GEORGIA INSTITUTE OF TECHNOLOGY

The George W. Woodruff School of Mechanical Engineering

NRE/HP Qualifier Exam

Fall Semester 2000

____________Your ID Code

Day 1 – NRE/HP Fundamentals

Instructions

1. Use a separate page for each answer sheet (no front to back answers).
2. The question number should be shown on each answer sheet.
3. Answer 4 of the 6 questions attached.
4. Staple your question sheet to your answer sheets and turn in.

1. Assume that a stable lithium-containing proportional gas has been identified. Sketch the differential pulse height spectrum that you could expect when thermal neutrons are incident on a detector filled with this gas if it is highly enriched in ^{6}Li and operating in the proportional region. Describe the features in this spectrum and their origin. If we used a standard proportional gas (e.g., P-10) and lined the inner walls of the detector with ^{6}Li. sketch the pulse height spectrum that you would expect from incident thermal neutrons.

m_n = 1.00866491 amu

m_α = 4.001474918 amu

$m_{^6Li}$ = 6.015122 amu

$m_{^7Li}$ = 7.016003 amu

$m_{^3H}$ = 3.01605 amu

$m_{^2H}$ = 2.0141078 amu

2. a. A radioisotope source is known not to emit any gamma ray with energy of 511 keV, but a peak is observed at this energy in the recorded pulse height spectrum. Give two possible origins of this peak. Note, the presence of a second source will not be considered a legitimate reason.

   b. Listed below are a number of parameters of interest in gamma-ray spectroscopy using scintillation detectors:

      i. Density of detector medium.
      ii. Average kinetic energy required to create a scintillation photon in the crystal.
      iii. Average atomic number (Z-value) of detector medium.
      iv. Geometry of source-detector system.
      v. Gain of photomultiplier tube.
      vi. Quantum efficiency of photocathode in the PMT.
      vii. Gain of amplifier used between the detector and multichannel analyzer.
      viii. Fraction of light generated in crystal that reaches the photocathode of the PMT (light collection efficiency).

      Identify those parameters from this list that have a major influence on the detector intrinsic peak efficiency. Repeat, but now identify those that have a major influence on energy resolution.

3. A ten-minute measurement of a source yields 15,346 counts. Exactly 4 days later a twenty-minute measurement yields 14,879 counts. Associated background measurements yield 392 and 411 counts, respectively, over thirty minutes. Based on this data, determine the half-life of the isotope. Also, determine the uncertainty of this half-life due to counting statistics.

4. In the following scenarios of elastic scattering between monoenergetic neutrons and various types of nuclei: (a) *1-keV* neutrons interacting with ^{1}H nuclei, (b) *1-keV* neutrons interacting with ^{12}C nuclei, (c) *10-MeV* neutrons interacting with ^{12}C nuclei, and (d) *10-MeV* neutrons interacting with ^{238}U nuclei.

   (8) a. Which scenario produces a scattered neutron that is most isotropic in the center-of-mass system? Apply partial-wave analysis for each scenario to justify your answer. Note that the radius of a nucleus can be estimated by $1.2 \times A^{1/3}$ *fm*.

   (2) b. Which scenario produces a scattered neutron that is most isotropic in the laboratory system? Why?

5. a. Use the following Compton-scattering formula (simplified from the Klein-Nishina formula) to calculate the mass attenuation coefficient (μ/ρ) for 1-MeV photon interacting with aluminum ($A=27$, $Z=13$, and $\rho=2.7\ g\ cm^{-3}$):

$$\left(\frac{d\sigma}{d\Omega}\right)_{e^-} = \frac{r_e^2}{2}(1+\cos\theta)$$

where r_e = the classical electron radius = $2.818 \times 10^{-13}\ cm$, and θ is the scattering angle.

b. Calculate the average energy of a scattered electron.

6. In the reaction $\alpha+{}^{9}Be\rightarrow{}^{12}C+n$, find the maximum and minimum neutron energies when the incident a energy is *5.0 MeV*. The rest mass for neutron is *1.008665 u*, where *1 u = 931.5 MeV*. The atomic masses for α, ^{9}Be, and ^{12}C are *4.002603 u*, *9.012182 u*, and *12.00000 u*, respectively.