

PHGN 326

Experiment 5:

Alpha – gamma coincidences

PURPOSE

The purpose of this experiment is to familiarize you with the use of coincidence and timing electronics. In many radioactive decays a primary alpha or beta decay does not go to the ground state of the daughter nucleus but to an excited state. This excited state decays following the radioactive decay law with a half life normally in the pico- or femtoseconds. Nevertheless, there are cases with considerably longer half lives. We will investigate with this experiment the half-life of the decay of the 59 keV excited state in 237-Np. This state is populated via the alpha decay of 241-Am (giving us our start signal for the time measurement) and decays with a low energy gamma ray emission (providing the stop signal) with a half life of app. 70 ns. Decay schemes are attached.

Equipment

Semiconductor charged-particle detectors have been used extensively in experimental nuclear research since the 1960's. These detectors can be used through an extensive range of energies. These include 20-keV electrons on one end of the spectrum and 200-MeV heavy ions on the other. The inherent resolution of these surface-barrier detectors is surpassed only by magnetic spectrometers. The detector output pulses rise rapidly and hence are well suited for fast (~ 1 ns) timing with coincidence circuitry or time-to-pulse-height converters. For further general information see the handout on solid-state detectors.
For the detection of the low energy gamma ray we will use a scintillation counter with a relatively thin scintillation crystal, which optimizes it for low energy radiation. See also here the general handout on scintillation detectors.

ALPHA SOURCES

Caution! Alpha sources offer a potential personal contamination problem. Never touch the face of a source with your fingers. Always handle an alpha source by the edge of the mounting disk under the supervision of the instructor.

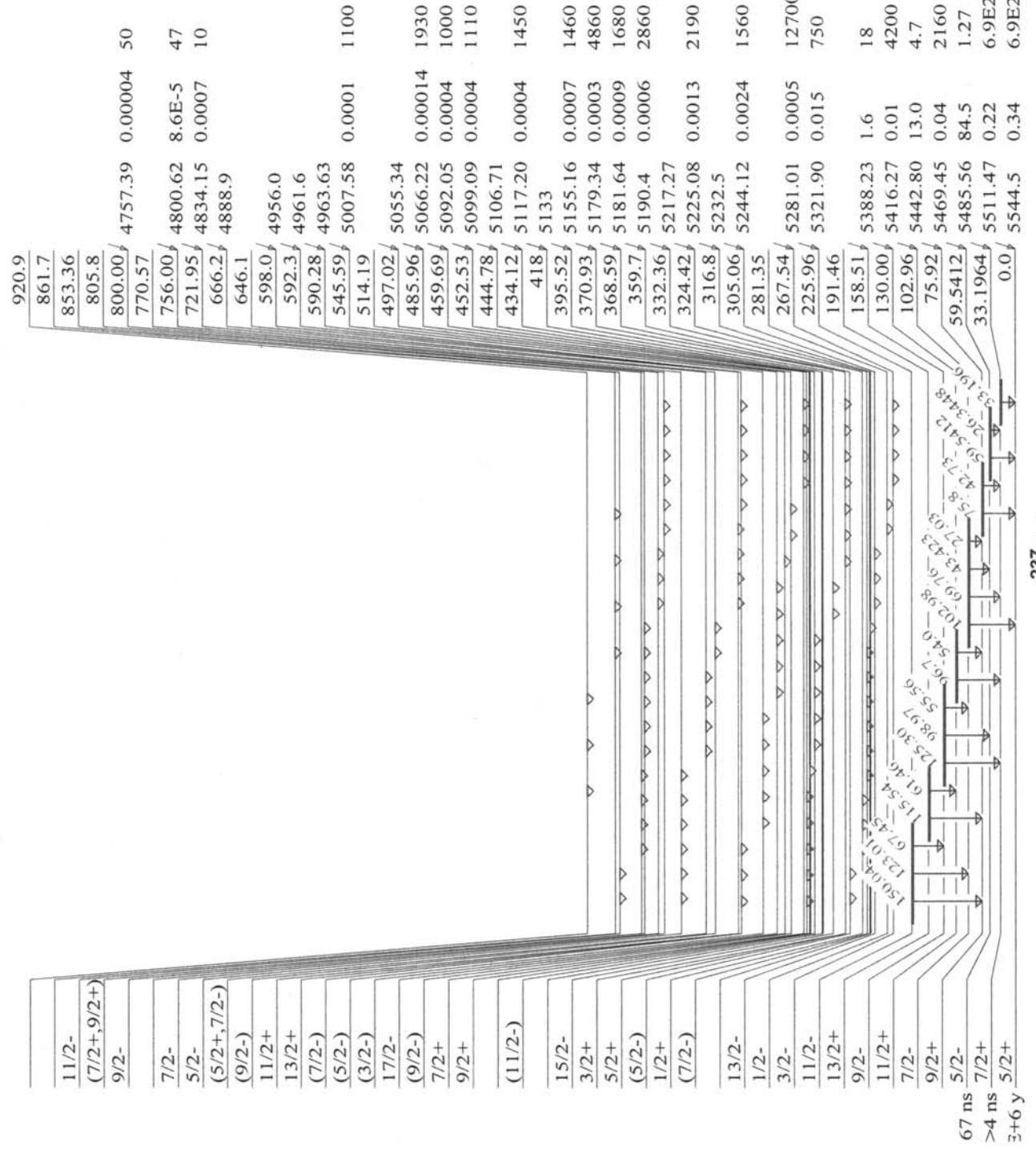
Procedure

1. Build a vacuum system (using one aluminum cube) with a port for a semiconductor detector on one end and a port for a radioactive alpha source on the other. Connect this cube to the existing pumping system.
2. The semiconductor detector is mounted on a special extension to bring it near to the alpha source position on the other side in vacuum.
3. The 241-Am source is mounted with a special flange that has an outside port for the low-energy-gamma detector. This detector has a relatively small crystal optimized for the app. 60 keV gamma rays we encounter in this experiment.
4. Close and evacuate system with roughing pump (to about 10 mTorr).
5. Connect: preamplifier to semiconductor detector feed-through; preamp output T (this is the output for good timing resolution, compared to output E for good energy resolution) to oscilloscope; preamp power to the outlet at the back of the amplifier. Power up the NIM bin. Connect the high voltage cable to the NIM HV power supply. Monitor the electronic noise level of the amplifier signal on the oscilloscope while you slowly turn the voltage up to +40 V. Describe what you see. Describe and sketch the signal you see on the oscilloscope. Risetime, falltime, noise.
6. In order to shape and amplify the signals further for our data acquisition, we connect the preamp output to the amplifier input. Select the correct polarity on the polarity switch. Connect the unipolar output to the oscilloscope. Describe and sketch the signal: risetime, falltime, noise level. What changes with using the gain switches and shaping time switch? Adjust the gain to a signal of 6 V for the highest alpha energies.
7. Startup the data acquisition program on the PC. Connect the unipolar output of the amplifier to the ADC/MCA input. Start the data acquisition and take a spectrum of the 241-Am source signal. Save for future printout on floppy disk.
1. Mount the scintillation detector in the slot foreseen for it. This detector has a built in photomultiplier base (base) connected to the photomultiplier (PM).
2. Connect the high voltage (HV) input cable of the PM base to the HV output of the HV power supply.
3. Connect the signal output cable of the PM base to the oscilloscope. Signals visible?
4. Turn on the HV power supply (polarity positive!!). Try if you see signals turning up the voltage in +100 V steps. Maximum + 1400 Volts!!!
5. Take notes of the results and sketch the signals on the oscilloscope at + 1400 V. Rise time, fall time, noise?
6. Connect the signal to the spectroscopy amplifier input. Check input signal polarity.
7. Connect the oscilloscope to the amplifier output (unipolar). Sketch the signal.
8. Connect the unipolar output with the ADC/MCA input and start a measurement. Adjust amplification so that you can clearly see the signal peak in the spectrum. Save for future printout

on floppy disk and sketch the spectrum. Check the signal again on the oscilloscope. Voltage of photo peak?

We have now coming out of our two amplifiers the detector signals as being useful for taking a normal energy spectrum of the radiation we are looking at. What we want is to measure the exponential decay law of the excited level in ^{237}Np , which we have populated with the alpha decay. In order to do this, we have to introduce to more types of NIM modules. The first is the Timing Single Channel Analyzer (TSCA). It produces a fast negative or positive standard pulse for each analogue signal received from an amplifier. It is possible to select a pulse height window on the TSCA within which signal are accepted and converted. This allows us to reject noise or other unwanted signals. The standard signals from the TSCA's provide the ideal input for our next module the Time to Amplitude Converter (TAC). This is basically a sophisticated stopwatch, providing an output pulse with a pulse height proportional to the time elapsed between start and stop pulse. The TAC output pulses can then be displayed again on the ADC/MCA system.

9. Connect the output of the semiconductor amplifier to the input of the TSCA. Check with the oscilloscope if negative output pulses are produced.
10. Connect the bipolar output of the scintillator amplifier to the input of the other TSCA. Check again with the oscilloscope if negative output pulses are produced.
11. Connect additionally the unipolar output of the amplifier to the oscilloscope and trigger with the TSCA output. Try to set the TSCA window on the dominant app. 60 keV signals. What happens if you introduce a delay at the TSCA.
12. Connect the semiconductor line TSCA output to the start input of the TAC. Check with the oscilloscope if a valid start signal is registered.
13. Connect the scintillator line TSCA output to the stop input of the TAC. Select a 2 microsecond delay time at the TSCA. At the TAC select a full scale time range of 10 microseconds.
14. Monitor the TAC output on the oscilloscope. Describe and sketch it.
15. Connect the TAC output to the ADC/MCA and take a spectrum for app. 1 hour.
16. Save the spectrum on floppy disk for future printout and analysis.
17. In order to calibrate the time spectrum introduce an additional delay in form of a long cable or a NIM module in the scintillator line between TSCA and TAC.
18. Take another spectrum for app. 1 hour.



^{237}Np
 $_{93}$



WWW Table of Radioactive Isotopes

$^{241}_{95}\text{Am}$ 146

Half life: 432.2 y 7

Jπ: 5/2-

S_n (keV): 6641 14

S_p (keV): 4480.1 3

Prod. mode: Thermal neutron activation

ENSDF citation: NDS 72,191 (1994)

Literature cut-off date: 1-Mar-1994

Author(s): Y.A. Akovali

References since cut-off: [241Am decay from 1994-98 \(NSR\)](#)

Decay properties:

Mode	Branching (%)	Q-value (keV)
α	100	5637.81 12
SF	4.3E-10 18	

Data sets:

Mode	Data set name	Display data
α	241AM A DECAY	
	Tables	Levels Gammas Alphas
	ENSDF data	Data
	Java applets	Level scheme

Gammas from ^{241}Am (432.2 y 7)

Eγ (keV)	Iγ (%)	Decay mode
13.81 2		α
26.3448 2	2.40 2	α
27.03		α

31.4		α
32.183	0.0174 4	α
33.1964 3	0.126 3	α
38.54 3		α
42.73 5	0.0055 11	α
43.423 10	0.073 8	α
51.01 3	0.000026 12	α
54.0		α
55.56 2	0.0181 18	α
56.8		α
57.85 5	0.0052 15	α
59.5412 2	35.9 4	α
61.46		α
64.83 2	0.000145 18	α
67.45 5	0.00042 10	α
69.76 3	0.0029 4	α
75.8 2	~0.0006	α
78.1		α
79.1		α
92.1		α
96.7		α
98.97 2	0.0203 4	α
102.98 2	0.0195 4	α
106.42 5	0.000015	α
109.70 7	0.0000049	α
115.5 1		α
120.36 8	0.0000045	α
123.01 2	0.00100 3	α
125.30 2	0.00408 9	α
128.05		α
129.2		α
135.3		α
136.7		α
138.5		α
146.55 3	0.000461 11	α
150.04 3	0.0000740 21	α
154.27 20	0.0000005	α
156.4 3		α
159.26 20	0.0000014 5	α
161.54 10	0.0000015	α
164.61 2	0.0000667 24	α
165.81 6	0.0000232 11	α
169.56 3	0.000173 4	α
175.07 4	0.0000182 10	α
190.40	0.0000022 5	α
191.96 4	0.0000216 10	α
197.0 2	0.00000049	α

201.70	14	0.0000008	α
204.06	6	0.00000290	19
208.00	1	0.000791	17
221.46	3	0.0000424	10
221.80	4		α
232.81	5	0.0000046	3
234.40	4	0.0000007	3
246.73	10	0.00000242	25
249.00	15	0.0000005	
260.80	15		α
260.80	15	0.00000121	19
264.89	6		α
264.89	6	0.0000090	4
267.54	4	0.0000263	8
270.63	15	0.00000064	20
275.77	8	0.0000066	4
278.04	15	0.00000044	
291.30	20	0.0000031	3
292.77	6	0.0000142	5
300.13	6		α
304.21	20	0.00000101	21
309.1	3	0.0000014	
316.8	2	<5.00E-08	
322.52	3		α
322.52	3	0.000152	3
332.36	4	0.000149	3
335.38	3	0.000496	10
337.7	2	0.00000429	23
340.56	8	0.0000043	
358.25	20	0.00000120	24
368.59	4	0.000217	5
370.94	3	0.0000523	12
376.65	3	0.000138	3
383.81	3	0.0000282	7
389.0	3	0.00000049	
390.62	10	0.0000059	3
398.64	15	0.000002	
401	3	0.00000049	
406.35	15	0.00000145	22
415.88	10	0.0000031	
419.33	4	0.0000287	8
426.47	4	0.0000246	7
429.94	10	0.00000115	23
442.81	7	0.0000035	3
446.43	15	0.00000049	
452.6	2	0.00000240	25
454.66	8		α

454.66 8	0.0000097 4	α
459.68 10	0.0000036 3	α
463.22 20	0.0000010	α
468.12 15	0.00000288 21	α
485.91 20	0.0000010 3	α
487.3 3		α
487.3 3	0.00000044	α
512.5 3	0.00000115 23	α
514.0 5	0.0000026 3	α
522.06 15	0.0000009 3	α
529.17 20	0.00000046	α
545.4 3	0.0000007	α
563.05 30	0.0000007	α
573.94 20	0.00000125 19	α
582.6	0.00000023 12	α
586.59 20	0.00000131 20	α
590.28 15		α
590.28 15	0.00000286 21	α
597.48 8	0.0000074 3	α
619.01 2	0.0000594 6	α
627.18 20	0.00000056 17	α
632.93 15	0.00000126 19	α
641.47 5	0.0000071 3	α
653.02 4	0.0000377 11	α
662.40 2	0.000364 8	α
666.5 3	0.00000049	α
669.83 20	0.00000038 12	α
676.03 30	0.00000064 13	α
680.10 10	0.00000313 17	α
688.72 4	0.0000325 8	α
693.62 8	0.00000368 17	α
696.60 5		α
696.60 5	0.00000534 20	α
709.45 5	0.00000641 18	α
722.01 3		α
722.01 3	0.000196 4	α
729.72 15	0.00000133 14	α
731.5	0.00000047 15	α
737.34 5	0.00000800 24	α
742.9 3	0.00000035	α
755.90 5	0.0000076 3	α
759.38 10	0.00000167 9	α
763.9 3	0.00000020 6	α
767.00 10	0.00000500 18	α
770.57 10	0.00000474 21	α
772.4 3	0.00000266 15	α
777.2	6.10E-08 3	α

780.7 2	0.00000025 5	α
782.2 5	0.00000015	α
786.00 15	0.0000006	α
789.17 25	0.00000039 6	α
794.92 20	0.0000009	α
801.94 20	0.00000136 14	α
806.3 3	0.00000031	α
812.01 30	0.00000061 8	α
819.0 10	0.00000040 6	α
822.6	0.00000022 6	α
828.5	0.00000024 6	α
835.6 10	0.00000021	α
841.5 10	4.00E-08 1	α
847.4 5	0.00000027 3	α
851.6 10	0.00000038 6	α
854.7	0.00000020 4	α
860.7 5	8.20E-08 25	α
862.7 5	0.00000053 6	α
870.7 3	0.00000046	α
887.3 3	0.00000022 5	α
898.4	7.20E-08 3	α
902.5	0.00000030 5	α
912.4	0.00000025 5	α
921.5 3	0.00000019 4	α
928.8	5.50E-08 3	α
945.7	5.60E-08 3	α
955.7	0.00000058 6	α
1014.7 5	6.40E-08 10	α

X-rays from ^{241}Am (432.2 y 7)

E (keV)	I (%)	Assignment
11.871	0.66 9	Np L _l
13.761	1.07 11	Np L _{α2}
13.946	9.6 10	Np L _{α1}
15.861	0.153 19	Np L _η
16.109	0.184 19	Np L _{β6}
16.816	2.5 3	Np L _{β2}
17.061	1.5 3	Np L _{β4}
17.505	0.65 7	Np L _{β5}
17.751	5.7 8	Np L _{β1}
17.992	1.37 24	Np L _{β3}
20.784	1.39 18	Np L _{γ1}
21.099	0.65 12	Np L _{γ2}
21.342	0.59 11	Np L _{γ3}
21.491	0.29 4	Np L _{γ6}
96.242	2.8E-05 23	Np K _{α3}
97.069	0.008 6	Np K _{α2}
101.059	0.012 10	Np K _{α1}
113.303	0.0015 12	Np K _{β3}
114.234	0.0028 24	Np K _{β1}
114.912	1.1E-04 9	Np K _{β5}
117.463	0.0011 9	Np K _{β2}
117.875	0.0004 3	Np K _{β4}

Alphas from ^{241}Am (432.2 y 7)

E α (keV)	I α (%)
4757.39 16	0.00004 3
4800.62 16	8.6E-5
4834.15 13	0.0007
4888.9 2	
4956.0 3	
4961.6 11	
4963.63 20	
5007.58 20	0.0001
5055.34 14	
5066.22 17	0.00014
5092.05 13	~0.0004
5099.09 13	~0.0004
5106.71 16	
5117.20 20	0.0004
5133 4	
5155.16 13	0.0007
5179.34 13	0.0003
5181.64 13	0.0009
5190.4 2	0.0006
5217.27 13	
5225.08 13	0.0013
5232.5 3	
5244.12 13	0.0024
5281.01 14	0.0005
5321.90 13	0.015 5
5388.23 13	1.6 2
5416.27 14	~0.01
5442.80 13	13.0 6
5469.45 14	<0.04
5485.56 12	84.5 10
5511.47 13	0.22 3
5544.5 16	0.34 5

Sort gammas by: E γ ,I γ I γ ,E γ Decay mode,E γ Sort alphas by: E α ,I α I α ,E α

Regenerate table