October 1992

Ph.D. Qualifying Examination
Interactions

1. (15 minutes) Describe the physical processes that take place when a scintillation detector (such as NaI) is used to acquire a gamma energy spectra. Start with the interaction (s) within the scintillator and continue to when a count is added to a channel on the MCA.

2. (15 minutes) ^{218}Po decays with a 3.05 minute half-life to ^{214}Pb which, in turn, has a half-life of 26.8 minutes. Starting with separated ^{218}Po containing 20 Po atoms for each Pb atom, how long will it take for equal numbers of atoms of Po and Pb to exist? At this time, what fraction of the original parent atoms will be Po and Pb (remember the Pb is decaying also)?

   The following formula may be useful:

$$N_2 = \frac{\lambda_1 N_1^0}{\lambda_2 - \lambda_1}\left(e^{-\lambda_1 t} - e^{-\lambda_2 t}\right)$$

3. (20 minutes) Some of the energy levels of a *hypothetical* one-electron atom are listed below:

n	1	2	3	4	5	∞
E (eV):	-15.60	-5.30	-3.08	-1.45	-0.80	0

   (a) (20%) What is the ionization potential of this atom?

   (b) (20%) What is the shortest wavelength of the series terminating on n=2?

   (c) (20%) What is the excitation potential to state n = 3?

   (d) (20%) What is the minimum energy that an electron will have after interacting with this atom in the ground state if the initial kinetic energy of the electron were 6 eV?

   (e) (20%) What is the minimum energy that an electron will have after interacting with this atom in the ground state if the initial kinetic energy of the electron were 11 eV?

   Note: $h = 6.63 \times 10^{-34}$ J s

4. (20 minutes) Consider the $^{7}_{3}Li(\gamma,n)$ reaction induced by a 10 MeV photon. Find the kinetic energies of the emitted neutron and the recoil nucleus. You may neglect the momentum of the photon. The mass of a neutron is 1.008665 amu.

Nuclide	Atomic Mass (amu)
^{6}Li	6.015122
^{7}Li	7.016003
^{8}Li	8.022486

5. (15 minutes) (75%) a) Compute the thermal neutron sensitivity factor (counts per second per unit thermal (Maxwellian) flux) for a counter having a sensitive volume of 58 cm^3 filled with 96% enriched BF_3 at a pressure of 12 cm of Hg. The 2200 m/s cross section for ^{10}B is 3838 barns.

(25%) b) What assumptions did you make?

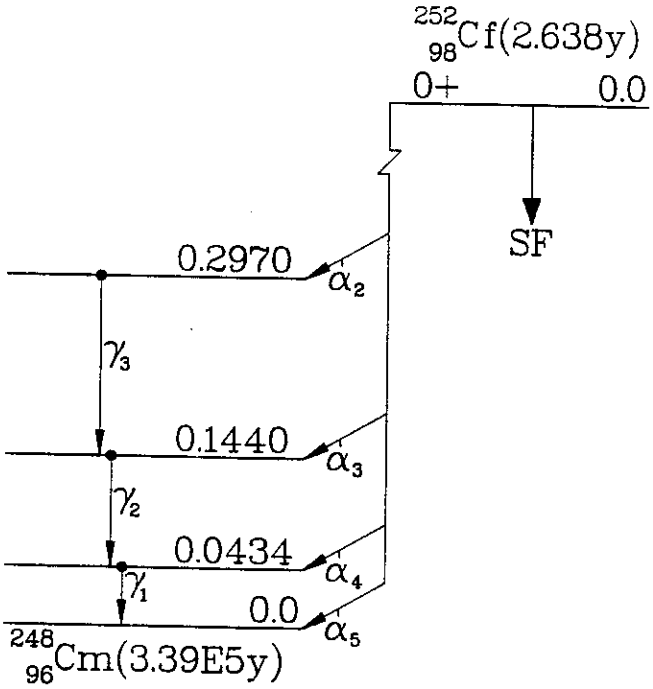
6. (15 minutes) Your Nuclear Engineering Department is purchasing a large Cf-252 sealed source (~50 mg). It is your job to design an adequate shield for storage in one of your laboratories. Discuss qualitatively the requirements for this shielding, i.e. materials appropriate to provide required protection from the Cf-252 emitted radiations, and your proposed arrangement of these shielding materials.

Possibly Helpful Information: See attached decay data.

7. (10 minutes) A 0.5 MeV neutron is absorbed by a $^{6}_{3}Li$ nucleus and causes an alpha particle to be ejected without any gamma radiation. Compute the center of mass kinetic energy of the alpha.

masses:

^{6}Li	6.01513
^{1}n	1.008665
^{3}H	3.01605
^{4}He	4.00260



98-CALIFORNIUM-252

HALFLIFE = 2.638 YEARS
DECAY MODE(S): SF, α

26-AUG-77

RADIATION	y(i) (Bq-s)$^{-1}$	E(i) (MeV)	y(i)×E(i)
SF n	1.15E-01	2.164E 00*	2.50E-01
SF f	6.18E-02	9.514E 01*	5.88E 00
SF p γ	2.67E-01	8.847E-01*	2.36E-01
SF d γ	2.51E-01	9.578E-01*	2.41E-01
SF β	1.92E-01	1.280E 00*	2.46E-01
α 3	2.32E-03	5.977E 00	1.39E-02
α recoil	2.32E-03	9.646E-02	2.24E-04
α 4	1.52E-01	6.076E 00	9.23E-01
α recoil	1.52E-01	9.806E-02	1.49E-02
α 5	8.15E-01	6.118E 00	4.99E 00
α recoil	8.15E-01	9.875E-02	8.05E-02
γ 1	1.48E-04	4.340E-02	6.43E-06
ce-L_1, γ 1	2.19E-03	1.894E-02	4.15E-05
ce-L_2, γ 1	5.87E-02	1.962E-02	1.15E-03
ce-L_3, γ 1	4.86E-02	2.447E-02	1.19E-03
ce-M, γ 1	3.07E-02	3.860E-02*	1.19E-03
ce-N^+, γ 1	1.21E-02	4.340E-02*	5.26E-04
γ 2	1.26E-04	1.002E-01	1.26E-05
ce-L_2, γ 2	1.02E-03	7.642E-02	7.79E-05
ce-L_3, γ 2	6.41E-04	8.127E-02	5.21E-05
ce-M, γ 2	4.85E-04	9.540E-02*	4.63E-05
ce-N^+, γ 2	1.91E-04	1.002E-01*	1.91E-05
γ 3	1.94E-05	1.600E-01	3.10E-06
Lα X-ray	2.39E-02	1.493E-02*	3.57E-04
Lβ X-ray	3.24E-02	1.922E-02*	6.22E-04
Lγ X-ray	7.56E-03	2.300E-02*	1.74E-04
Lη X-ray	6.73E-04	1.749E-02	1.18E-05
Lℓ X-ray	1.27E-03	1.264E-02	1.60E-05
Auger-LMM	2.49E-02	1.174E-02*	2.92E-04
Auger-LMX	1.77E-02	1.573E-02*	2.78E-04
Auger-LXY	2.96E-03	1.884E-02*	5.57E-05
Auger-MXY	1.49E-01	4.388E-03*	6.55E-04
ΔE	4.81E-02	1.007E-03*	4.84E-05

LISTED X, γ AND $\gamma\pm$ RADIATIONS	1.20E-03
OMITTED X, γ AND $\gamma\pm$ RADIATIONS**	3.74E-07
LISTED β, ce AND Auger RADIATIONS	5.62E-03
OMITTED β, ce AND Auger RADIATIONS**	1.07E-05
LISTED α AND α recoil RADIATIONS	6.02E 00
OMITTED α AND α recoil RADIATIONS**	1.18E-04
LISTED RADIATIONS	1.26E 01
OMITTED RADIATIONS**	1.29E-04

* AVERAGE ENERGY (MeV)
** EACH OMITTED TRANSITION CONTRIBUTES <0.100% TO Σy(i)×E(i) IN ITS CATEGORY.
SF YIELD IS 3.0920E-02.
CURIUM-248 DAUGHTER, YIELD 9.691E-01, IS RADIOACTIVE.