Chemistry 985

Fall, 2o13 | Exam # 1 **OPEN BOOK**

Distributed: Thurs., 17 Oct. 13, 8:30AM | Due: 17 Oct. 13, 10:00AM

Some constants: q_e 1.602x10^{-19}Coul, ϵ_0 8.854x10^{-12} F-m

1. The textbook indicates that a ^{137}Cs ($T_{1/2}$=30.2y, β^- emitter) will emit a β ray (Q_β=1176 keV), and each beta decay is followed by either (1) a single gamma ray (662 keV), (2) a single conversion electron (624 keV) and an x-ray, or (3) a slightly different conversion electron (656 keV) and a different x-ray. The NSCL has several ^{137}Cs sources and they are all covered by some thickness of aluminum metal (density 2.70 g/cm^3) to absorb some of the radiations.

   (a) (2 points) What are the values of the two x-ray energies in keV?

   (b) (5 points) Use the figure attached at the bottom of this exam to calculate the thickness of aluminum metal in μm, mm, or cm that would be necessary to attenuate the intensity of the higher energy x-ray by a factor of 10.

   (c) (4 points) By what factor will the absorber calculated in part -b- attenuate the intensity of the gamma ray?

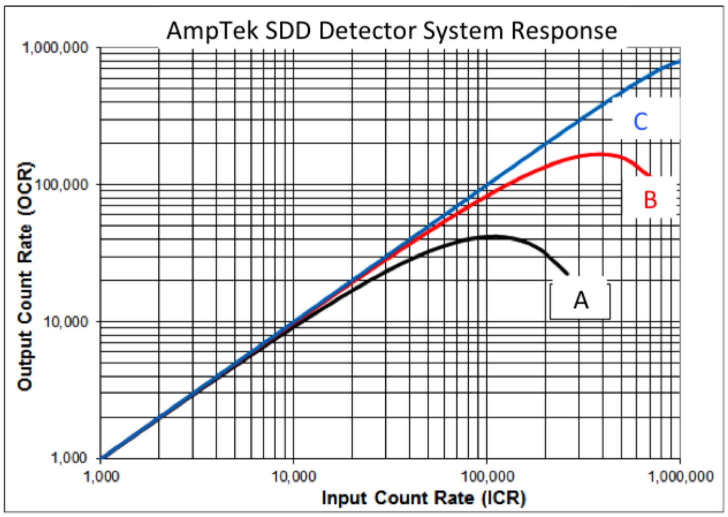
   (d) (5 points) Estimate the range in μm, mm, or cm of aluminum of the higher energy conversion electron. HINT: There is a useful figure in Chapter 2 of the text given the assumption that silicon (Z=14) is very similar to aluminum (Z=13).

   (e) (4 points) By what amount will the absorber calculated in part -b- attenuate the intensity of the β rays?

2. (10 points) The following figure shows the response of a commercial x-ray spectrometer system as a function of incident x-ray rate with three different "user options." The options are labeled A, B and C for our purposes. Answer the following questions based on the information for Option-A in the figure.

   (a) (1 point) Is this system paralyzable or non-paralyzable based on the information in the figure? Explain your answer.

(b) (9 points) Make an estimate of the deadtime of this system running with Option-A.



3. (20 points, 4 each) Provide **concise** and accurate answers to the following five questions about vacuum equipment.

   (a) Give a general description of the operation of a Piranni vacuum gauge (i.e., what is measured and how is that sensitive to pressure).

   (b) Describe the purpose of the filament in a standard (Bayard-Alpert) hot-cathode vacuum gauge.

   (c) What is the most likely (highest pressure) gas and what is its source in a sealed metal beam pipe (no leaks) that might be found at the NSCL immediately after the air is removed and the pumping system has just reached its base pressure?

   (d) How does the conductance of a round pipe scale with the radius of that pipe in the laminar flow region?

   (e) What is the effective speed of a high vacuum pump, S=250 L/s for air, that is connected to a vacuum chamber with a straight pipe with a molecular-flow conductance of 150 L/s for air?

4. (20 points) The positions of particles in the focal plane of the S800 and the Sweeper Magnet are measured with Cathode-Readout Drift-Chambers (CRDC). These devices are proportional counters with a Frisch grid attached to larger volume to drift the ions before collection. The anode is mounted in the middle of a rectangular volume (30 x 8.62 x 8.62 cm^3). For the present analysis you can assume that the proportional region is a cylindrical volume with r=4.3 cm. The anode wire is 12.5μm in radius and held at +850 V relative to the Frisch grid. What is the signal height produced by this device if 1.0 MeV is deposited by alpha particles in pure methane fill gas at 0.2 atm? Note that the high voltage is supplied to the anode through a 100 pF capacitor (that is larger than the stray capacitance) and the output is measured across a 50 Ω resistor. The expression for the capacitance of a cylindrical detector of length L, should you need it, is $C=\pi\epsilon_o L/ln(r_{cathode}/r_{anode})$.

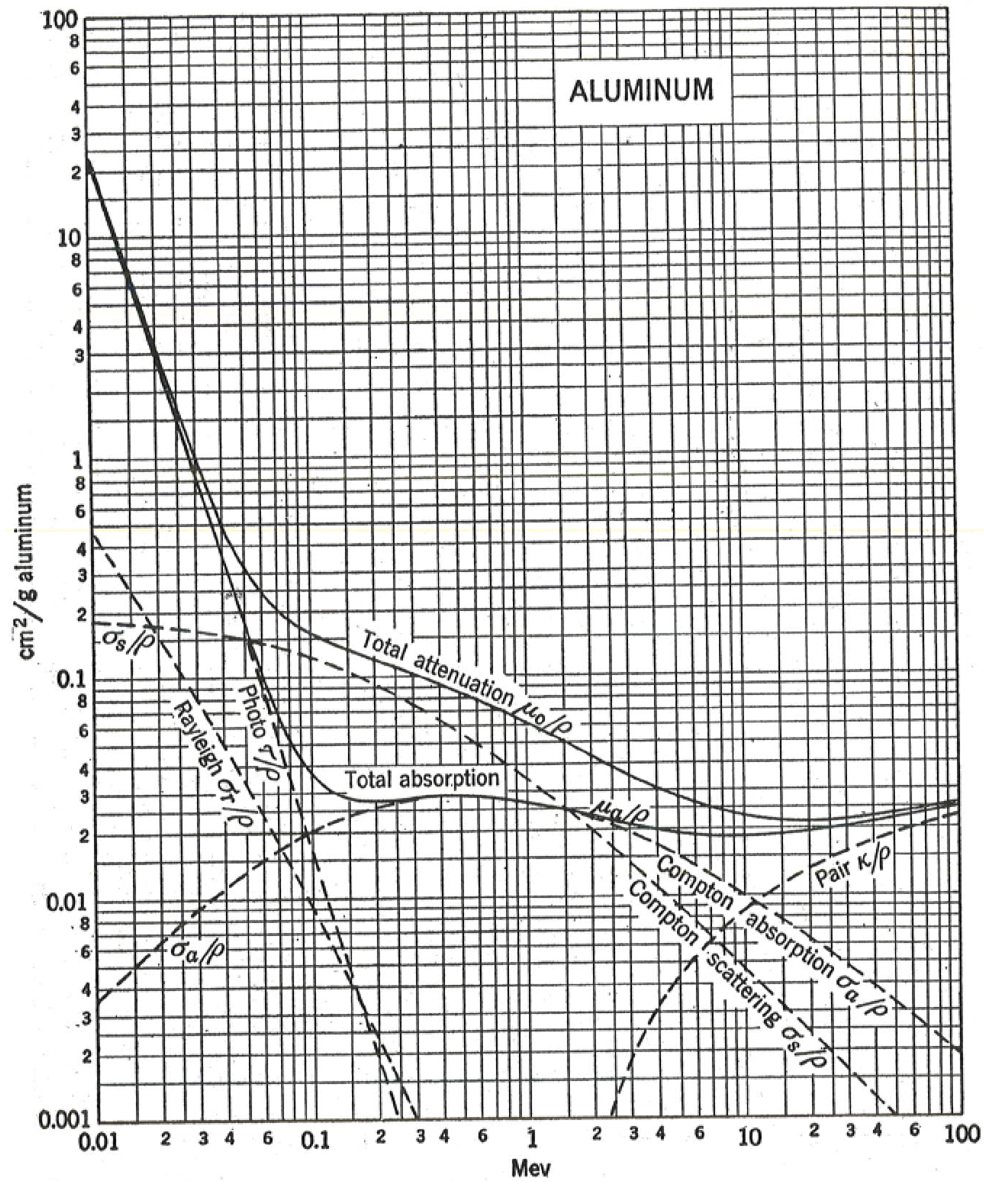
5. The NSCL has a Hyperpure germanium (HPGe) detector that is called a 130% detector. The device has a closed-end geometry and is operated with a negative bias of 2500 V.

   (a) (10 points) Make an estimate of the intrinsic efficiency of this detector for the 1332 keV gamma ray emitted by ^{60}Co.

   (b) (2 points) Assuming that this device consists of n-type germanium, which charge carriers are collected on the central contact of the detector?

   (c) (4 points) Assume that a 1.0 MeV gamma ray enters this HPGe detector and the full energy is absorbed. Describe a likely sequence of events that lead to the full energy absorption.

   (d) (4 points) Describe the difference between true coincidence summing and random summing as those terms are used in gamma-ray spectroscopy.


ALUMINUM
cm²/g aluminum
Mev
Total attenuation μ_0/ρ
Total absorption
μ_a/ρ
σ_s/ρ
σ_a/ρ
Photo τ/ρ
Rayleigh σ_r/ρ
Compton absorption σ_a/ρ
Compton scattering σ_s/ρ
Pair κ/ρ