Spring 2001

Ph.D. Qualifying Examination
Interactions

1. (15 min. total) A 1-ampere beam of 10 eV electrons is perpendicularly incident on a 1-mm thick, solid slab of a material comprised of a single type of atom. You know the inelastic interaction of a 10 eV electron with this atom results in emission of a 1 eV photon.

   a. (7 min.) If you measure 99% transmission of the 10 eV electrons through the slab, what is the upper limit for the radiant power emitted from the slab due to the electron interactions?

   b. (4 min.) What is the charge per centimeter of the incident beam taken parallel to the beam direction? (Assume electrons are nonrelativistic)

   c. (4 min.) Describe how the 10 eV electron's inelastic interaction with a slab atom can result in the emission of a photon?

2. (15 min.) Consider a surface source: $S_a(\hat{\Omega}) = C\eta^2$ neutrons/cm^2-sec-sr emitting into 2π steradians, where C is a constant, and η is the cosine of the angle between $\hat{\Omega}$ and the surface normal. In terms of the source strength, S_a neutrons/cm^2-sec, find:

   a. The constant, C.
   b. The angular flux density at the surface.
   c. The scalar flux density at the surface.

3. (20 min.) Consider the thermal neutron radiative capture, (n,γ), reaction with $^{28}_{14}\text{Si}$. Find the kinetic energy of the recoil nucleus.

Nuclide	Atomic Mass (amu)
n	1.0086649
p	1.0072765
$^{28}_{14}\text{Si}$	27.976927
$^{29}_{14}\text{Si}$	28.976495

4. (15 min.) A spherical reactor has a uniform power density of 50 watts/cm^3 and an outer radius of 40 cm. Find the uncollided exposure rate at the center of the reactor due to fission photons. You may assume that the volumetric fission rate is uniform and that there are seven 2 MeV photons emitted per fission. At 2 MeV, the linear attenuation coefficient (μ) of the core material is 0.50 cm^{-1}. Take the energy release per fission reaction to be 3.20E-11 watt-sec. Recall that the exposure rate is related to the uncollided photon flux as follows:

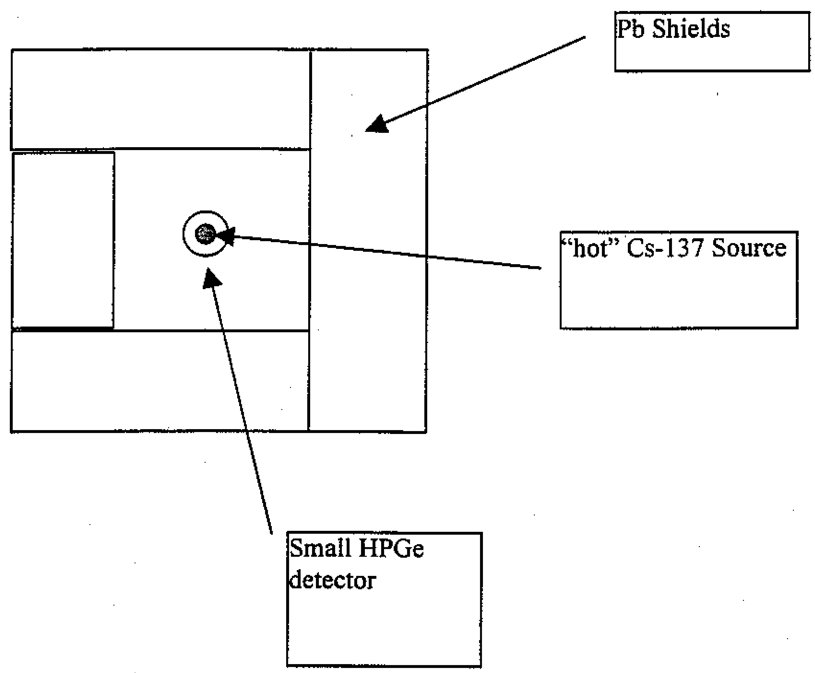
$$\dot{X}_U \text{ (R/sec)} = K\phi_U, \text{ where } K = (1.835 \times 10^{-8})(\mu_a/\rho)_{air}E_0.$$

Also, $(\mu_a/\rho)_{air}$ at 2 MeV = 0.0279 cm^2/g.

5. (15 min.) An engine oil wear test is to be carried out by measuring the mass of radioactive (metallic) particles in an oil sample. A 10-milliliter sample of the oil yields 15,852 counts over a three-minute period. A "standard" sample has also been prepared using 100 micrograms of the same radioactive particles in 10 milliliters of oil. This "standard" sample yielded 94,496 counts over a 10-minute period. The background counting rate for the detector system has been determined to be 280 counts per minute measured over a very long counting period (48 hours). Determine the mass and its associated standard deviation of the radioactive (metallic) particles in the sample.

6. (15 min. total)

6a. (10 min.) For a HPGe detector setup as shown below, sketch what the measured energy spectrum would look like. Label and briefly explain pertinent features of your sketch. Assume that the source is a relatively high activity Cs-137 source (Cs-137 emits a 662 keV photon) sitting directly on the detector. The dead time is on the order of 30%.



6b. (5 min.) A typical HPGe efficiency curve is shown below. The photoelectric cross section of NaI (which is close enough to that of Ge for this problem) is also shown on the following page. Why doesn't the peak efficiency curve follow the photoelectric curve at high photon energies?

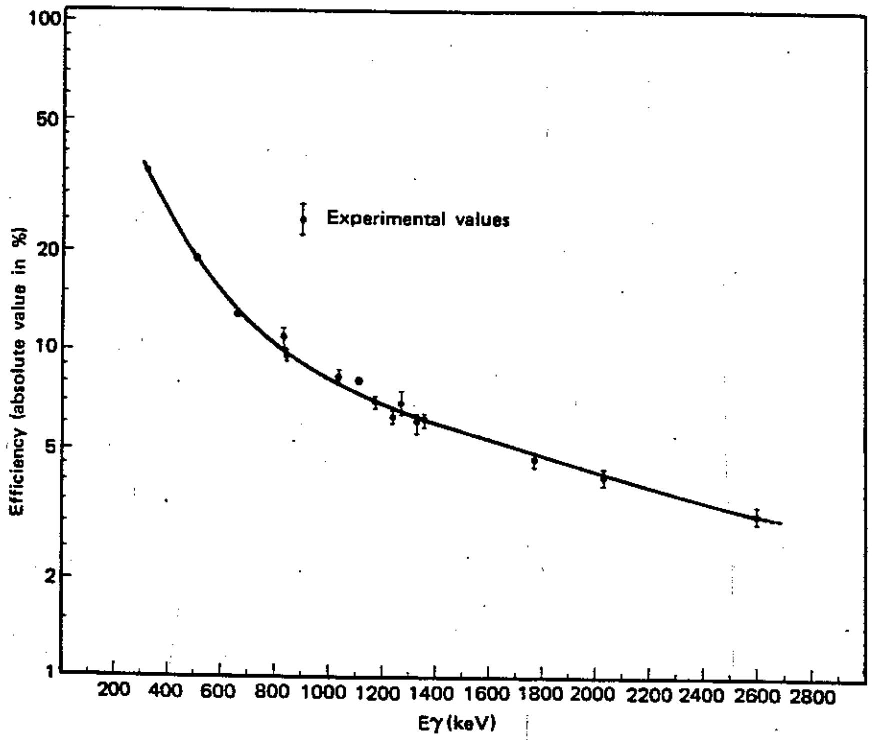


Figure 12-28 Measured intrinsic full-energy peak efficiency for a coaxial 38 cm^3 Ge(Li) detector.

SEE NEXT PAGE.

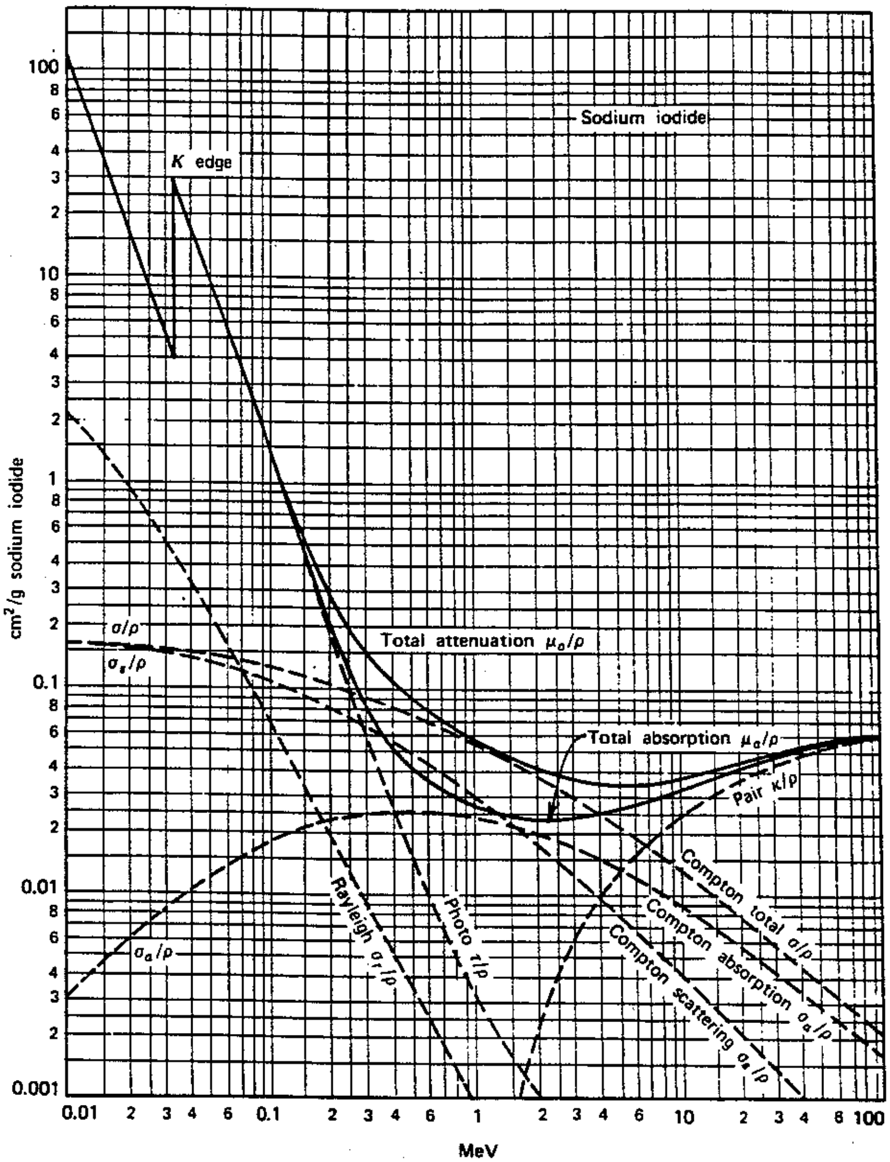
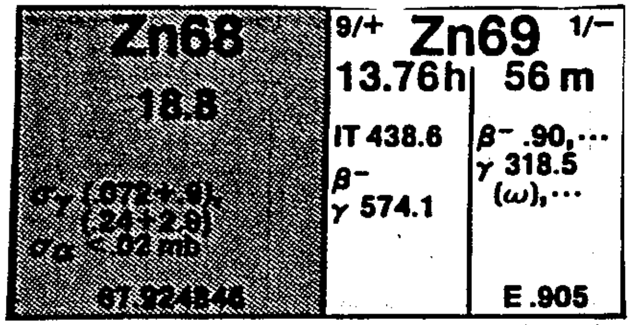


Figure 2-18 Energy dependence of the various gamma-ray interaction processes in sodium iodide. (From *The Atomic Nucleus* by R. D. Evans. Copyright 1955 by the McGraw-Hill Book Company. Used with permission.)

7. (15 min.) One gram of ^{68}Zn is exposed to a pulse of 10^{16} n/cm^2 of thermal neutrons. What are the activities of ^{69m}Zn and ^{69}Zn 20 hours after the pulse?



8. (10 min.) The U.S. and Russia have agreed to destroy excess nuclear warheads. One proposal is to put the Pu in a reactor and generate power. Assume that 1 kg of ^{239}Pu is put into the NSC core and could be uniformly subjected to a 2200 m/s flux of 1E13 n/cm^2-s. The 2200 m/s cross-section for fission is 750 barns. Considering fissions only, after how many hours in the reactor will:

a. half of the original Pu remain?

b. 1% of the original Pu remain?