GEORGIA INSTITUTE OF TECHNOLOGY

The George W. Woodruff
School of Mechanical Engineering

Ph.D. Qualifiers Exam – Spring Semester 2020

Day 2: Radiation Detection

EXAM AREA

Assigned Number (DO NOT SIGN YOUR NAME)

✷ Please sign your **name** on the back of this page —

Georgia Institute of Technology

The George W. Woodruff School of Mechanical Engineering

Nuclear and Radiological Engineering/Medical Physics Program

PhD Qualifying Exam

Spring 2020

____

(Your ID Code)

NE Radiation Detection

(Day 2)

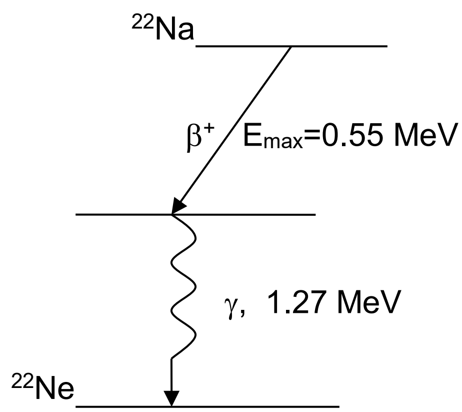
Instructions

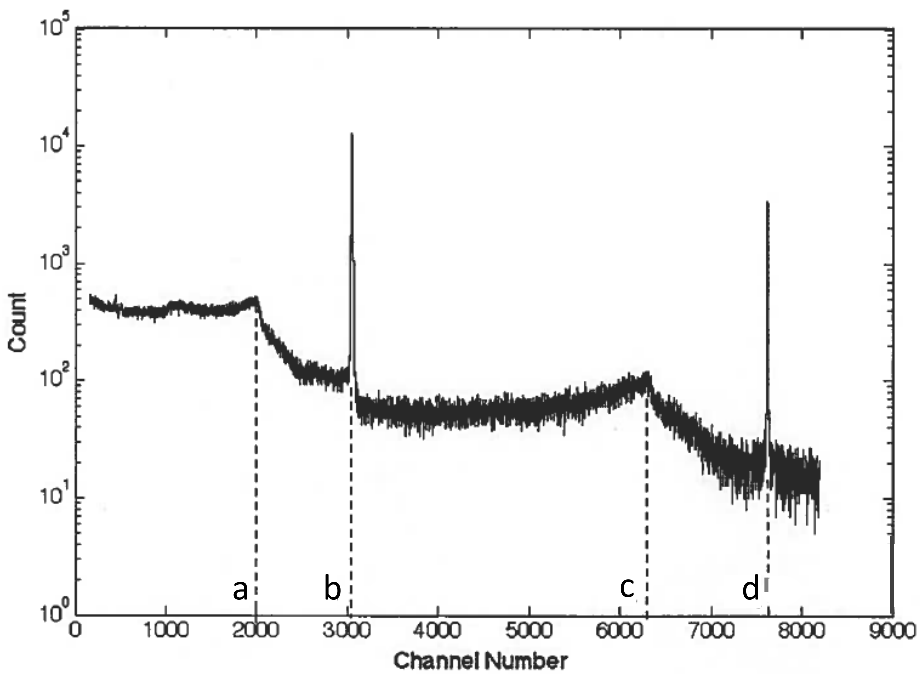
1. Use a separate page for each answer sheet using only the front side of the paper. DO NOT write on the back of the answer sheet
2. The **question nuclear and your ID Code** should be shown clearly on each answer sheet
3. **ANSWER 4 OF 6 Questions**
4. Staple your question sheet to your answer sheet and turn in

Radiation Detection

RD01

Referring to the following decay scheme of ^{22}Na and the corresponding gamma-ray spectrum measured with a HPGe detector, estimate the values of a, b, c, and d (in MeV) shown in the spectrum, and please show your work.





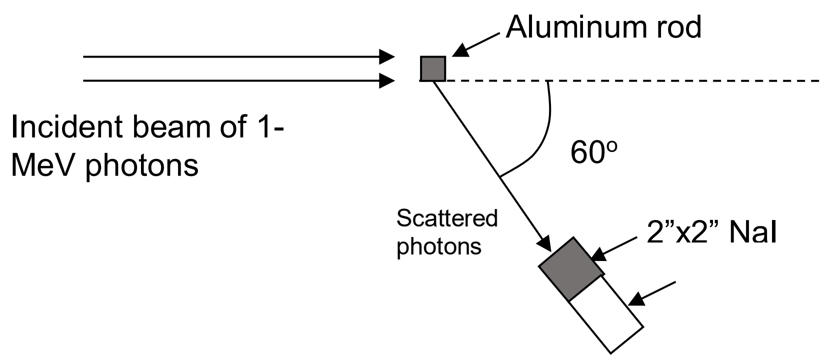
RD 02

In a Compton Scattering experiment (shown below), a well-collimated 1-MeV gamma-ray beam was brought to perpendicularly incident on a 1cm × 1cm square aluminum rod. The scattered photons were being measured at 60° angle with a 2"×2" NaI(Tl) detector located at some distance away. Given that: (1) the incident beam intensity hitting the aluminum rod was 1.0×10^{5} photons sec^{-1}, (2) the linear attenuation coefficient of aluminum for 1-MeV photons is 0.2 cm^{-1}, and (3) the total counts recorded by the NaI(Tl) detector was 10,000 in 5 minutes, and refer to Attachment A to estimate:

(a) the number of photons that underwent Compton scattering with the aluminum rod in 5 minutes,

(b) the energy of the scattered photons entering the NaI(Tl) detector, and

(c) the probability for a scattered photon to enter the NaI(Tl) detector.



RD 03

(a) Given the graph below what is the proper setting for voltage for the Geiger-Müller detector? (3 points)

(b) Why do we choose to operate detectors in that voltage region? (3 points)

(c) Will the number of counts observed by the detector be proportional to the energy of the gamma-rays hitting the detector? Explain your answer. (2 points)

(d) A Geiger-Müller detector is not intended for neutron detection. What design modifications could you make to improve sensitivity to neutrons? Explain your answer. (2 points)

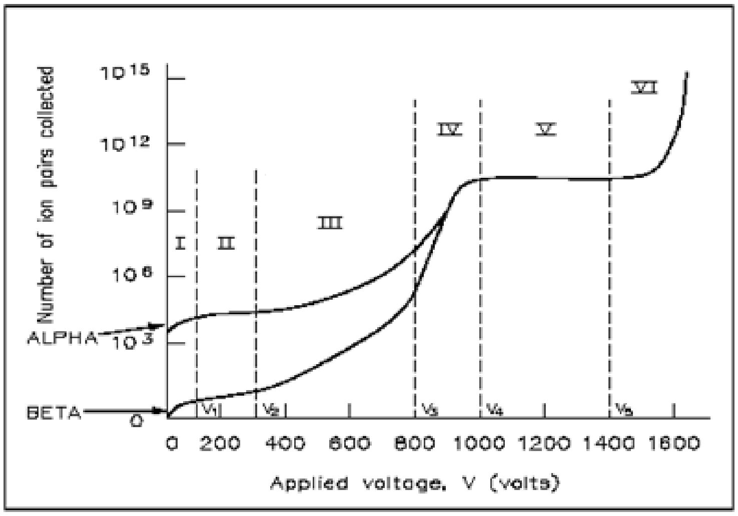


Figure 23 Gas Ionization Curve

RD04

You have a radiation detector with an efficiency of 0.05 ± 0.0003 counts per gamma-ray emission from a ^{137}Cs source placed 1 cm from the detector.

a. A 1-minute measurement of a ^{137}Cs sample gives you 1,682 counts. A 10-minute background count gives you 320 counts. What is the net number of counts from the sample (in counts per minute (include uncertainty))? (3 points)

b. ^{137}Cs decays 85.1±0.2% of the time with a gamma-ray that can be detected with the detector. What is the activity of the sample being measured in Bq (decays per second)? (3 points)

c. What is the associated uncertainty for the activity calculated in "b"? (4 points)

$$\sigma_u^2 = \left(\frac{\partial u}{\partial x}\right)^2 \sigma_x^2 + \left(\frac{\partial u}{\partial y}\right)^2 \sigma_y^2 + \left(\frac{\partial u}{\partial z}\right)^2 \sigma_z^2 + ...$$

RD05

Calculate the irradiation time needed to produce Au-198 in such a quantity that the gross counting rate is 1000 counts per minute using a counter with which the Au sample subtends a solid angle of 0.01 sr and has an intrinsic efficiency of 0.90. The background counting rate is 100 counts per minutes. It takes 10 minutes to get the sample from the reactor, place it under the detector and start counting.

Data:

$\phi=10^{16}$ n/(m^2-sec)

$T_{1/2}$=2.7 days

Capture cross section for Au-197 converted to Au-198 is 99 barns

Mass of sample is 1 microgram of Au-197.

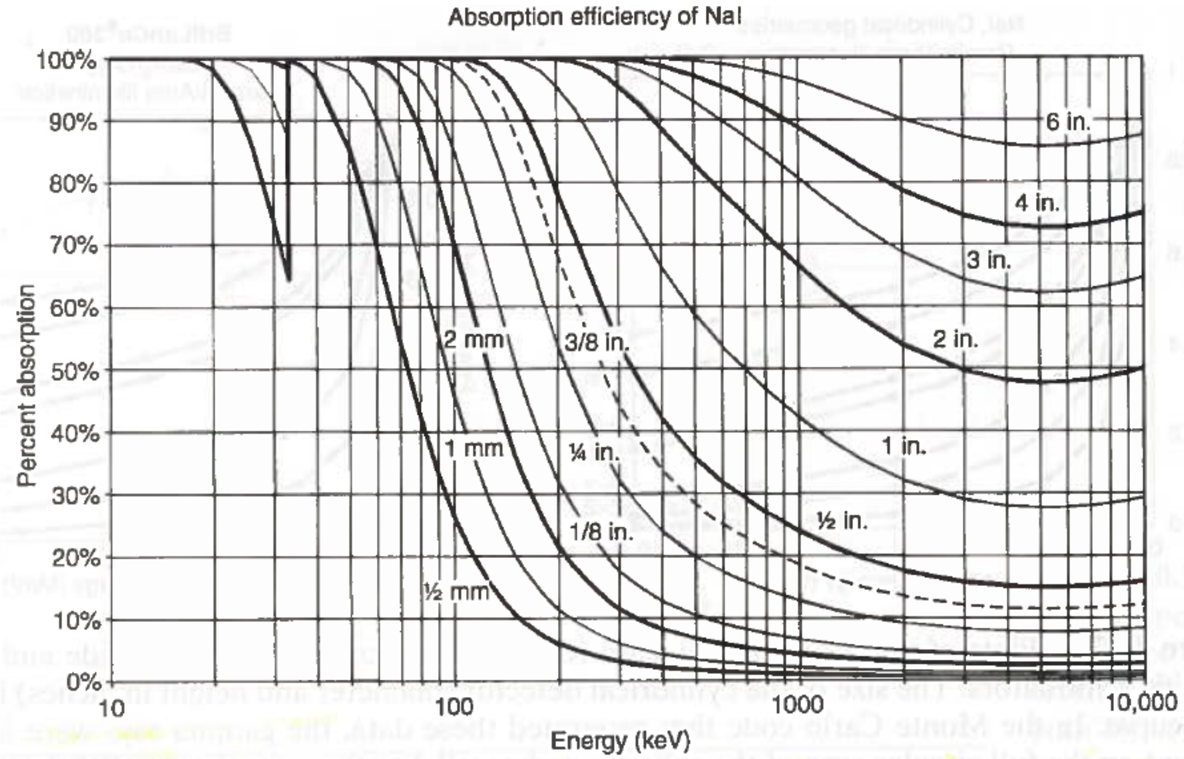
RD06

A pocket dosimeter with a volume of 2.2 cm^3 and capacitance of 8pF was fully charged at a potential difference of 200V. After being worn during a gamma-ray exposure, the potential difference was found to be 192 V. Assume STP.

a) Calculate the exposure in roentgens(R).
b) What charging voltage would have to be applied to the dosimeter if it is to read exposures of up to 3 R?

Recall 1 R = 2.58 (10^{-4}) C/kg and is based on the sum of all charges of one sign produced in air by photon interactions. The *w* value for air is about 34 eV/ion pair.

Attachment A



Plots of the intrinsic total efficiency for sodium iodide (NaI) of assorted thicknesses. The gamma rays are assumed to be normally incident to the surface of the NaI detector.