

4. Staple your question sheet to your answer sheets and turn in

**MP Radiation Physics**

**Answer any 2 of the 3 questions** **in Radiation Physics**

**Use the Nuclear Wallet Cards booklets for any nuclear data or physical constants you need.**

**Question 1:**

The neutron cross section data for 16O show that there is a resonance at 450 keV and that the resonance width is 40 keV.

(a) What is the energy level (from the ground state) of the compound nucleus (i.e. 17O) that corresponds to this resonance?

(b) What are the possible  for the corresponding excited state of 17O?

(c) Which type of neutron interaction is this resonance most likely associated with? e.g. (n, γ), elastic scattering, inelastic scattering, (n, 2n), (n, p), (n, fission), etc. Justify your answer quantitatively.

**Question 2:**

As shown, a 10-MeV electron beam is brought to perpendicularly impinge on a thin (10 μm) tungsten foil. Given that the collision stopping power of 10-MeV electron in tungsten is 2.3 keV μm-1, that the radiative stopping power is approximately equal to the collision stopping power, and that the CSDA range for 10-MeV electron in tungsten is 3.2 mm,

1. Draw the energy spectrum of the bremsstrahlung x-ray, justify why the spectrum appears the way it is, and then use it to estimate the average energy of the x-ray?

(b) For a beam current of 1 μA, estimate the x-ray emission rate (photons sec-1) and the rate of heating (in Joules sec-1) in the tungsten foil.

10 μm tungsten

10-MeV

electrons

Transmitted electrons

Bremsstrahlung x-ray

**Question 3:**

In many cases the decay of radionuclides is accompanied by the creation of new ones, either from the decay of a parent or from production by nuclear reactions such as cosmic ray interactions in the atmosphere or from neutron interactions in a nuclear reactor. Consider a radionuclide being so created.

1. If *Q(t)* is the rate at which the radionuclide of interest is being created,  is the decay constant for this nuclide, and N0 is the amount of nuclide present at time t=0 (when radionuclide creation begins), derive an integral expression for N(t), the amount of radionuclide at a time t.
2. Solve the expression in (a) for the specific case of where the radionuclide creation is constant Q(t) = Q0
3. Solve the expression in (a) for the specific case of a three component decay chain

**MP Detection**

**Answer any 2 of the 3 questions** **in Detection**

**Use the Nuclear Wallet Cards booklets for any nuclear data or physical constants you need.**

**Question 4:**

A scintillation spectrometer consists of an anthracene crystal and a 10-stage photomultiplier tube. The crystal yields about 15 optical photons for each 1 keV of energy dissipated. The quantum efficiency of the photomultiplier is 10%, and each dynode produces 3 secondary electrons.

1. Explain the principle of light generation in anthracene (organic scintillator). What is the mechanism behind neutron-gamma discrimination capabilities?
2. Estimate the pulse height observed at the output of the spectrometer if a 1 MeV electron deposits its energy in the crystal. The capacitance of the output circuit is 1010 F.
3. Discuss the sources of the relative fluctuations in the output signal. You can assume Poisson statistics. Calculate relative fluctuations in the output signal due to the photomultiplier tube using the parameters provided above.

**Question 5:**

You are to determine the half-life and activity of a very weak 116mIn sample based on two consecutive 1-hr measurements with a GM counter. Given that the two measurement results are 1000 counts and 475 counts, respectively, that the detection efficiency of the GM counter is 1% (i.e. it measures 1 counts per 100 disintegrations of 116mIn atoms), and that the background count is negligible, (a) calculate the half-life and the standard deviation (or error) associated with it, and (b) calculate the initial activity (in dpm) and the associated error of the sample.

**Question 6:**

Answer the following:

1. A liquid scintillation counter I has a low-energy window and a high energy window. In LSC’s, the two windows refer to the use of two upper level discriminator settings. The low-energy window (window #1) has a counting efficiency of 30% for H-3 and the higher energy window (window #2) has a counting efficiency of 72% for P-32. When a P-32 standard is counted, it is noted that 12% of the counts in window #2 are recorded in window 1. A mixed sample containing P-32 and H-3 yields 3800 counts in window #1 and 5800 counts in window #2. Determine the activity of each radionuclide. The beta endpoint energies are 18.6 keV and 156 keV for H-3 and C-14, respectively.
2. For Y-88 photons incident on an intrinsically pure germanium detector/spectrometer, calculate the energies of the single and double escape peaks. The two principal (>1% yield) gamma rays emitted in Y-88 decay are given below.

|  |  |
| --- | --- |
| Gamma Energy  (MeV) | Emissions  per decay |
| 0.89802 1.83604 | 0.93389 0.9935 |

1. For this problem, assume a 12% scintillation efficiency for NaI(Tl), an average

light photon energy of 3 eV, 25% loss of light photons in the crystal/PMT assembly, and a conversion the photocathode of 20%.

i. For the 0.364 MeV gamma rays emitted in I-131 decay, determine the number of photoelectrons produced by each gamma ray at the photocathode of the photomultiplier tube.

ii. Estimate the energy resolution of the detection system.