INTERACTIONS, MEASUREMENTS, AND RADIATION

QUALIFYING EXAMINATION

1. (5 min) The fission products of the thermal n –induced fission of ^{235}U reaction are generally radioactive. Explain why and give the most common type of decays.

2. (15 min, total) You perform a sequence of simple, elastic scattering experiments with identical scattering particles and find a fractional transmission curve through material 1 that is fit by the equation $T_1 = \exp(-a\ x_1)$
Here, a is a constant for material 1 and x_1 is the distance into the material.

a. (6 min) Is there a maximum thickness of this material on which you could perform this experiment and still expect to find this exponential fit? Suggest a thickness, if there is a maximum, and explain your choice.

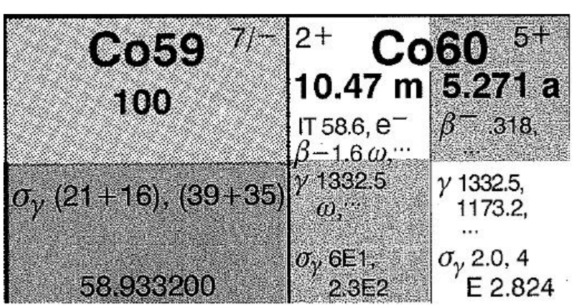
b. Suppose you have a second material 2 with measured fractional transmission
$T_2 = \exp(-b\ x_2)$
where b is a constant and x_2 is the distance into the material.

(1) (6 min) Assume materials 1 and 2 are mixed uniformly and in equimolar proportions to give a final density equal to the average of the densities of the two materials. What is the fractional transmission at a depth $x_1 + x_2$ in the mixed medium?

(2) (3 min) If slabs of media 1 and 2 are kept separate but parallel to each other, what would be the transmission through the two slabs of a perpendicularly incident beam of scattering particles? Assume x_1 is thickness of medium 1 and x_2 is thickness of medium 2.

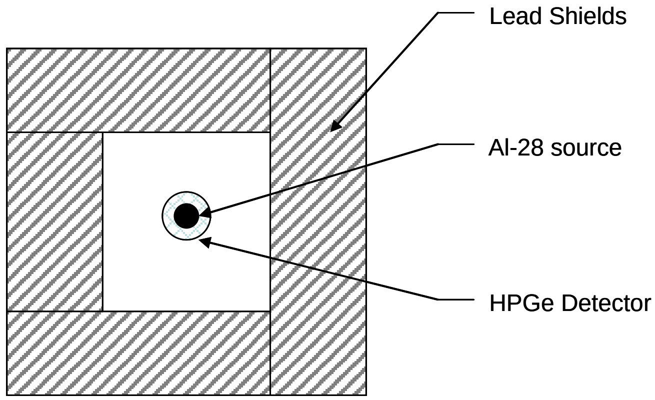
In both cases, quantitatively express the assumptions you are making.

3. (20 minutes) One hundred milligrams of pure cobalt is irradiated for one hour at the NSC reactor. The 2200 m/s neutron fluence rate is 1E13 n/cm^2-s. There is also an epi-cad neutron fluence that is 3% of the 2200 m/s fluence. Using the cross sections shown in the chart of nuclides, calculate the activity of all isotopes 20 minutes after the end of the irradiation. Hint: If you make reasonable assumptions, this problem is easy. List these assumptions.



4. (15 minutes) A nuclide decays with a half-life of 2.0±0.1 hours. The initial activity is 10±0.5 mCi. Calculate the uncertainty in the predicted activity after 5 hours.

5. (15 minutes) For an intermediate-sized 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 ^{28}Al source sitting directly on the detector (^{28}Al emits a single 1778 keV photon per decay).



6. (15 minutes) Another type of proportional counter is widely used in a number of areas, including as reactor start-up instrumentation. In some cases, boron is used in the proportional counter either as a gas, $^{10}BF_3$, or coated onto the internal electrodes of the counter with the gas-filling being a standard counting gas. Another type proportional counter is commonly called a "fission counter," because the internal electrodes are coated with a thin layer of ^{235}U with the gas-filling being a standard counting gas. Discuss the advantages and disadvantages of these detectors for use in a thermal neutron environment. Include in your discussion the influence of other radiation types.

7. (10 min) Consider neutron, proton and α -particle beams. For each of these beams, which nuclides would you select as target materials for producing $^{24}_{11}Na$? To get credit, you must justify your answer.

8. (10 min) Consider a sample of radioactive material A. Material A decays to radioactive material B.

Derive an expression for the long-term concentrations of both materials if B is decaying significantly faster than A.

9. (15 min) One approach to measuring the fluence of fast neutrons is to use a hydrogenous moderator (and perhaps some other materials) surrounding a small thermal neutron detector.

a. Discuss the energy response of a thermal neutron detector located at the center of a spherical polyethylene moderator.
b. Describe design characteristics (physical shape, size, etc.) that might be used to give the detector a constant response per neutron per cm^2 over a wide range of neutron energies.