INVESTIGATION OF THE GAMMA SPECTRUM OF Ce^{140}

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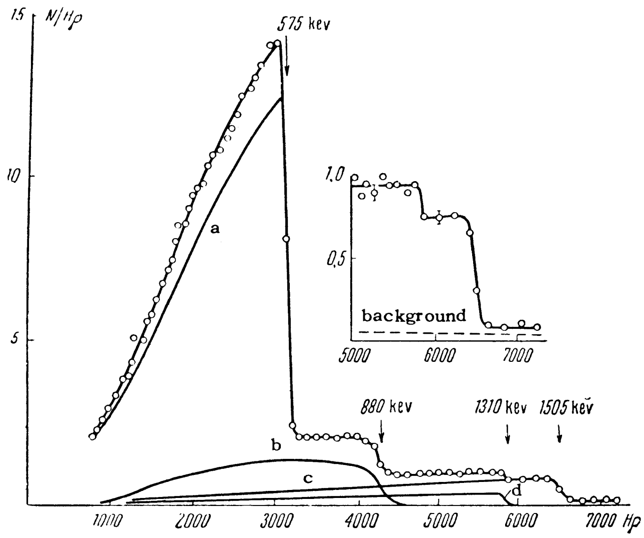
Gamma radiation with energy above $2mc^2$ from Ce^{140} was investigated by measuring the internal pair-conversion positron spectrum of decaying La^{140}. The multipolarities and intensities of γ quanta with energies $E_\gamma = 1596$, 2330, and 2525 kev have been determined by comparison with the corresponding K-shell electron-conversion lines. It is shown that for transitions involving energies above $2mc^2$ such a method of determining γ-quantum characteristics has certain advantages.

An investigation of γ quanta of energy greater than 1 Mev, which accompany the transition of nuclei from the excited state to the ground state, entails many difficulties. The principal method of investigating low-energy γ rays, by means of the internal-conversion electrons, has little effectiveness at energies > 1 Mev, since the internal conversion becomes very small and in addition depends weakly on the multipolarity of the transition. Gamma rays with energy $E_\gamma > 2mc^2$ can also be investigated by internal conversion with production of electron-positron pairs, but the probability of this process is relatively low. Consequently, γ radiation from nuclei was investigated by means of the internal pair-conversion process only in a few cases.[1]

In the present work we investigated the hard γ radiation from Ce^{140} by simultaneously measuring the spectrum of the pair-conversion positrons and the corresponding K-shell conversion lines. This method has several advantages. Thus, for example, in determining the multipolarity of the γ radiation by the absolute value of the conversion coefficient one must have not only the conversion spectrum but also data on the γ-ray intensity. On the other hand, when determining the multipolarity by the ratio of the internal pair coefficient (Γ_p) and the electron conversion on the K shell (α_K), no data on the γ-ray intensity are necessary, and both the spectra of the positron pair conversion and of the electron conversion can be obtained with the same instrument. Furthermore, as seen from Table I, the ratio of the coefficients of pair conversion to electron conversion depends more strongly on the multipolarity than on the absolute values of these coefficients. Thus, for example, for Ce^{140} at $E_\gamma = 5mc^2$ the conversion coefficients from the K shell, for M1 and E2 radiations, differ by 10%, whereas the ratio Γ_p/α_K differs in this case by 50%.

The spectrometer used for the measurements has been described earlier.[2,3] The La^{140} sources were obtained by bombarding lanthanum oxide, deposited on an aluminum foil $5\,\mu$ thick, with thermal neutrons. The source density was $1-2$ mg/cm^2, the source dimensions 25×10 mm. The spectrometer resolution $\Delta(H\rho)/H\rho$ was 1.5%.



Positron spectrum of internal conversion of Ce^{140}; a,b,c,d,—partial positron spectra, due to internal pair conversion of transitions with respective energies 1597, 1902, 2527, and 2332 kev.

The spectrum of the internal-conversion positrons is shown in the diagram. As can be seen, the positron spectrum is complex. Many steep drops, observed in the spectrum, are due to the presence of corresponding energy transitions for the Ce^{140} nucleus. The transition energies, ac-

TABLE I

γ-quantum energy, kev	Quantity	Calculated data[5,6]					Measurement data
		$E1$	$E2$	$E3$	$M1$	$M2$	
1597	$10^3\ \alpha_K$	0.32	0.68	1.24	0.87	1.91	
	$10^4\ \Gamma_p;\ Z=0$	3.48	1.23	0.48	0.64	0.28	
	$10^4\ \Gamma_p;\ Z=84$	2.14	0.92				
	$10^2\ \Gamma_p/\alpha_K;\ Z=0$	109	18.1	3.86	7.35	1.45	$I_{e+}/I_{e-} = 15.5 \pm 0.5$
	$10^2\ \Gamma_p/\alpha_K;\ Z=84$	67	13.5				
2332	$10^3\ \alpha_K$	0.16	0.33	0.56	0.38	0.76	
	$10^4\ \Gamma_p;\ Z=0$	8.84	4.80	2.56	3.20	1.95	
	$10^4\ \Gamma_p;\ Z=84$	7.32	3.70				
	$10^2\ \Gamma_p/\alpha_K;\ Z=0$	550	145	45.5	84	25.8	$I_{e+}/I_{e-} = 116$
	$10^2\ \Gamma_p/\alpha_K;\ Z=84$	460	112				
2527	$10^3\ \alpha_K$	0.15	0.30	0.48	0.33	0.64	
	$10^4\ \Gamma_p;\ Z=0$	10.1	5.84	3.44	4.20	2.60	
	$10^4\ \Gamma_p;\ Z=84$	8.68	4.44				
	$10^2\ \Gamma_p/\alpha_K;\ Z=0$	680	194	71.5	130	40.5	$I_{e+}/I_{e-} = 105$
	$10^2\ \Gamma_p/\alpha_K;\ Z=84$	580	148				

cording to our data, are 1597, 1902, 2332, and 2527 kev. These values are in good agreement with those obtained by others.[4] The partial spectra (see diagram) were separated by the value of the steep drop in the summary positron spectrum. It was assumed here that the energy distribution of the internal pair-conversion positrons for Ce^{140} (Z = 58) differs little from the distribution for Z = 84.

As already noted, the multipolarity of the γ rays was determined from the ratio Γ_p/α_K. The calculated and the experimental values of Γ_p/α_K are listed in Table I. The values of α_K were calculated from the Sliv and Band tables.[5] The Γ_p/α_K ratios listed in Table I are given for two values of Γ_p (for Z = 0 and Z = 84), since calculations are available at present only for these values of Z.[6] The experimental ratio of the coefficients of pair conversion and electron conversion was determined from the ratio of the areas of the corresponding partial positron spectra and the conversion K lines. Since the internal-conversion electron spectrum was measured only partially, data on the weakest conversion lines were taken from the work of Dzhelepov, Prikhodtseva, and Khol'nov.[4]

As can be seen from Table I, γ quanta with energy 1597 and 2332 kev have multipolarity of type E2, while the γ quantum of energy 2527 kev is of type M1. Knowing the multipolarity of γ quanta from the ratio Γ_p/α_K, one can determine the values of Γ_p.

Since the intensities of the partial positron spectra are known, then, by knowing Γ_p, one can determine the intensity of the γ quanta. These data are listed in Table II. The same table gives the results of references 4 and 7. As seen from the table, our data on the energy, multipolarity, and intensities of the γ rays are in good agreement with those of Dzhelepov et al.

It was established recently[4] that the 1902-kev transition is a 0 — 0 transition. Our results confirm this. The experimentally obtained value of the ratio of the conversion probabilities on the K shell and with pair production was W_K/W_p = 6.3. At the same time, calculation by the Thomas formula[8] gives for this case a value close to the experimental, W_K/W_p = 7.6.

[1] K. Siegbahn, Beta- and Gamma-Ray Spectroscopy, North Holland, Amsterdam, 1955.
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TABLE II. Data on γ radiation from Ce^{140}

Our data				Data of Dzhelepov et al.[4,7]		
E_γ, kev	Multipolarity	$10^4\ \Gamma_p$	Relative Intensity	E_γ, kev	Multipolarity	Relative Intensity
1597	$E2$	1.15	100	1597	$E2$	100
2332	$E2$	3.9	0.9	2343	$M1$, $E2$	0.78
2527	$M1$	3.2	5.0	2525	$M1$	3.7
2900			0.3	2910	$E2$, $M1$	0.08

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