EXPERIMENT 11

The Proportional Counter and Low-Energy X-Ray Measurements

EQUIPMENT NEEDED FROM EG&G ORTEC

Low-energy x-ray calibration sources SK-1X (see Table 11.1)
Bin and Power Supply
904-1B Thin-Window Proportional Counter
556 High Voltage Power Supply
142PC Preamplifier
575A Amplifier
ACE-2K MCA System including suitable IBM PC (other EG&G ORTEC MCAs may be used)
12 AlFl-2 aluminum and 12 NiFl-1 nickel absorbers (see Appendix)
Absorber Kit 3-Z2
310 Special Chamber, designed for source, absorbers, and proportional counter geometry
Oscilloscope
ORC-11 Cable Set
Optional ^{241}Am 0.1 μCi for Experiment 11.1, Exercise b

Purpose

The technique for operating a thin-window proportional counter is demonstrated in this experiment, and some typical spectra are obtained with this instrument.

CAUTION: The thin beryllium window that is typically built into these proportional counters is very fragile. Do not permit any material to contact the window and do not touch it.

Introduction

The photoelectric interaction is the most pronounced type of gamma interaction for gamma energies below 100 keV, as discussed in Experiments 3 and 7. In this experiment the proportional counter will be used to detect x-ray energies below 50 keV.

The typical proportional counter is basically a metal cylinder that has a concentric electrode in the center of the cylinder. 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 end to permit the low-energy x rays to enter into the counting region with a 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 normally ~10% efficient for 5-keV x rays, and resolutions around 1.5 keV are common with these devices for 20-keV x rays.

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

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

EXPERIMENT 11.1

Energy Calibration

Procedure

1. Connect the instruments as shown in Fig. 11.1. Be careful to prevent touching the beryllium window on the proportional counter. Set the high voltage at the level recommended for the counter tube. Set the 575A Amplifier for a positive input. Place the ^{137}Cs source at a distance of ~1 cm from the window of the proportional counter.

2. Adjust the gain of the 575A Amplifier so that the 32.1-keV x ray is being stored in the middle channels of the 1024-channel range in the analyzer. Accumulate for a period of time long enough to determine the channel at which the centroid is being stored. Read out the data from the MCA and clear its memory to zero.

3. Replace the ^{137}Cs source with ^{57}Co and accumulate for a

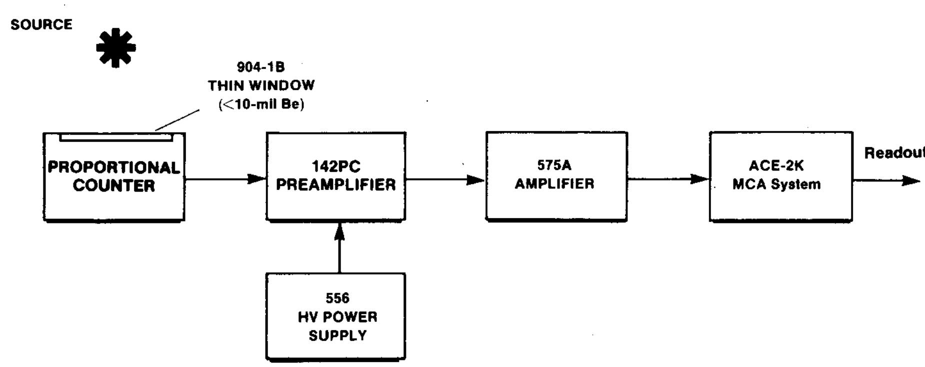

Fig. 11.1. Interconnections of Electronics for Experiment 11.1.

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

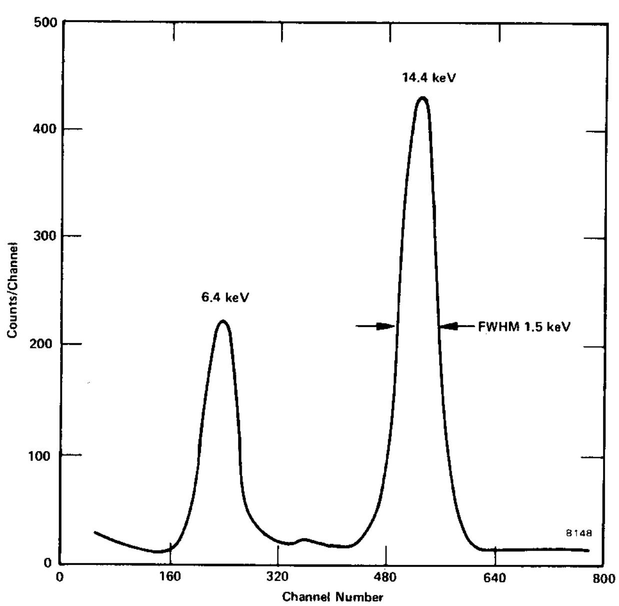

Fig. 11.2. ^{57}Co Spectrum (Proportional Counter).

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 accumulate for a period of time long enough to determine the locations of the most pronounced peaks. From the calibration curve, determine the energy of each peak. Figure 11.3 is a typical ^{241}Am x-ray spectrum that was made with a xenon-filled proportional counter.

c. Obtain an unknown x-ray source from the instructor. Accumulate its spectrum and determine what it is from the tabulation in ref. 6.

EXPERIMENT 11.2

Mass Absorption Coefficient for Low-Energy X Rays

The mass absorption coefficient was measured for 0.662-MeV gammas from ^{137}Cs in Experiment 3.7. These same measurements will be repeated in this experiment 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 window of the proportional counter. During the experiment, absorbers will be placed between the source and the detector as shown in Fig. 11.4. Adjust the gain of the 575A Amplifier so that the 8.05-keV peak from the ^{65}Zn has an amplitude of ~6 V at the amplifier output.

2. Accumulate a spectrum in the MCA for a period of time 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 accumulation 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 that is long enough to obtain reasonable statistics. Clear it after each run, and then accumulate for the preset live time for each set of data. After the initial accumulation interval,

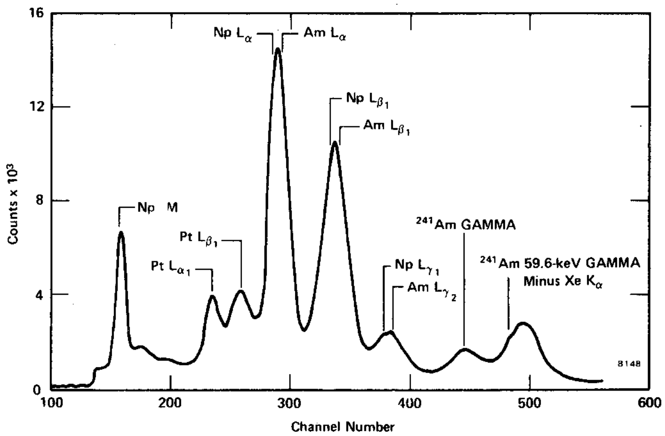

Fig. 11.3. ^{241}Am Spectrum Using Xenon-Filled Proportional Counter.

Table 11.2

Absorber Thickness (mg/cm^2)	Counts with Aluminum Absorber	Counts with Nickel Absorber
0		
5		
10		
15		
20		
25		
30		
35		
40		
45		
50		
55		
60		

record the integrated count total for zero absorber thickness in Table 11.2.

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

EXERCISES

a. Make a plot on semilog paper of counts vs absorber thickness (mg/cm^2) for both aluminum and nickel. Figures 11.5 and 11.6 show some typical data that were 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.

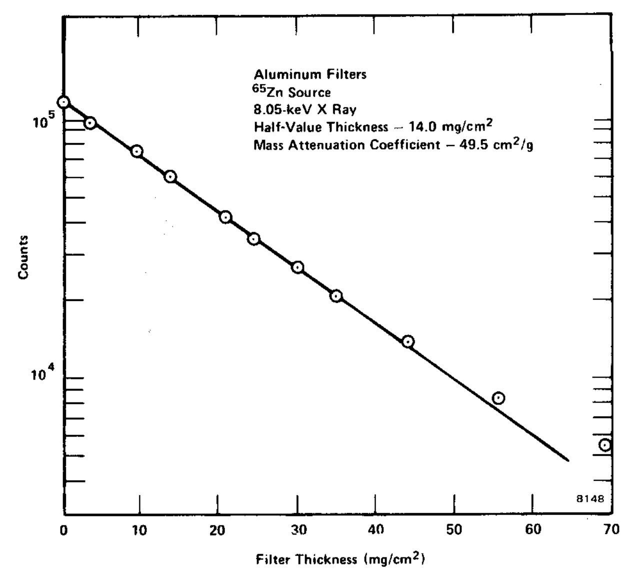

Fig. 11.5. Counts vs Aluminum Absorber Thickness for ^{65}Zn X Rays.

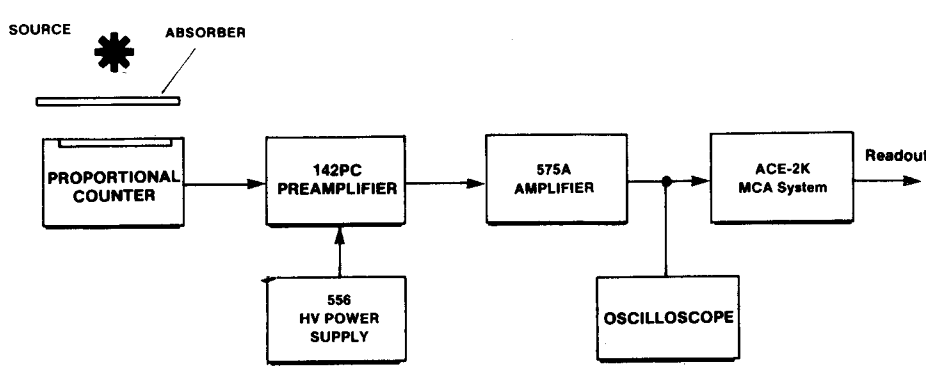

Fig. 11.4. Electronics Interconnections for Experiment 11.2.

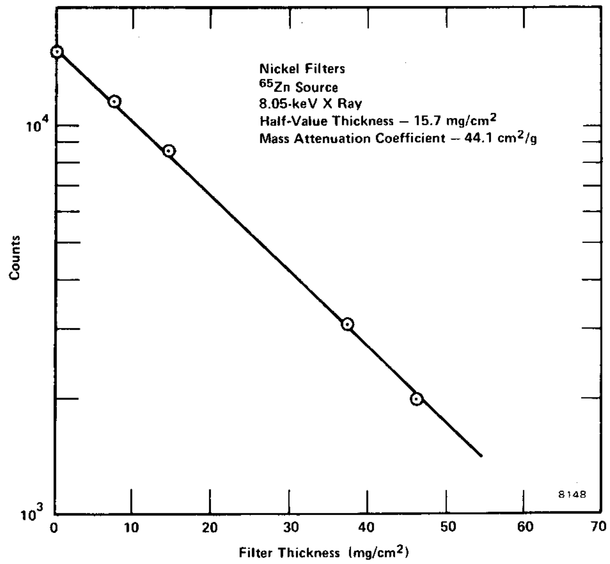

Fig. 11.6. Counts vs Nickel Absorber Thickness for ^{65}Zn X Rays.

References

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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).

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