1. As part of a recent search for neutron-gamma correlations the front face of an intrinsic germanium detector with a radius of 5 cm and a volume of 750 cm^3 was placed 12 cm from a neutron source. During this experiment the source emitted neutrons at an average rate of 200,000/s and the experiment was carried out continuously for four days.

   (a) (5 points) What is the probability that an incident neutron will undergo a scattering reaction in the detector if the average cross section for (n,n') scattering is 4 barns?

   (b) (5 points) What is the activity due to the neutron capture product in Bq at the end of the irradiation if the important neutron capture nucleus is ^{74}Ge with an abundance of 38% and has a cross section of 1 barn? Note that the half-life of the product (^{75}Ge) is 83 min. (Assuming that the incident neutrons are thermalized.)

   (c) (5 points) The neutrons were identified by their time of flight to a plastic scintillator (BC400, effectively CH_2) placed 100 cm from the source that was 2.54cm thick. Estimate the intrinsic efficiency of this detector for 1.00 MeV neutrons. Indicate sources of any necessary data.

2. (10 points) An Am(Be) source is available at the NSCL to provide neutrons for detector calibration. This source is an alloy of ^{241}Am (dissolved) in beryllium metal. The neutrons are produced by the (α,n) reaction on ^{9}Be and the neutrons emerge with a distribution of energies. Calculate the maximum neutron kinetic energy for this source. Indicate any sources of necessary data.

3. In a certain experiment the photopeak efficiency of the symmetrical arrangement of twelve detectors from the SeGA (intrinsic germanium detector) array was 2.0% at 1 MeV and the total efficiency was 10.0%.

   (a) (5 points) One goal of the experiment was to measure gamma-gamma coincidences from ^{26}Ne. Assuming that ^{26}Ne emits two gamma rays in cascade (every decay) with energies of approximately 1 MeV, what is the probability that the full-energy photopeak of the second gamma ray will be observed by the array in coincidence with the first one? Ignore summing losses.

   (b) (5 points) What is the counting rate of the full energy peak using the whole array for one of the gamma rays from ^{26}Ne if the emission rate is 100/s but the total rate of gamma ray emission from all reaction products is 5000/s? The typical resolving time of the array is 500 ns at 1 MeV.

   (c) (10 points) The newest graduate student working on the experiment suggests recording all of the gamma-ray signals (5000/s) but student in charge demurs saying "We never do that." Estimate the electronic deadtime for recording all of the gamma-ray events (the so called single-coincidences) if the pulse heights are recorded in twelve individual 400MHz Wilkinson 13 bit ADC's and the data-acquisition system requires 3 μs/word reading two words (E,T) for each gamma ray detector.

   (d) (5 points) Cross-talk between the gamma-ray detectors in the close geometry of this experiment can be very significant. What is the source of cross-talk and what are the most likely energies of the signals in the two detectors that are "cross-talking?"

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4. A CsI(Tl) detector is mounted on an ETL-9266 photomultiplier tube (operated at its nominal voltage). The PMT is connected to a $10^5\Omega$ load resistor and is operated with positive high voltage, AC-coupled through 100 pF. Assume complete light collection.

   (a) (10 points) Estimate the size (10 points) of the signal for a 1 MeV gamma ray that is completely stopped in the CsI(Tl) detector. Indicate any sources of necessary data.

   (b) (10 points) Estimate the resolution of the signal for a 1 MeV gamma ray that is completely stopped in the CsI(Tl) detector. Indicate any sources of necessary data.

5. The A1900 group has considered placing a standard setup consisting of a position-sensitive PPAC and a silicon PIN detector at the end of each beam line at the NSCL before each experimental apparatus. The purpose of the detectors is to provide a unique identification of each projectile fragment that is delivered to the experiments.

   The PPAC has an active area of 10cm x 10cm, a sensitive gas thickness of 3mm and is filled with isooctane (2,2,4-trimethylpentane, C_8H_{18}) gas at a pressure of 5 Torr at 300 K. Assume that the W of isooctane is the same as that of methane. The electric potential applied across the sensitive thickness is 600 V.

   The silicon detector has an area of 5cm x 5cm and is 0.5mm thick, it is connected by a lossless cable to a charge sensitive preamplifier that is set to "1 GeV full-scale." The preamp is connected by a 100 m RG 58C/U cable to a shaping amplifier (CR-$(RC)^3$).

   (a) (5 points) What is the gain of the silicon preamp in the more conventional units of mV/pC if the maximum output signal size is 1 V?

   (b) (5 points) Estimate the signal/noise ratio of the preamp signal when a $^{44}S^{16+}$ ion at 90 MeV/A passes through the silicon if the preamp noise is 30,000 electrons FWHM (approximately 5 fC). Indicate any sources of necessary data. Hint: use your favorite energy-loss program to get ΔE.

   (c) (5 points) The major contaminant in this secondary beam is $^{45}Cl^{17+}$. The ions delivered by the A1900 have the same magnetic rigidity, so that m v/q = constant. In this case, 45 v(Cl)/17 = 44 v(S)/16. Estimate the ratio of the separation in pulse heights of these two ions to value of the preamp noise. (I.e., will the two signals be resolved?)

   (d) (5 points) Estimate the value of the gain of the shaping amplifier necessary to give a 5.0 V output pulse when the $^{44}S^{16+}$ ion at 90 MeV/A passes through the silicon. Include cable attenuation after the preamp in the estimate and indicate any sources of necessary data.

   (e) (10 points) The PPAC is readout using charge division on a linear resistor chain consisting of eighty 100 Ω resistors. Estimate the gas-gain of the PPAC if a 5 mV signal is generated across 50Ω load resistors at both ends of the resistor chain when a $^{44}S^{16+}$ ion at 90 MeV/A passes through the center of the PPAC and deposits 0.2 MeV. Assume that electronics is "slow" and integrates the full charge from the detector. Indicate any sources of necessary data.

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