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**GAMMA-RAY ENERGIES AND
ABSOLUTE BRANCHING INTENSITIES
FOR ^{238}Pu , ^{239}Pu , ^{240}Pu , ^{241}Pu AND ^{241}Am**

R. Gunnink
R. J. Morrow

July 22, 1971

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Contents

Abstract	1
Introduction	1
Summary of Procedures	1
Results	2
Plutonium-238	3
Plutonium-239	3
Plutonium-240	9
Plutonium-241	14
Americium-241	14
Acknowledgments	22
References	23

GAMMA-RAY ENERGIES AND ABSOLUTE BRANCHING INTENSITIES FOR $^{238,239,240,241}\text{Pu}$ AND ^{241}Am

Abstract

Using sources of very high isotopic purity, we have obtained precise values for the energies and absolute branching

intensities of the gamma rays following the alpha-decay of $^{238,239,240,241}\text{Pu}$ and ^{241}Am .

Introduction

An accurate analysis of a radioactive sample by Ge(Li) gamma-ray spectrometry generally requires correct information on the gamma-ray energies and intensities for each of the nuclides present in such a sample.

In this report, we present our measure-

ments of the gamma- and x-ray energies and absolute branching intensities from the decay of ^{241}Am and $^{238,239,240,241}\text{Pu}$. With properly calibrated Ge(Li) detector systems our data can be used for non-destructive analyses of samples containing these nuclides.

Summary of Procedures

The spectra were taken on one or more of the following Ge(Li) detector systems: X-ray detector (430 eV FWHM at 14.4 keV), 8-cc planar detector (~2.1 keV FWHM at ^{60}Co), and a 38-cc coaxial detector (2.3 keV FWHM at ^{60}Co). These spectrometers, which are used for routine analysis, have been carefully calibrated for efficiency to an overall accuracy of $\pm 3\%$. The spectra were accumulated with 4096-channel pulse-height analyzers and were analyzed by GAMANAL,^{1,2} a computer program that

can be used to reduce the spectral data to peak energies, intensities, and related quantities. In addition to calculating energies and intensities from peak positions and areas, this code corrects the observed intensities for sample self-attenuation and for external absorbers, which are frequently used to reduce the intensity of low-energy gamma rays. This feature was a great asset in deducing accurate gamma-ray intensities.

The errors associated with the gamma-ray energies and intensities are dependent

on several factors. The error in energy, although not reported here, will in general be much less than 100 eV, except on statistically poor peaks. The intensity error reported with each gamma ray is primarily due to counting statistics. However, other considerations, such as quality of peak fitting and agreement between separate runs, were also folded into the listed errors.

The gamma branching intensities were normalized by counting samples that had been accurately assayed by weighing

and/or α -counting. The error associated with these absolute calibrations was in general less than $\pm 1-2\%$.

Sources of high isotopic purity were used in these studies. Table 1 lists the nuclide sources used and their isotopic purities. For ^{239}Pu and ^{240}Pu , small amounts of very-high-purity material were available and were used to obtain the low-energy spectrum. The higher-energy gamma rays were studied with much larger amounts of less pure material.

Table 1. Isotopic impurities of nuclide sources. Isotopic composition.

Mass	^{238}Pu	^{239}Pu (Source A)	^{239}Pu (Source B)	^{240}Pu (Source A)	^{240}Pu (Source B)	^{241}Pu
238	99.98	< 2 ppm	—	< 0.001%	0.016%	—
239	—	99.999%	99.10%	0.053%	0.955%	nil
240	—	7.9 ppm	0.888%	99.86%	93.76%	nil
241	—	< 0.5 ppm	0.014%	0.053%	0.699%	99.997%
242	—	< 0.5 ppm	—	0.029%	4.56%	nil
243	—	—	—	< 0.0001%	—	—

Results

In this report we do not attempt to compare our results with earlier work. Near the conclusion of our work, J. E. Cline³ published a report that contains much of the same data we report here. There is general agreement in the gamma-ray listings and in their energies. The major disagreements lie in some of the branching intensities. The disparity is least in the case of ^{239}Pu and greatest for ^{241}Pu and ^{241}Am , where some values differ by more than a factor of two.

We would also like to call attention to the rather severe interferences that exist in the low-energy gamma rays of ^{240}Pu and ^{241}Pu . It is not difficult to

determine the ^{241}Pu content in a sample because both ^{241}Pu and its ^{237}U daughter emit several noninterfering gamma rays. However, the only noninterfering low-energy gamma ray of ^{240}Pu , the 45.24-keV line, is rarely seen because it appears at a lower energy than the dominating 59.536-keV line of ^{241}Am and is severely attenuated by sample containers and by the sample itself. The 104.23-keV line from $^{240}\text{Pu}^{(4,5)}$ must be resolved from both the ^{241}Pu 103.67-keV line and from the alpha-induced plutonium fluorescent x rays at 103.750 keV, which may be present. The 160.35-keV line of $^{240}\text{Pu}^{(5)}$ lies extremely close to the

previously unreported 160.00-keV line of ^{241}Pu , and this gamma-ray doublet is generally only partially resolved from the 161.45-keV line of ^{239}Pu .

We are currently continuing to study the magnitude of these and other interferences in typical plutonium samples.⁶

In the following paragraphs, we briefly report the data that we have obtained for each of the nuclides listed.

PLUTONIUM-238*

The spectra obtained from our sources of ^{238}Pu showed several lines that have not been assigned to the level scheme for $^{234}\text{U}^{(7-9)}$ (see Figs. 1 and 2). Some of these lines are known to be due to (α, x) reactions, and others may be due to impurities. Table 2 lists the energies

$$^*t_{\frac{1}{2}} = 87.7 \text{ yr.}^{10}$$

and intensities for gamma transitions known to belong to this decay scheme.

The absolute disintegration rates were determined by α -counting.

PLUTONIUM-239*

Several different sources were counted and then normalized to give a consistent set of intensities. A 1-mg source of 99.999% pure material was used to obtain the low-energy spectrum shown in Fig. 3. Sources of 99.1%-purity material (up to 15 g) were used to obtain data on the higher-energy regions. (See Figs. 4 and 5.) Absolute normalization was made by α -counting weighed quantities of plutonium on our detectors. The resulting gamma-ray energies and intensities are listed in Table 3.

$$^*t_{\frac{1}{2}} = 2.44 \times 10^4 \text{ yr.}$$

Table 2. Gamma rays of ^{238}Pu .

Energy, keV	Intensity, ^a γ/dis	Energy, keV	Intensity, ^a γ/dis
43.492 $\pm$ 0.010	3.92×10^{-4} (1)	742.82	5.55×10^{-8} (1)
94.665 $K\alpha_2$	9.00×10^{-7} (3)	766.41 $\pm$ 0.02	2.40×10^{-7} (1)
98.439 $K\alpha_1$	1.48×10^{-6} (2)	786.30	3.53×10^{-8} (1)
99.871 $\pm$ 0.010	7.40×10^{-5} (1)	805.42	1.39×10^{-9} (15)
110.41 $K\beta_3$	1.99×10^{-7} (2)	808.23	8.58×10^{-9} (3)
111.29 $K\beta_1$	3.07×10^{-7} (2)	851.73	1.39×10^{-8} (2)
114.32 $K\beta_4$	1.16×10^{-7} (2)	883.21	6.53×10^{-9} (10)
114.55 $K\beta_2$		904.34	6.21×10^{-10} (30)
115.41 K_x		926.73	6.15×10^{-9} (4)
152.77 $\pm$ 0.03	1.01×10^{-5} (1)	942.02	5.26×10^{-9} (4)
200.98	4.28×10^{-8} (2)	946.12	1.03×10^{-9} (20)
258.23	6.77×10^{-10} (20)	1001.10	1.30×10^{-8} (6)
705.6	5.40×10^{-10} (40)	1041.90	2.29×10^{-9} (10)
708.4	5.38×10^{-9} (10)	1085.40	2.29×10^{-9} (10)

^aNumbers in parentheses are percent errors.

Fig. 1. Low-energy spectrum of ^{238}Pu .

Fig. 2a. High-energy spectrum of ^{238}Pu . Many of the peaks are due to (α, x) type reactions. The broadened peaks result from Doppler shifts that occur in these reactions when gamma rays are emitted before the product nucleus comes to rest.

Fig. 2b. High-energy spectrum of ^{238}Pu . Many of the peaks are due to (α, x) type reactions. The broadened peaks result from Doppler shifts that occur in these reactions when gamma rays are emitted before the product nucleus comes to rest.

Fig. 3. Low-energy spectrum of ^{239}Pu .

Fig. 4. Intermediate-energy region of a ^{239}Pu spectrum.

Fig. 5. High-energy region of a ^{239}Pu spectrum.

PLUTONIUM-240*

A source of high isotopic purity was used to measure the low-energy gamma rays (see Fig. 6), and larger samples of lower isotopic purity were used to obtain the high-energy spectrum shown in

* $t_{1/2} = 6600$ yr.

Fig. 7. Although a rather large number of gamma rays are observed, many of these are due to the known presence of contaminants such as ^{239}Pu and ^{241}Am . Some of the others are due to fission products from the spontaneously fissioning ^{240}Pu .

A proper delineation of the origin of all of the observed gamma rays will require considerably more experimental

Table 3. Gamma rays of ^{239}Pu .

Energy, keV		Intensity, ^a γ/dis	Energy, keV	Intensity, ^a γ/dis
30.09		1.05×10^{-6} (10)	158.3	8.00×10^{-8} (30)
31.98	}	1.37×10^{-5} (3)	161.45	1.30×10^{-6} (3)
32.24			168.1	3.80×10^{-8} (25)
36.39		4.23×10^{-6} (2)	171.34	1.09×10^{-6} (2)
37.28		1.03×10^{-6} (8)	173.6	4.90×10^{-8} (25)
38.69		5.86×10^{-5} (1)	179.17	6.39×10^{-7} (2)
(40.57)		2.56×10^{-7} (25)	184.3	1.63×10^{-8} (35)
46.23		5.11×10^{-6} (3)	188.27	9.60×10^{-8} (10)
47.56		2.87×10^{-7} (25)	189.34	7.76×10^{-7} (2)
51.628		2.08×10^{-4} (1)	195.65	1.07×10^{-6} (2)
54.05		1.69×10^{-6} (4)	197.98	5.00×10^{-8} (15)
56.828		9.30×10^{-6} (1)	203.52	5.60×10^{-6} (2)
65.69		3.35×10^{-7} (15)	225.43	1.63×10^{-7} (4)
67.69		1.42×10^{-6} (5)	237.77	1.50×10^{-7} (10)
68.73		5.99×10^{-6} (5)	242.09	8.32×10^{-8} (15)
74.96		3.80×10^{-7} (15)	243.33	2.32×10^{-7} (5)
77.60		4.27×10^{-6} (2)	244.80	5.23×10^{-8} (15)
78.38		1.69×10^{-6} (5)	248.95	7.50×10^{-8} (7)
89.59		1.34×10^{-7} (40)	255.33	8.03×10^{-7} (1)
94.665	$K\alpha_2$	3.67×10^{-5} (1)	263.93	2.55×10^{-7} (5)
98.439	$K\alpha_1$	5.90×10^{-5} (1)	265.54	2.85×10^{-8} (25)
98.81		1.3×10^{-5} (10)	281.2	2.14×10^{-8} (30)
103.03		1.79×10^{-6} (5)	285.3	1.50×10^{-8} (40)
110.41	$K\beta_3$	7.76×10^{-6} (1)	297.43	5.00×10^{-7} (1)
111.29	$K\beta_1$	1.47×10^{-5} (1)	302.87	5.70×10^{-8} (10)
114.32	$K\beta_4$ } $K\beta_2$ }	5.59×10^{-6} (1)	307.81	6.20×10^{-8} (10)
114.55			311.69	2.74×10^{-7} (2)
115.35		6.76×10^{-6} (1)	313.5	2.0×10^{-8} (40)
116.24		5.96×10^{-6} (1)	316.35	1.41×10^{-7} (4)
119.72		3.03×10^{-7} (15)	(319.7) }	5.69×10^{-7} (2)
123.67		1.68×10^{-7} (10)	320.81 }	
124.52		6.23×10^{-7} (4)	323.76	5.39×10^{-7} (2)
125.17		5.79×10^{-7} (4)	332.80	5.05×10^{-6} (1)
129.28		6.20×10^{-5} (1)	336.06	1.13×10^{-6} (1)
141.64		3.11×10^{-7} (5)	341.48	6.63×10^{-7} (1)
143.4		5.7×10^{-8} (20)	344.96	5.61×10^{-6} (1)
144.19		2.86×10^{-6} (3)	354.1	8.00×10^{-9} (40)
146.05		1.13×10^{-6} (3)	361.9	1.17×10^{-7} (3)

Table 3. (Continued).

Energy, keV	Intensity, ^a γ/dis	Energy, keV	Intensity, ^a γ/dis
367.02	8.72×10^{-7} (1)	646.02	1.45×10^{-7} (2)
368.53	8.96×10^{-7} (1)	649.5	8.10×10^{-9} (20)
375.02	1.58×10^{-5} (1)	652.19	6.40×10^{-8} (3)
380.16	3.07×10^{-6} (1)	654.86	2.15×10^{-8} (8)
382.70	2.60×10^{-6} (1)	658.99	9.50×10^{-8} (2)
392.45	1.16×10^{-6} (10)	664.67	1.54×10^{-8} (4)
393.06	4.44×10^{-6} (3)	674.2	5.20×10^{-9} (4)
399.44	6.13×10^{-8} (5)	686.16	8.90×10^{-9} (4)
410.77	8.00×10^{-8} (50)	690.85	5.50×10^{-9} (6)
413.69	1.51×10^{-5} (1)	701.00	5.40×10^{-9} (6)
422.57	1.19×10^{-6} (2)	703.79	3.88×10^{-8} (2)
426.67	2.29×10^{-7} (3)	717.76	2.67×10^{-8} (3)
(428.4)	—	727.81	1.09×10^{-9} (8)
430.0	4.91×10^{-8} (6)	756.40	3.37×10^{-8} (2)
445.78	9.10×10^{-8} (4)	769.38	1.10×10^{-7} (1)
451.45	1.92×10^{-6} (1)	779.5	1.33×10^{-9} (5)
457.57	1.54×10^{-8} (7)	787.3	8.40×10^{-10} (7)
461.29	2.02×10^{-8} (10)	793.0	2.5×10^{-10} (20)
463.8	1.57×10^{-9} (30)	796.5	3.2×10^{-10} (16)
474.4	9.42×10^{-10} (30)	803.3	4.4×10^{-10} (16)
481.55	4.77×10^{-8} (2)	808.2	1.47×10^{-9} (8)
487.0	2.50×10^{-9} (15)	813.9	6.22×10^{-10} (13)
493.1	8.80×10^{-9} (6)	821.1	5.12×10^{-10} (12)
538.9	3.00×10^{-9} (20)	828.8	1.38×10^{-9} (6)
550.6	4.00×10^{-9} (10)	832.1	2.54×10^{-10} (22)
557.7	6.00×10^{-10} (40)	839.	4.0×10^{-10} (40)
586.4	1.42×10^{-9} (15)	843.8	1.60×10^{-9} (8)
598.1	1.90×10^{-9} (3)	879.0	5.0×10^{-10} (15)
607.3	1.45×10^{-9} (15)	891.1	7.7×10^{-10} (15)
612.9	8.10×10^{-9} (4)	940.1	4.2×10^{-10} (15)
617.4	2.04×10^{-8} (4)	956.4	5.6×10^{-10} (16)
618.9	2.44×10^{-8} (4)	979.5	2.3×10^{-10} (19)
624.8	4.00×10^{-9} (6)	986.7	1.2×10^{-10} (40)
633.19	2.32×10^{-8} (3)	992.5	2.3×10^{-10} (21)
637.97	2.50×10^{-8} (3)	1005.5	1.2×10^{-10} (34)
640.15	7.95×10^{-8} (3)	1057.3	4.5×10^{-10} (15)

^aNumbers in parentheses are percent errors.

Fig. 6. Low-energy spectrum of ^{240}Pu .

Fig. 7. High-energy spectrum of ^{240}Pu . Many of the peaks are due to ^{239}Pu , ^{241}Am , (α, x) reaction and fission products resulting from the spontaneous fission of ^{240}Pu .

effort. For this reason, in Table 4 we report only the energies and intensities of low energy and the two most intense high-energy lines, which are quite clearly due to ^{240}Pu decay.¹¹

PLUTONIUM-241^{*}

Samples of ^{241}Pu were chemically purified from the ^{237}U and ^{241}Am daughter products. Although the $^{237}\text{U}^\dagger$ grows in rather quickly, the spectra taken right after chemical separation produced good data for the low-energy regions as shown in Fig. 8.

The decay of ^{241}Pu is principally by β^- decay to ^{241}Am . Since the β^- emissions are not very energetic, the absolute decay rate of the ^{241}Pu is more easily determined by observing the growth of ^{241}Am after it has been chemically removed from a sample. The small α -decay branch of ^{241}Pu to ^{237}U was assayed by direct α -counting after the chemical removal of ^{241}Am and ^{237}U , and also by measuring, by gamma spectroscopy, the amount of ^{237}U present in the sample after it had attained secular equilibrium. These two measurements agreed to within 1% and were used for normalizing the γ -branching intensities. The α -branching intensity of ^{241}Pu that was obtained from the above measurement is $0.00246 \pm 0.00010\%$, which agrees very well with the published value of 0.0023% .¹⁰

^{*} $t_{1/2} = 14$ yr; however, a recent report¹² places $t_{1/2}$ at 15.16 yr.

[†] $t_{1/2} = 6.75$ days.

Table 4. Gamma rays of ^{240}Pu .

Energy, keV	Intensity, ^a γ/dis
45.235 ± 0.020	4.50×10^{-4} (1)
94.665 $K\alpha_2$	6.15×10^{-7} (10)
98.439 $K\alpha_1$	1.00×10^{-6} (5)
104.233 ± 0.010	7.00×10^{-5} (1)
111.29 $K\beta_{1+3}$	3.60×10^{-7} (10)
114.5 $K\beta_{2+4}$	$\sim 1.23 \times 10^{-7}$
160.35 ± 0.050	4.20×10^{-6} (1)
642.30	1.45×10^{-7} (3)
687.63	3.70×10^{-8} (4)

^aNumbers in parentheses are percent errors.

The proposed decay scheme shown in Fig. 9 shows several gamma transitions that have not been previously reported. The gamma-ray energies and intensities are tabulated in Table 5.

AMERICIUM-241^{*}

Several spectra were taken using small and large sources (~ 100 mg). (See Figs. 10 and 11). Spectra taken of IAEA standards were used to establish the branching intensities for several of the low-energy gamma rays below 208 keV. The remaining data were normalized to these intensities.

Table 6 lists the gamma-ray energies and intensities that we have measured.

^{*} $t_{1/2} = 433$ yr.

Fig. 8. Spectrum of ^{241}Pu . Some ^{237}U is also present.

Fig. 9. Proposed decay scheme of ^{241}Pu .

Table 5. Gamma rays of ^{241}Pu .

Energy, keV	Intensity, ^{a,b} γ/dis	Intensity, ^{a,c} γ/dis
11.39		
44.19	1.82×10^{-3} (3)	4.48×10^{-8} (3)
44.83	4.50×10^{-4} (10)	1.11×10^{-8} (10)
56.30	1.50×10^{-3} (5)	3.69×10^{-8} (5)
71.60	1.10×10^{-3} (5)	2.71×10^{-8} (5)
76.96	9.80×10^{-3} (3)	2.41×10^{-7} (3)
94.665 $K\alpha_2$	1.21×10^{-1} (1)	2.98×10^{-6} (1)
98.439 $K\alpha_1$	1.91×10^{-1} (1)	4.70×10^{-6} (1)
103.67 ± 0.04	4.21×10^{-2} (1)	1.04×10^{-6} (1)
110.42 $K\beta_3$	2.39×10^{-2} (1)	5.87×10^{-7} (1)
111.30 $K\beta_1$	4.41×10^{-2} (1)	1.08×10^{-6} (1)
111.96 $K\beta_5$	$\sim 1.72 \times 10^{-3}$	$\sim 4.23 \times 10^{-8}$
114.33 $K\beta_4$ }	1.82×10^{-2} (2)	4.48×10^{-7} (2)
114.56 $K\beta_2$ }		
115.41 $K\beta_x$	5.4×10^{-3} (3)	1.33×10^{-7} (3)
121.2	3.60×10^{-4} (10)	8.86×10^{-9} (10)
148.60 ± 0.04	7.74×10^{-2} (1)	1.90×10^{-6} (1)
160.00 ± 0.04	2.62×10^{-3} (2)	6.45×10^{-8} (2)

^aNumbers in parentheses are percent errors.

^bNormalized to ^{241}Pu α -branching intensity by (a) α -counting the sample after removal of ^{241}Am and (b) counting the ^{237}U in equilibrium with the ^{241}Pu .

^cNormalized to total ($\alpha + \beta$) decay for ^{241}Pu . It was found that α -branching is 0.00246% of the total decay.

Fig. 10. Low-energy spectrum of ^{241}Am .

Fig. 11a. High-energy spectrum of ^{241}Am .

Fig. 11b. High-energy spectrum of ^{241}Am .

Table 6. Gamma rays of ^{241}Am .

Energy, keV	Intensity, ^a γ/dis	Energy, keV	Intensity, ^a γ/dis
(43.4)	9.1×10^{-4} (20)	322.48	1.44×10^{-6} (2)
59.536	0.359 (1)	332.33	1.45×10^{-6} (2)
69.9	2.01×10^{-5} (6)	335.38	4.70×10^{-6} (2)
97.095 $\text{K}\alpha_2$	1.13×10^{-5} (7)	337.69	3.05×10^{-8} (15)
99.00 ± 0.03	2.02×10^{-4} (2)	340.40	2.5×10^{-8} (25)
101.085 $\text{K}\alpha_1$	1.88×10^{-5} (5)	350.40	1.4×10^{-8} (30)
103.00 ± 0.03	1.95×10^{-4} (2)	358.20	1.51×10^{-8} (20)
113.27 $\text{K}\beta_3$	2.40×10^{-6}	368.60	2.08×10^{-6} (2)
114.20 $\text{K}\beta_1$	4.78×10^{-6}	370.91	4.91×10^{-7} (2)
117.47 $\text{K}\beta_{2+4}$	2.30×10^{-6}	376.57	1.33×10^{-6} (1)
118.40 Kx		383.74	2.90×10^{-7} (3)
123.01	1.02×10^{-5} (3)	390.53	6.10×10^{-8} (5)
125.30	3.95×10^{-5} (3)	398.50	1.5×10^{-8} (30)
146.55	4.58×10^{-6} (3)	406.46	1.20×10^{-8} (35)
150.12	7.20×10^{-7} (4)	415.90	1.61×10^{-8} (25)
158.8	1.14×10^{-8} (50)	419.19	2.76×10^{-7} (3)
(161.6)	2.30×10^{-8} (20)	426.34	2.40×10^{-7} (4)
164.60	6.20×10^{-7} (4)	429.6	5.0×10^{-9} (50)
165.95	2.43×10^{-7} (5)	442.75	3.4×10^{-8} (20)
169.57	1.68×10^{-6} (3)	452.23	1.7×10^{-8} (25)
175.16	1.84×10^{-7} (6)	454.58	9.30×10^{-8} (6)
191.90	2.20×10^{-7} (4)	459.40	3.2×10^{-8} (15)
194.7	1.70×10^{-8} (25)	467.9	2.5×10^{-8} (25)
204.00	3.20×10^{-8} (25)	486.3	1.20×10^{-8} (40)
207.98	7.6×10^{-6} (2)	514.1	2.70×10^{-8} (30)
221.49	4.00×10^{-7} (4)	(521.9)	7.0×10^{-9} (50)
233.02	4.8×10^{-8} (10)	574.0	1.45×10^{-8} (20)
234.4	6.0×10^{-9} (40)	586.52	1.43×10^{-8} (20)
246.72	2.0×10^{-8} (25)	590.3	1.52×10^{-8} (20)
260.98	8.6×10^{-9} (30)	597.39	6.50×10^{-8} (5)
264.92	8.27×10^{-8} (5)	618.86	5.55×10^{-7} (2)
267.5	2.45×10^{-7} (3)	626.9	3.60×10^{-9} (50)
275.72	6.22×10^{-8} (6)	632.8	1.10×10^{-8} (25)
291.15	3.15×10^{-8} (15)	641.37	6.45×10^{-8} (4)
292.72	1.31×10^{-7} (5)	652.88	3.54×10^{-7} (2)
300.09	5.74×10^{-8} (8)	662.37	3.46×10^{-6} (1)
304.16	8.00×10^{-7} (3)	675.7	6.8×10^{-9} (30)
311.94	3.90×10^{-7} (3)	679.99	2.6×10^{-8} (10)

Table 6. (Continued).

Energy, keV	Intensity, ^a γ/dis	Energy, keV	Intensity, ^a γ/dis
688.70	2.92×10^{-7} (2)	759.37	1.65×10^{-8} (8)
693.41	3.16×10^{-8} (5)	766.87	5.10×10^{-8} (4)
696.34	4.90×10^{-8} (4)	770.93	6.47×10^{-8} (4)
709.30	5.80×10^{-8} (4)	780.42	2.7×10^{-9} (50)
721.92	1.85×10^{-6} (1)	811.80	5.20×10^{-9} (20)
729.46	1.30×10^{-8} (15)	851.9	2.8×10^{-9} (45)
737.22	7.51×10^{-8} (3)	862.9	5.1×10^{-9} (30)
755.87	7.10×10^{-8} (3)		

^aNumbers in parentheses are percent errors.

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