LAB 3: Neutron activation

The purpose of this experiment is to measure the half-lives of short-lived radionuclides created by neutron activation. The neutron source (located in the basement of Meyer Hall – activity = a few Ci!) is an alloy of Pu and Be. ^{239}Pu is an alpha emitter (that represents most of the activity of the source). The neutrons are produced, when the alphas emitted from ^{239}Pu interact with the ^{9}Be in the alloy through the nuclear reaction ^{9}Be(α,n)^{8}Be. The activation (done in the basement vault) consists in placing blocks of Aluminum immediately near the source. The neutrons emitted from the source in turns produce short-lived radionuclides in the Aluminum block through the reactions ^{27}Al(n,γ)^{28}Al, ^{27}Al(n,p)^{27}Mg and ^{27}Al(n,α)^{24}Na. Since the half-lives of the ^{28}Al and ^{27}Mg are relatively short, the samples are irradiated the morning of your lab. Once you are ready to take data, the samples will be brought to your experimental station.

Measurements:

1. Set up the NaI detector on the rail and the source holder a few cm away from the face of the detector.
2. Make sure the NIM crate power is off and the HV supply switch is OFF and both voltage knobs are set to ZERO. Connect PMT to HV power supply (use a SHV cable) and the PMT anode or dynode output directly to the oscilloscope. Obtain the ^{137}Cs source from the instructor or one of the TAs. Turn on HV to 200V, find the source signal on the oscilloscope.
3. Increase HV (by step of 100V) until the anode signal reaches a max amplitude (photopeak signal) of about 300-400mV. Connect the anode/dynode output to the amplifier input and the amplifier output to oscilloscope. The polarity of the output signal needs to be positive. Adjust the amplifier setting accordingly. The final HV setting should not be greater than about 400 V
4. Set the amplifier gain, so that the amplitude of the photopeak signal from ^{137}Cs source is about 1.5V. Once done, connect the amplifier output to the Multi-Channel Analyzer (MCA). Start Maestro and acquire a sample energy spectrum.
5. Locate the 662keV photopeak. Make sure that you will be able to see up to 3MeV γ-rays within the MCA scale.
6. Take a ^{137}Cs energy spectrum, determine the centroid of the peak. Obtain the ^{60}Co source from the instructor or one of the TAs. Take a ^{60}Co energy spectrum, determine the centroid of the 1173keV and 1332keV photopeak.
7. Take a background energy spectrum, identify the ^{40}K decay γ-ray photopeak (1461keV) and the ^{232}Th peak at 2614 keV.
8. From the 662 keV, 1173 keV, 1332 keV, 1461 keV and 2614 keVgamma rays determine the energy calibration of the spectrum (Energy vs. channel).

9. Use the energy calibration to determine the channels where you expect to see the γ-rays from the decay of the short-lived radionuclides ^{28}Al (1779 keV), ^{27}Mg (843 keV and 1014 keV) Set MCA ROI's (regions of interest) around these channels.
10. After the instructor retrieves the first activated Al sample from the ground floor radiation vault, place the sample in front of detector and count from 5 minutes to check expected γ-rays. Refine your MCA regions of interests, so that they bracket well the peaks of interest.

<u>THE FOLLOWING STEPS ARE CRITICAL FOR THE SUCCESS OF YOUR LAB!</u>

You will now measure the evolution of the number of counts (net area) of the peaks as a function of time. To do this, you have to be ready to take data as soon as the sample is provided to you. You need to keep track of the time starting from when the sample is given to you (t=0). At first, you will measure the decay of ^{28}Al and ^{27}Mg.

11. Preset the data acquisition to 100s live time. Have a chronometer take an independent measurement of the time. You will take 100s measurements, then you'll have 20s to save the date file, clear the spectrum and be ready to take the next data set. You will repeat this 10 times.
12. Once ready, the instructor will retrieve the second activated Al sample and place it in front of detector. Start your chronometer and start the first 50s measurement. At the end of the measurement wait until the chronometer indicates 60s before starting the new measurement. Repeat 45 times. Note that after about 5 count cycles, the yield of the 1779 keV γ ray from the ^{28}Al should be reduced to just background. Note that you can reopen the saved files in Maestro and run the peak analysis on the various photopeaks.

Plots to be provided at the end of the lab (these plots should also appear in your final report possibly associated with further analysis):

1. STEP 6 and 7: individual MCA spectra of ^{137}Cs, ^{60}Co sources and background.
2. STEP 8: Plot of the linear relationship between Energy and Channels (E = a . Channel + b) using the identified γ-rays. Perform a linear fit and extract a and b with their associated errors.
3. STEP 10: Energy spectrum obtained for the first neutron-activated Aluminum sample. Identify all the γ-rays observed.
4. STEP 11 & 12: Counts vs time for 1779 keV gamma ray from ^{28}Al and the 843 keV and 1014 keV γ's from the ^{27}Mg.

Calculations in lab report

1. Determine the half-lives $T_{1/2}$ of the γ-rays from the short-lived radionuclides ^{28}Al (1779 keV), ^{27}Mg (843 keV and 1014 keV) by fitting the data collected with the radioactive decay law. Do not forget to state the error on your measurements.
2. Compare with accepted experimental values available at: http://www.nndc.bnl.gov/nudat2/ (Click of the nuclei of interest – look at $T_{1/2}$ data). Conclusions?