Chemistry 985

Fall, 2o15 Exam # 1 **OPEN BOOK**
Distributed: Mon., 19 Oct. 15, 12:30PM Due: 19 Oct. 15, 1:45PM

Some constants: q_e 1.602x10^{-19} Coul, ϵ_0 8.854x10^{-12} F/m
h 6.626x10^{-34} J-s, Aluminum mass density 2.70 g/cm^3, c 299 792 458 m/s

1. The following information is available on the NSCL website describing the SuN detector:
`http://www.nscl.msu.edu/users/equipment.html#sun`

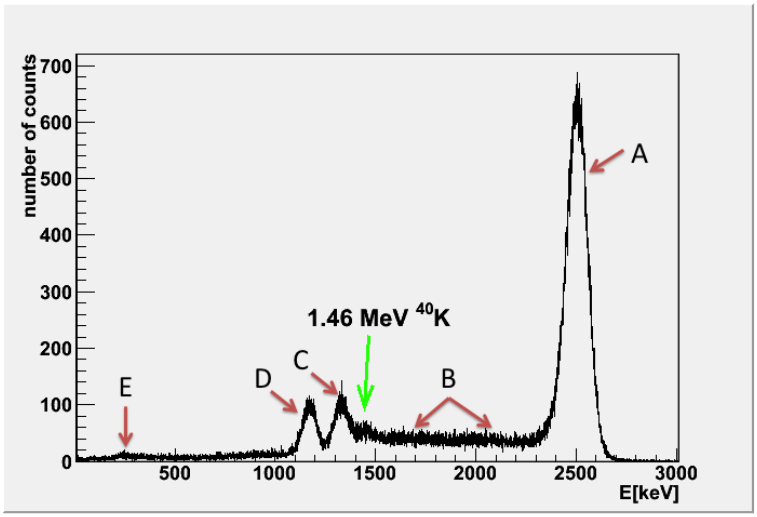
"SuN is a γ-ray Total Absorption Spectrometer. It is a cylindrical shape[d] NaI(Tl) detector, 16-inch in diameter and 16-inch in height [I think that they mean long] with a 45 mm [1.8 inch diameter] borehole along its axis. It is segmented in 8 optically separated segments, which are positioned above and below the beam axis as [not] shown in the figures. Each segment is being read by three photomultiplier tubes resulting in a total of 24 signals coming out of the detector."
"The [I assume total] efficiency of SuN for a ^{137}Cs source (E_γ = 661 keV) is 85%. For the summing of the two sequential γ-rays from the decay of ^{60}Co the sum-peak [total] efficiency is 65%. The summing efficiency of SuN highly depends on the multiplicity of the γ-cascade being detected; the higher the multiplicity the lower the efficiency."

   (a) Make an estimate of the geometrical efficiency for a gamma-ray point source that is positioned exactly in the middle of the bore tube and the middle of the device.

   (b) Use your estimate of the geometrical efficiency and their statement about the [total] efficiency to calculate the intrinsic efficiency of the device for the ^{137}Cs gamma ray.

   (c) The NaI(Tl) crystals are housed inside a 0.5 mm thick aluminum container. Make an estimate of the attenuation of the ^{137}Cs gamma ray by the aluminum housing.

(d) The spectrum shown below was obtained with a ^{60}Co source placed in exactly the middle of the SuN detector. Describe the physical phenomena that create the features labeled A through E in the figure. In case you don't recall, ^{40}K is a naturally occurring radioisotope that emits a beta particle and then a gamma ray (1462 keV).



2. The NSCL has two types of Ludlum survey meters that are used to check for activated parts. One device uses a 2 inch diameter by 2 inch long cylindrical NaI(Tl) crystal (Ludlum #44-10) and the other, called a pancake detector, uses a Geiger-Mueller counter that is 2 inch in diameter and is 0.5 inch deep (an example of this detector was circulated in lecture). The background counting rates of the two detectors when sitting next to each other in a hallway at the NSCL are 2000 counts/min and 60 counts/min, respectively. This question relies on some information in the textbook.

   (a) Give the most plausible explanation for the very large difference in counting rates in these two devices.

   (b) The NaI(Tl) detector is readout by a Hamamatsu 1306 that is operated at its recommended voltage. What is the value of δ for this eight stage tube operated under these conditions?

(c) Calculate the quantum efficiency for this tube.

(d) The dark current of this tube operating under these conditions is listed as 2 nA. What is the emission rate of photoelectrons if this dark current is caused by photoelectrons that are amplified by the tube?

3. A gas-filled ion chamber is filled with P-10 gas. What is the resolution in keV of this device for the 6.404 keV x-ray that is characteristic of iron atoms? Recall that the Fano factor of this gas was found in a homework problem to be 0.21

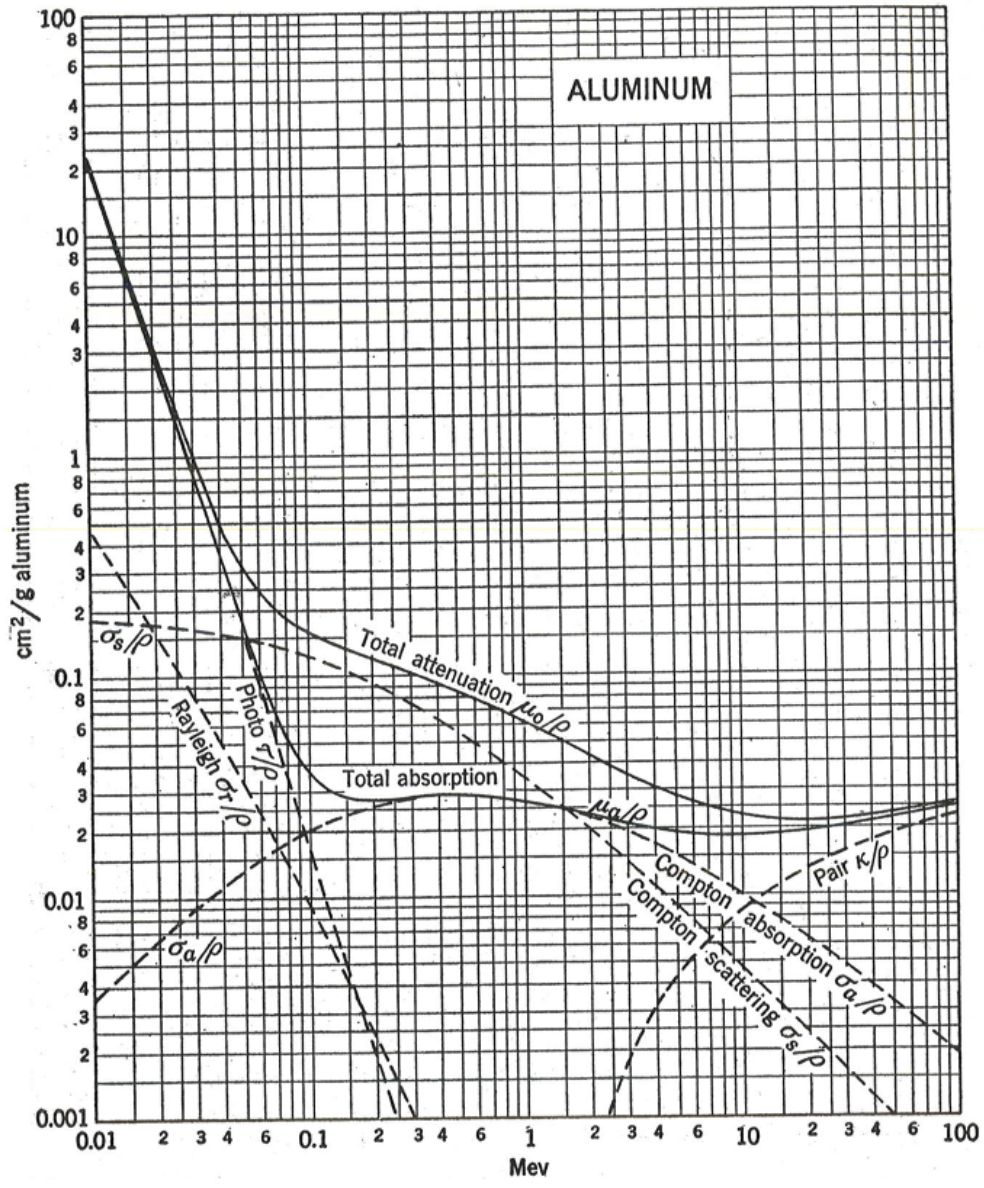
4. Give short answers to the following questions.

   (a) Describe the physical basis of the two parameters, K and ΔV, for a particular gas that are used in the Diethorn Equation for proportional counters.

   (b) Why is a Geiger-Mueller counter insensitive to the energy deposited in the detector?

   (c) What is the role of a Frisch grid in a gas-filled detector?

   (d) A ten stage PMT is AC-coupled by a passive base into a 50 Ω circuit with a 120 pF capacitor. How does the characteristic time constant of this device compare to the decay constant of the fast component of light from a BaF_2 scintillator?


ALUMINUM
cm²/g aluminum
Mev
Total attenuation μ_a/ρ
Total absorption
σ_s/ρ
Photo τ/ρ
Rayleigh σ_r/ρ
μ_a/ρ
Pair κ/ρ
Compton absorption σ_a/ρ
Compton scattering σ_s/ρ
σ_a/ρ