ORTEC®

AN34 Experiment 11

The Proportional Counter and Low-Energy X-Ray Measurements

EQUIPMENT NEEDED FROM ORTEC

- 4001A/4002D NIM Bin and Power Supply
- 855 Amplifier
- 556 High Voltage Power Supply
- 142PC Preamplifier
- TRUMP-2K-32 MCA System including suitable PC
- C-36-12 Cable
- C-36-2 Cable
- C-24-12 Cable (3 ea.)
- C-29 BNC Tee Connector
- Am-1C ^{241}AM, 0.1 µCi Source (Optional for Exp. 11.1, Exercise b)

OTHER EQUIPMENT NEEDED

- Aluminum Foil Absorber, 2 x 2-in. x 5 mg/cm^2 (12 ea.)
- Nickel Foil Absorber, 2 x 2-in. x 5 mg/cm^2 (12 ea.)
- Multiple Metal Foil Kit containing 3 ea. of the following: Al, Fe, Cu, Mo, Sn, Ta, and Pb. Thicknesses range from 400 mg/cm^2 to 1500 mg/cm^2.
- Proportional Counter Vacuum Chamber; vacuum chamber 8-in. diameter x 3-in deep. Should have four sample positions which can be indexed under vacuum.
- Sealed X-Ray Sources (disk type) 1–5 µCi, ^{57}Co, ^{55}Fe, ^{65}Zn (substitute alternate sources with similar energies).
- Thin-Window Proportional Counter
- Oscilloscope

Purpose

In this experiment, the technique for operating a thin-window proportional counter is demonstrated, and some typical spectra are obtained.

CAUTION: The thin beryllium window built into these proportional counters is very fragile. DO NOT allow any material to contact the window and DO NOT TOUCH IT.

Introduction

As discussed in Experiments 3 and 7, the photoelectric interaction is the most pronounced type of gamma interaction for gamma energies below 100 keV. This experiment utilizes the proportional counter to detect x-ray energies below 50 keV.

The typical proportional counter is basically a metal cylinder with a concentric electrode located along the center of its longitudinal axis. The tube is filled with a counting gas mixture (e.g., 760 Torr of Xe-CH_4), and a positive high voltage of ~2000 V is applied to the central electrode. A thin beryllium window is built into the cylinder wall or its end to allow low-energy x-rays to enter into the counting region with minimum absorption. Beryllium is used because it has a Z value (atomic number) of only 4, and the photoelectric cross section varies as Z^5 (as discussed in Experiments 3 and 7). When the x-rays enter the tube, they make photoelectric interactions in the counting gas, and the pulse that is detected is proportional to the recoil electron energy. Proportional counters are typically ~10% efficient for 5-keV x-rays, and resolutions of around 1.5 keV for 20-keV x-rays are common with these devices.

Table 11.1. Low-Energy X-Ray Calibration Sources Recommended (~1 µCi).

Isotope	X-Ray Energy (keV)
^{54}Mn	5.414 Kα 5.946 Kβ
^{57}Co	6.40 Kα 7.06 Kβ 14.41 γ
^{65}Zn	8.04 Kα 8.90 Kβ
^{85}Sr	13.38 Kα 15.00 Kβ
^{88}Y	14.12 Kα 15.85 Kβ
^{109}Cd	22.10 Kα 25.00 Kβ
^{113}Sn	24.14 Kα 27.40 Kβ
^{137}Cs	32.1 Kα 36.6 Kβ

EXPERIMENT 11.1
Energy Calibration

Procedure

1. Connect the instruments as shown in Fig. 11.1, being careful to prevent touching the Be window on the proportional counter. Set the high voltage at the level recommended for the counter tube, and set the 855 Amplifier for a Positive input. Place the ^{137}Cs source at a distance of ~1 cm from the proportional counter window.

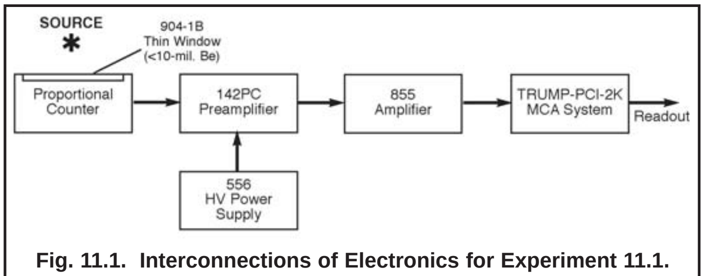

Fig. 11.1. Interconnections of Electronics for Experiment 11.1.

2. Adjust the 855 gain so that the 32.1 keV x-ray is being stored in the middle channels of the 1024-channel range of the MCA. Accumulate for a period of time long enough to determine the channel at which the centroid is being stored. Read out the data and clear the MCA to zero.

3. Replace the ^{137}Cs with ^{57}Co and acquire a spectrum long enough to accurately determine the locations of the 6.4 and 14.4 keV peaks. Read out the data, clear the MCA, and repeat with ^{65}Zn. For reference, Fig. 11.2 is a typical ^{57}Co spectrum.

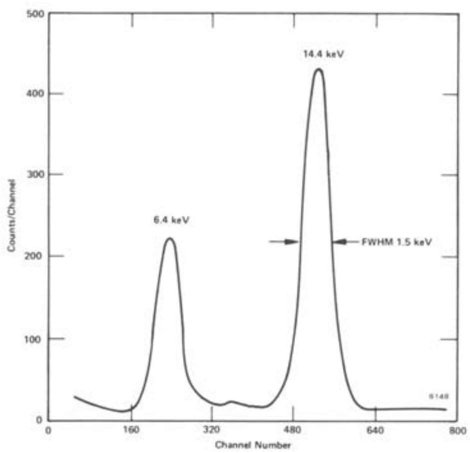

Fig. 11.2. ^{57}**Co Spectrum (Proportional Counter).**

EXERCISES

a. Plot a calibration curve for the data and determine the slope in keV/channel. Measure the resolution (FWHM in keV) of all the peaks and make a plot of resolution vs. energy.

b. (Optional). Place a ^{241}Am source in front of the detector and acquire a spectrum for enough time to determine the locations of the most pronounced peaks. From the calibration curve, determine the energy of each peak. Fig. 11.3 is a typical ^{241}Am x-ray spectrum made with a xenon-filled proportional counter.

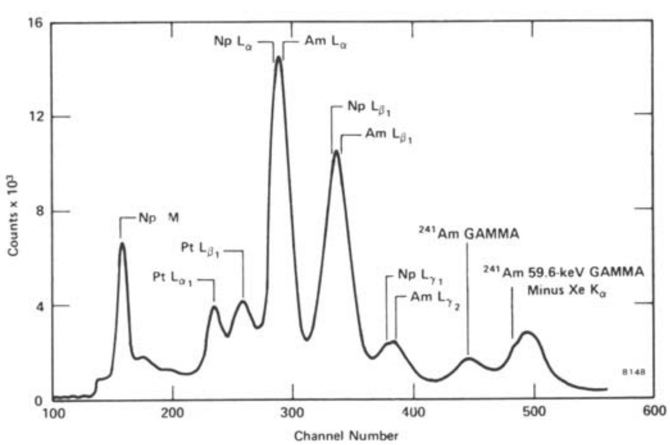

Fig. 11.3. ^{241}**Am Spectrum Using Xenon-Filled Proportional Counter.**

c. Obtain an unknown x-ray source from the instructor. Acquire its spectrum and determine its identification from the tabulation in ref. 6.

EXPERIMENT 11.2
Mass Absorption Coefficient for Low-Energy X-Rays

In Experiment 3.7, the mass absorption coefficient was measured for 0.662 MeV gammas from ^{137}Cs. In this experiment, these same measurements will be repeated for the 8.05 keV x-rays from ^{65}Zn. The procedure will be similar, but the source and absorber thicknesses will differ.

Procedure

1. Connect the instruments as shown in Fig. 11.4. Place the ^{65}Zn source ~2 cm from the proportional counter window. During the experiment, absorbers will be placed between the source and detector as shown in Fig. 11.4. Adjust the 855 Amplifier gain so that the 8.05 keV peak from the source has an amplitude of ~6 V at the amplifier output.

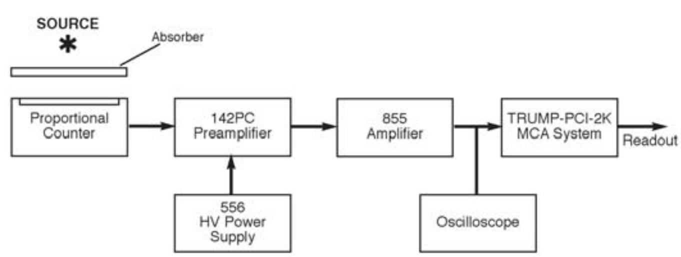

Fig. 11.4. Electronics Interconnections for Experiment 11.2.

2. Acquire a spectrum in the MCA long enough to identify the peak location. Adjust the Region of Interest (ROI) controls of the MCA to select the channels that make up the peak for the 8.05 keV line from the ^{65}Zn source.

3. When the ROI is set properly, stop the acquisition and clear the MCA. From the analyzer data, determine the number of Zn K α x-rays detected per second. From this point on, record only the integrated total number of counts in the peak.

4. Set the MCA to operate for a preset time interval long enough to obtain reasonable statistics. Clear it after each run, and then acquire for the preset live time for each set of data. After the initial acquisition interval, record the integrated count total for zero absorber thickness in Table 11.2.

5. Place the first 5-mg/cm^2 aluminum foil absorber between the source and the detector and acquire for the preset time. Continue and repeat for each of the aluminum and nickel thickness indicated in Table 11.2.

Table 11.2.		
Absorber Thickness (mg/cm²)	Counts with Aluminum Absorber	Counts with Nickel Absorber
0		
5		
10		
15		
20		
25		
30		
35		
40		
45		
50		
55		
60		

EXERCISES

a. Make a plot on semilog paper of counts vs. absorber thickness (mg/cm²) for both aluminum and nickel. Figs. 11.5 and 11.6 show some typical data taken under conditions similar to those described.

b. From your plots and the discussion in Experiment 3, determine the half-value thicknesses and the mass attenuation coefficients.

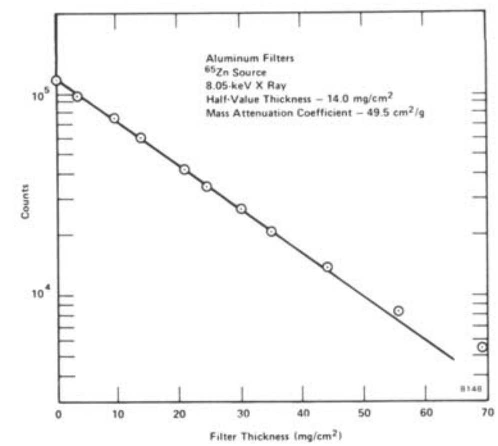

Fig. 11.5. Counts vs. Aluminum Absorber Thickness for ^{65}Zn X-Rays.

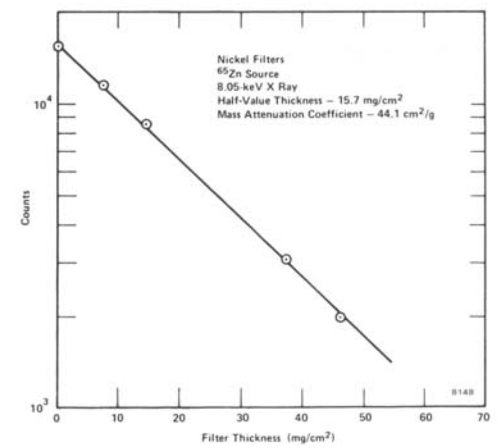

Fig. 11.6. Counts vs. Nickel Absorber Thickness for ^{65}Zn X-Rays.

References

1. G. F. Knoll,Radiation Detection and Measurement, John Wiley and Sons, Inc., New York (1979).

2. R. W. Hendriks, Nucl. Instrum. Methods 102, 309 (1972).

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6. C. M. Lederer and V. S. Shirley, Eds., Table of Isotopes, 7th Edition, John Wiley and Sons, Inc., New York (1978).

7. C. E. Crouthamel, Applied Gamma-Ray Spectrometry, Pergammon, New York (1960).