February 1992

Ph.D. Qualifying Examination
Interactions

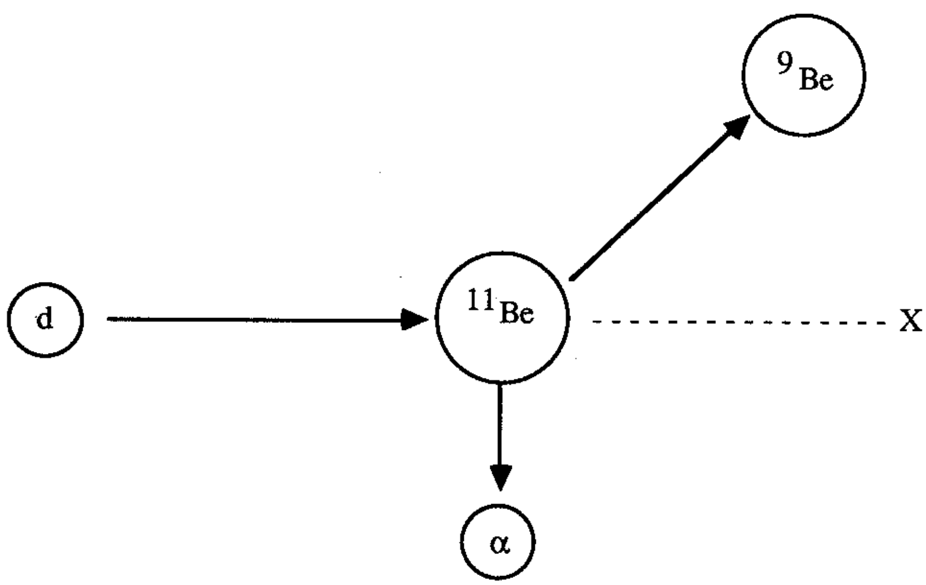
1. (20 min.) One of the reactions which occurs when boron is bombarded with 1.510 MeV deuterons is

$$^{11}B\ (d,\alpha)\ ^{9}Be$$

In the lab system the α-particles coming off at an angle of 90° with respect to the direction of the deuteron beam have a kinetic energy of 6.37 MeV. What is the Q-value of the reaction?

Useful data:

m_d = 2.0147361 amu
m_α = 4.0038727 amu
$m_{^9Be}$ = 9.015041 amu



2. (20 min.) Explain the process of beta decay, including both negative and positive decay (β^- and β^+):

a) Write generic equations to show the changes occurring in the nucleons during decay.

b) Sketch typical spectra of beta emitters in the two groups and explain the shapes of these curves.

c) Explain the production of annihilation radiation as it is related to the beta decay processes?

3. (20 min.) You have been assigned the task of determining the 2200 m/sec neutron flux in the thermal column at a research reactor facility. You have selected foil activation as the means to acquire this flux data. You have available a high-resolution gamma-ray spectrometer with a germanium detector.

Using any or all of the following information, calculate the 2200 m/sec neutron flux, explaining your procedures and **all assumptions made**:

Activation foil:	1% by weight cobalt in aluminum alloy
Foil mass:	0.900 grams
Foil dimensions:	1 cm. diameter, 0.05cm. thick
Atomic weights:	Co = 58.93 g/g. atom
	Al = 26.98 g/g. atom
Irradiation time:	14 hours
Decay time before counting:	18 hours after termination of irradiation
Detection efficiency:	0.015 net counts at 1.33 MeV per photon
Detector resolution:	1.8 KeV FWHM at 1.33 MeV
Gamma-ray spectrometer calibration:	1.01 KeV/channel
Spectrum region integrated:	channels 1025 through 1040
Net 1.33 MeV counts:	1095 counts per minute

Thermal neutron activation cross sections:

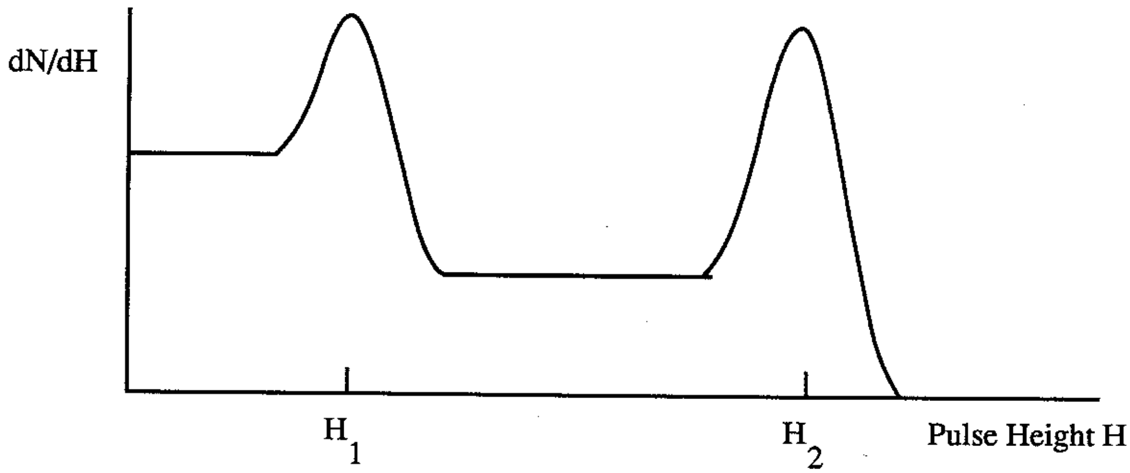
Al = 0.23 barn (production of 2.3 min. Al-28)
0.005 barn for Al-27 (n, α) Na-24

Co = 20 barns (production of 10.5 min. Co-60m)
17 barns (direct production of 5.3 yr. Co-60)
0.01 barn for Co-59 (n,2n) Co-58 reaction

4. (20 min.) You have studied several different "particles" arising from nuclear and atomic processes. Specifically, recall the characteristics of the interaction of electrons, neutrons, alphas, and gammas with matter. Very briefly describe how each of these is or is not of importance in the listed areas by filling in this table. One entry per box is sufficient:

	materials damage	**health hazards and/or medical uses**	**appropriate radiation detector**
α			
β			
γ			
n			

5. (10 min.) A scintillation counter operated at a given voltage produces a differential pulse height spectrum as sketched below:



(50%) a. Draw the corresponding integral pulse height spectrum.

(50%) b. Sketch the expected counting curve (counting rate versus applied voltage). This graph is obtained by varying the voltage to the detector while counting above a fixed pulse-height discriminator setting.

6. (10 min.) An air-equivalent pocket ionization chamber having a capacitance of 75 pF is initially charged to a voltage of 25 V. If the active volume contains 50 cm^3 of air at STP, what value of exposure (in mR) will reduce the voltage to 20 V?

Note that 1 C/kg of exposure is equal to 3876 R.

7. (20 min.) ^{140}Ba decays by beta emission to ^{140}La which, in turn, decays to stable ^{140}Ce. The half life of ^{140}Ba is 12.8 days; the half life of ^{140}La is, 40.2 hours. If 1 Ci of pure ^{140}Ba exists at time t=0, derive an expression and evaluate the maximum activity of ^{140}La, and the time this occurs.