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LOW ENERGY GAMMA-TRANSITIONS IN Pu^{238} AND Pu^{240}

G. G. Akalaev, N. A. Vartanov, and P. S. Samoilov

Translated by K. W. Foster

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The radioactive nuclei curium-242 and curium-244 transform by alpha decay into the long-lived isotopes plutonium-238 and plutonium-240. Fundamental radiation data about energy levels of the nuclei plutonium-238 and plutonium-240 of these isotopes are in the literature.^{1, 2} However, in these works there has been no comparison of internal conversion coefficients of gamma transitions of the plutonium nuclei with theoretical values of internal conversion coefficients for L and M subshells of the atoms. Such a comparison should reveal possible anomalous internal conversion coefficients of accelerated E2-transitions in strongly deformed nuclei.³

The gamma emission spectra of isotopes curium-242 and curium-244 have not been analyzed in published works. Moreover, such an analysis would indicate the degree of separation of curium from other radioactive products generated in the process of its production.

In order to obtain the indicated information, we investigated electron and gamma spectra of mixtures of isotopes of curium; this was done on a beta spectrometer with double focusing at an angle of $\pi\sqrt{2}$ and on a scintillation gamma spectrometer⁵ with a 40x40mm NaI(Tl) single crystal detector.

The preparation containing the mixture of curium isotopes was deposited on a celluloid film 0.1 μ thick in the form of a little strip 1.5x35mm and coated with a semitransparent layer of Aquadag. The counter window was 2x35 mm and was covered by a celluloid film 0.05 μ thick which permitted the system to count electrons starting with an energy of ~ 1 KeV. The electron spectrum was measured in interval numbers from 90 to 1250 oersted-cm, which corresponds to electron energies of 0.8 to 120 KeV. The observed electron lines are interpolated in Table 1.

NOTE: Manuscript received by the editor, Sept. 19, 1963.

Table 1

INTERPRETATION OF LINES IN THE ELECTRON SPECTRUM OF PLUTONIUM-238 AND PLUTONIUM-240

Line Number in Spectrum	Electron Energy (KeV)	Conversion Shell	Transition Energy (KeV)	Intensity of Line (rel. units)	Remarks
3	21.05	L _i	44.15	27	Pertains to Cm ²⁴²
4	21.82	L _{i i}	44.08	45	"
6	26.07	L _{i i i}	44.14	35	"
9	38.08	M _i	44.01	2	"
10	38.46	M _{i i} + M _{i i i} (Cm ²⁴⁴)	44.02	41	"
11	39.58	M _{i i i}	44.14	18	"
13	42.83	N	44.09	11	"
--	--	Average	44.09	--	"
1	19.82	L _i	42.92	6: 5	Pertains to Cm ²⁴⁴
2	20.62	L _{i i}	42.88	69	"
5	24.79	L _{i i i}	42.86	45	"
7	36.89	M _i	42.82	4.4	"
8	37.41	M _{i i i} + M _{i i i i} (Cm ²⁴²)	42.97	28	"
12	41.68	N	42.88	12	"
--	--	Average	42.9	--	"
0 ₁	Auger Electrons	M _i - N _j N _k L _i - L _j M _k	--	--	----
0 ₁ : 0 ₃	Auger Electrons	M _i → M _j M _k	--	--	----
0 ₄	Auger Electrons	L _{i i i} - M _i M _j	--	--	----
0 ₅	Auger Electrons	L _{i i i i} - M _i M _j L _i - M _j M _k	--	--	----
0 ₆	Auger Electrons	L _i - M _j N _k	--	--	----

In Table 2 experimental results of the ratio of conversion at L and M subshells are compared with theoretical values taken from the literature. As it is seen from the tables, experimental values of the conversion coefficients $L_{II}:L_{III}$ and $M_{II}:M_{III}$ agree with theoretical values within a precision of 5 - 10%.

Since the observed intensity of the weak line L_I includes the contribution of Auger electrons, it does not seem possible to disengage accurately its true intensity.

In addition to the lines considered in Table 1, two more lines were also observed in the spectrum with energies of 72 and 115 KeV. For the purpose of identification of these lines a gamma spectrum of the sample was measured in which gamma lines are observed at 45, 123, 248, 385, 720, 873, 1003, and 1280 KeV, which are attributed to europium-155. From analysis of the electron and gamma spectra it is seen that the sample in question contains, besides the isotopes curium-242 and curium-244, the impurities europium-154 and europium-155. The electron lines at 72 and 115 KeV are due to conversion of gamma transition energies at 123 KeV in the K and L subshells of gadolinium.

The Auger electron lines were not quantitatively interpreted in the present work.

Table 2

RATIO OF INTERNAL CONVERSION COEFFICIENTS E2-TRANSITIONS
WITH ENERGY 43 AND 44 KEV, FOR Z = 94

Ratio	Theoretical Values	Experimental Values					
	References	Present Work		Reference 2		Reference 3	
	6 & 7	43 KeV	44 KeV	43 KeV	44 KeV	43 KeV	44 KeV
$L_1:L_{11}$	0.032	0.09	0.06	-	-	-	-
$L_{11}:L_{111}$	1.82	1.21	1.28	-	1.18	1.1	1.16/1.27
$M_1:M_{11}$	0.053	0.07	0.085	-	-	-	-
$M_{11}:M_{111}$	1.13	1.25	1.3	-	1.9	1.1	1.23
L:M:N	2.27:1:?	2.3:1:0.22	2.24:1:0.25	-	1.85:1:0.16	2.4:1:0.3	2.5:1:0.3

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