Georgia Institute of Technology

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

Ph.D. Qualifier Exam

Fall Semester 2007

_______________ Your ID Code

Radiation Detection & Protection (Day 3)

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 Detection & Protection

Answer 4 of the following question.

1. To avoid using neutron-gamma-ray discrimination circuitry in a proton-recoil proportional counter to be used for neutron spectroscopy, the maximum-energy proton must travel less than about 0.7 of the counter radius. Assume the maximum energy neutron to be encountered in a particular neutron field is 700 keV and the counter is filled with methane (CH_4) at 3.5 atmospheres. (Data Attached; Assume STP: R=8.314472 J/mole-K)
   a. What should the radius (cm) of the detector be?
   b. What is the most energy that a 1-MeV electron from a photoelectric effect event can deposit in the chamber?
   c. Such a recoil spectrometer might more typically have a 5% N_2 and 95% CH_4 filling. Why?

Methane – Electron Stopping Power and Range Tables

Kinetic Energy (MeV)	Total Stopping Power (MeV-cm^2/g)	Range (g/cm^2)
1.00E-02	2.83E+01	1.98E-04
1.25E-02	2.37E+01	2.95E-04
1.50E-02	2.05E+01	4.09E-04
1.75E-02	1.81E+01	5.39E-04
2.00E-02	1.63E+01	6.84E-04
2.50E-02	1.37E+01	1.02E-03
3.00E-02	1.19E+01	1.41E-03
3.50E-02	1.06E+01	1.86E-03
4.00E-02	9.54E+00	2.36E-03
4.50E-02	8.73E+00	2.91E-03
5.00E-02	8.08E+00	3.50E-03
5.50E-02	7.53E+00	4.15E-03
6.00E-02	7.08E+00	4.83E-03
7.00E-02	6.35E+00	6.33E-03
8.00E-02	5.79E+00	7.98E-03
9.00E-02	5.35E+00	9.78E-03
1.00E-01	5.00E+00	1.17E-02
1.25E-01	4.35E+00	1.71E-02
1.50E-01	3.92E+00	2.32E-02
1.75E-01	3.61E+00	2.98E-02
2.00E-01	3.37E+00	3.70E-02
2.50E-01	3.05E+00	5.27E-02
3.00E-01	2.84E+00	6.97E-02
3.50E-01	2.69E+00	8.79E-02
4.00E-01	2.58E+00	1.07E-01
4.50E-01	2.50E+00	1.27E-01
5.00E-01	2.44E+00	1.47E-01

Methane – Proton Stopping Power and Range Tables

Kinetic Energy (MeV)	Total Stopping Power ($MeV\text{-}cm^2/g$)	Range (g/cm^2)
1.00E-03	3.49E+02	3.20E-06
5.00E-03	6.36E+02	1.14E-05
1.00E-02	8.78E+02	1.80E-05
5.00E-02	1.50E+03	4.97E-05
1.00E-01	1.45E+03	8.28E-05
2.00E-01	1.04E+03	1.65E-04
3.00E-01	8.04E+02	2.75E-04
4.00E-01	6.63E+02	4.13E-04
5.00E-01	5.68E+02	5.76E-04
6.00E-01	5.00E+02	7.64E-04
7.00E-01	4.49E+02	9.76E-04
7.50E-01	4.27E+02	1.09E-03
8.00E-01	4.08E+02	1.21E-03
8.50E-01	3.90E+02	1.34E-03
9.00E-01	3.75E+02	1.47E-03
9.50E-01	3.60E+02	1.60E-03
1.00E+00	3.47E+02	1.74E-03
1.25E+00	2.94E+02	2.53E-03
1.50E+00	2.56E+02	3.44E-03
1.75E+00	2.28E+02	4.48E-03
2.00E+00	2.06E+02	5.63E-03
1.00E-03	3.49E+02	3.20E-06
5.00E-03	6.36E+02	1.14E-05

2. A 10 micro-amp beam of 15-MeV deuterons with an area of 1 cm^2 is focused on an iron wall that is 0.2-cm thick. Assume that the average interaction cross section throughout the portion of the irradiated wall for the $^{56}Fe(d,\alpha)^{54}Mn$ reaction is 0.05 barns and the half life of ^{54}Mn is 312.2 days.

   a. What activity (MBq) of ^{54}Mn will be induced in the wall if the beam hits it for 5 days?
   b. ^{54}Mn decays by electron capture, emitting a 0.835-MeV photon 100% of the time. If this section of wall is removed, what is the tissue dose rate (in Gy/hr) from it at 1 meter in a vacuum? You may treat at as a point source at this distance and ignore any self-attenuation.

Charge on an electron:	1.6022(10^{-19}) C
Atomic abundance of ^{56}Fe	91.75
Elemental atomic mass of natural iron	55.845 amu
Density of iron	7.87 g/cm^3
$\left(\frac{\mu_{en}}{\rho}\right)_{tissue}$	0.0318 cm^2/g @ 800 keV 0.0307 cm^2/g @ 1 MeV

3. (a) What is radiation-induced bystander effect? (b) What is radiation-induced genomic instability? (c) How are they related to the linear-no-threshold model used in radiation protection?

4. In a radiological accident, a worker is suspected to have swallowed certain amount of Cs-137. (a) Describe the measurement method you will use to determine the quantity (or activity) of Cs-137 that is deposited in the worker's body, (b) Describe the measurement method you will use if the isotope is Pu-239.

5. Answer the following questions about neutron dosimetry.

    a) Calculate the kerma deposited in muscle per unit fluence of thermal neutron as a result of the (n,p) reaction. The energy released from this reaction is shared by the proton (0.58 MeV) and the recoiling nucleus (0.04 MeV).

        Given:
        Interaction cross section (σ) = 1.84×10^{-24} cm^2/atom,
        Atomic mass of one mole of target atom = 14.01 g
        Mass of the target atoms per gram of muscle tissue = 0.035 g
        Conversion factor from MeV/g to cGy = 1.602×10^{-8}

    b) Suppose the kerma from a) above was obtained at the center of a spherical muscle tissue with a radius of 0.5 cm. Is the kerma equal to the absorbed dose at the same point then? Why or Why not?

6. Suppose a K-shell vacancy appears as a result of a photoelectric absorption and an electron falls in from the L-shell to fill the vacancy. Assuming that the atom opts entirely for the Auger effect, an M-shell electron is subsequently ejected. Finally, the two electron vacancies in the L- and M-shell are filled by two N-shell electrons and two more N-shell electrons are emitted as Auger electrons (i.e., There are four N-shell vacancies at the end). Calculate the total kinetic energy of the three Auger electrons? Given: $(E_b)_N$ = 1.329E-03 MeV, $(E_b)_M$ = 5.182E-03 MeV, $(E_b)_L$ = 2.047E-02 MeV, $(E_b)_K$ = 1.097E-01 MeV.