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Abstract

Full Text

PHYSICS

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RADIATION OF Tb¹⁶⁰

(Presented by Academician A. A. Lebedev, 13 IX 1957)

Using a double-focusing spectrometer through an angle $\pi\sqrt{2}$ (¹), with a relative line half-width of 0.5%, the continuous spectrum, the conversion-electron spectrum, and the photoelectron spectrum of radioactive Tb¹⁶⁰ were measured. The latter was obtained by irradiating chemically pure (99.99%) terbium oxide Tb₂O₃ with slow neutrons.

The continuous spectrum was studied with a source of thickness ~ 1 mg/cm², which was prepared by depositing Tb₂O₃ on a mica backing of thickness ~ 1.5 mg/cm². For a more reliable determination of the endpoint energy and the relative intensity of the hardest component, a source of thickness ~ 4 – 5 mg/cm² was prepared in the same way. The spectrum was decomposed into components by the Curie method. It was assumed in this procedure that their shape was Fermi-like. The results of the measurements are given in Table 1. In view of the comparatively large thickness of the sources, the spectrum below 300 keV may be considerably distorted. Therefore the relative intensity of the softest component was not determined.

Table 1

Results of measurements of the continuous β -spectrum of Tb¹⁶⁰

Components	E_{gr} , keV	Relative intensity
1	450 ± 50	—
2	562 ± 5	100 ± 2.5
3	858 ± 5	64 ± 3
4	1710 ± 10	0.8 ± 0.2

The conversion spectrum was measured with sources of thickness from ~ 0.03 to 4 – 5 mg/cm². Thin sources were prepared by electrolytic deposition of Tb on an aluminum backing of thickness 0.27 mg/cm², and thick ones by depositing Tb₂O₃ on a mica or aluminum backing of thickness ~ 1.5 mg/cm². Nineteen lines were found, belonging to 11 transitions in Dy¹⁶⁰. The measurement results are given in Table 2. The general form of the β -spectrum is shown in Fig. 1.

In studying the decay of Ho^{160} , which was carried out on the same instrument but with a resolving power of 0.3% (²), it was found that the lines belonging to transitions in Dy^{160} with energies 878 and 965 keV are double. These two transitions were also investigated in the decay of Tb^{160} , likewise with a resolving power of 0.3% (Fig. 2).

It is seen from Fig. 2 that the line corresponding to the transition with energy 877 keV is either single, or its softer component is so weak that it cannot be separated on the rise of the harder component. The upper limit of the intensity of the soft component is 7% of the harder one. Although the line corresponding to transitions with energies 961 and 964 keV was not completely resolved, from its shape and half-width it is clearly seen that it consists of two components with the indicated energies and relative intensities of 1 and 2.1, respectively. The decomposition of this line was carried out according to the shape of the 877-keV line.

Table 2

Results of measurements of the spectrum of conversion electrons of Tb^{160}

No.	E_e , keV	Interpretation	$h\nu$, keV	Relative intensity	K/L
1	32.9 ± 0.5	<i>K</i>	86.5 ± 0.5	4600 ± 500	
2	78.6 ± 1.1	<i>L</i>	86.4 ± 1.1	5500 ± 500	0.83 ± 0.2
3	85.3 ± 1	<i>M</i>	86.6 ± 1	1550 ± 150	
4	144.1 ± 1	<i>K</i>	197.9 ± 1	222 ± 10	
5	160 ± 2	<i>K</i>	214 ± 2	37 ± 4	
6	189.9 ± 1	<i>L</i>	197.7 ± 1	61 ± 5	3.65 ± 0.5
7	243.0 ± 1	<i>K</i>	296.8 ± 1	100 ± 5	
8	823.6 ± 1	<i>K</i>	877.4 ± 1	30.5 ± 0.5	
9	869.6 ± 1	<i>L</i>	877.5 ± 1	4.9 ± 0.5	6.2 ± 0.7
10	878 ± 2	<i>M</i>	879 ± 2	1.1 ± 0.2	
11	907.0 ± 1	<i>K</i>	960.8 ± 1	8.6 ± 2	
12	910.2 ± 1	<i>K</i>	964.0 ± 1	18.2 ± 2	26.8 ± 0.5
13	$963.1 \pm 2^*$	<i>L + M</i>	$961 + 964$	5.3 ± 0.4	5.1 ± 0.7
14	1058 ± 2	<i>K</i>	1112 ± 2	0.7 ± 0.2	
15	1123 ± 2	<i>K</i>	1177 ± 2	3.2 ± 0.3	
16	1147 ± 2	<i>K</i>	12.01 ± 2	0.56 ± 0.07	
17	1171 ± 2	<i>L</i>	11.79 ± 2	0.44 ± 0.10	6 ± 2
18	1219 ± 2	<i>K</i>	1273 ± 2	1.3 ± 0.1	
19	1264 ± 3	<i>L</i>	1272 ± 3	0.7 ± 0.2	1.7 ± 0.6

* Complex line.

The source for the photographic experiments was a copper cylinder 36 mm long with an inner diameter of 0.3 mm and an outer diameter of 1.2 mm, which was

Fig. 1. β -spectrum of Tb160

Figure 1: Fig. 1. β -spectrum of Tb160

Fig. 2

Figure 2: Fig. 2

filled with Tb_2O_3 powder. As targets from which photoelectrons were knocked out, the following substances were used: Ag of thickness 0.25 mg/cm^2 , Bi 0.65 and 3 mg/cm^2 , Th 2 mg/cm^2 , and Au 7.7 mg/cm^2 . In all, 13 lines belonging to 8 transitions in Dy^{160} were found. The results of the measurements are given in Table 3.

Fig. 1. β -spectrum of Tb^{160}

The relative intensities of the γ -transitions were obtained by dividing the areas of the lines by the corresponding photoelectric absorption coefficient. A correction was introduced for absorption of γ -rays in the source itself and in the cylinder walls, as well as for absorption of photoelectrons in the target and in the counter windows. Determination of the relative intensities of γ -transitions in this way is justified as follows:

Fig. 2. Conversion lines K 877 keV (a) and K 961 + 964 keV (b). Instrumental half-width of the lines, 0.3%.

The relative intensities of γ -transitions of certain radioactive isotopes (for example, J^{131} , Sb^{124}), known from the literature, were compared with the intensities obtained by us on the basis of photo-line measurements; cascade lines in Co^{60} were also used. In measurements with a source of internal diameter 1 mm it turned out that above 1 MeV the instrument transmits intensities with a relatively small error, but in the region of lower energies the difference becomes appreciable. Thus, for 600 keV the difference reaches 20%, and in the region of 200 keV, 40%. The use of a source with an internal diameter of 0.5 mm makes it possible to determine relative intensities in a broader region. In this geometry, in the region of 600 keV, the error in determining relative intensities amounts to several percent.

In the measurements to which the present work is devoted, the internal diameter of the source was 0.3 mm. Therefore it may be assumed that the relative intensities will be transmitted correctly over a broader energy interval.

Table 3

Averaged results of measurements of the photoelectron spectrum of Tb^{160} with targets of Ag, Au, Bi, and Th

Fig. 3. Photo-peaks of the 878-keV (a) and 967-keV (b) transitions. Half-width of the single line 0.33%, of the doublet 0.62%. Target Th 2 mg/cm²

Figure 3: Fig. 3. Photo-peaks of the 878-keV (a) and 967-keV (b) transitions. Half-width of the single line 0.33%, of the doublet 0.62%. Target Th 2 mg/cm²

No.	$h\nu$, keV	Interpretation	Relative intensity of γ -transition	K/L of photo-lines (Au target)
1	86.2 ± 0.3	K	—	—
2	86.8 ± 0.3	$L_I + L_{II}$	—	—
3	86.6 ± 0.3	L_{III}	—	—
4	196.8 ± 1	K	17 ± 4	—
5	297.8 ± 1	K	100 ± 20	—
6	295 ± 3	L	—	5.6 ± 2.3
7	878 ± 1	K	125 ± 20	—
8	878 ± 3	L	—	5.7 ± 2
9	967 ± 1	K	162 ± 30	—
10	1178 ± 2	K	71 ± 15	—
11	1179 ± 3	$L + M$	—	5.1 ± 1.1 ($K/L + M$)
12	1201 ± 2	K	10 ± 2	—
13	1273 ± 2	K	39 ± 8	—

The correction for absorption for the K - and L -lines of 86.5 keV amounts to more than 50%. In view of the large error, the relative intensity and K/L for this transition are not given.

An attempt was made to separate the 967-keV line into its two components, using a Th target 2 mg/cm² thick and 0.5 mm wide. The measurement results confirmed the presence of two components, but because of the small

statistical accuracy and overlap with the L -line from the 878-keV transition, their intensity ratio could be determined only roughly (see Fig. 3):

$$I_{961}/I_{964} = 1_{-0.5}^{+1.0}.$$

Fig. 3. Photo-peaks of the 878-keV (a) and 967-keV (b) transitions. Half-width of the single line 0.33%, of the doublet 0.62%. Target Th 2 mg/cm².

The ratios of the intensities of the conversion lines and of the corresponding γ -transitions differ only by a numerical factor from the conversion coefficient α_k . This factor was obtained by comparing the intensity ratio of the conversion line and the γ -transition with energy 197 keV with the theoretical value of the conversion coefficient of this transition, since in (2) it was found to be an

electric quadrupole. By multiplying by this factor, the conversion coefficients were obtained for those transitions for which relative intensities are available both for the conversion lines and for the γ -transitions. Their values are given and compared with theoretical ones in Table 4.

Table 4

Experimental and theoretical values of conversion coefficients for some transitions in Dy¹⁶⁰

Transition energy, keV	α_k exper	α_k theor	(K/L) exper	(K/L) theor
86.3	—	—	0.84 ± 0.2	0.98(E2)
197.3	—	$1.7 \cdot 10^{-1}$ (E2)	3.6 ± 0.5	2.9(E2)
297.3	$(1.3 \pm 0.3) \cdot 10^{-2}$	$1.5 \cdot 10^{-2}$ (E1)	—	—
878	$(3.2 \pm 0.5) \cdot 10^{-3}$	$3.4 \cdot 10^{-3}$ (E2)	6.2 ± 0.7	6.5(E2)
961+964	$(2.2 \pm 0.4) \cdot 10^{-3}$	$2.8 \cdot 10^{-3}$ (E2)	5.1 ± 0.7	6.7(E2)
1178	$(5.9 \pm 1.8) \cdot 10^{-4}$	$8.1 \cdot 10^{-4}$ (E1)	6.0 ± 2.0	7.8(E1)
1201	$(7.3 \pm 2.4) \cdot 10^{-4}$	$7.8 \cdot 10^{-4}$ (E1)	—	—
1273	$(4.2 \pm 1.2) \cdot 10^{-4}$	$6.9 \cdot 10^{-4}$ (E1)	1.7 ± 0.6	7.7(E1)

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