INVESTIGATION OF THE RELATIVE INTENSITIES OF SOME CONVERSION LINES OF THE SPECTRUM OF NEUTRON-DEFICIENT LUTETIUM ISOTOPES

M. G. IODKO, V. V. TUCHKEVICH, V. A. ROMANOV, and O. M. KRESIN

Leningrad Physico-Technical Institute, Academy of Sciences, U.S.S.R.

Submitted to JETP editor August 7, 1959

J. Exptl. Theoret. Phys. (U.S.S.R.) **38**, 1027-1030 (April, 1960)

A prism spectrometer was employed to investigate a number of the more intense lines in the conversion spectrum of neutron-deficient lutetium isotopes. The relative intensities and energies of the lines were determined, and the multiplicities of the corresponding γ transitions were derived from the relation between the L -subshell intensities.

SOME of the more intense lines in the conversion spectrum of neutron-deficient isotopes of lutetium were investigated. The measurements were made with a prism spectrometer having a transmission ~ 0.1% and an instrument half width ~ 0.1%.[1,2] It must be noted that the widths of the conversion lines were greater than the instrument width, owing to the finite source thickness.

Two sources were used, comprising isotopes of the lutetium fraction separated from a tantalum target bombarded by fast protons (660 Mev). The first source was used to measure the energies and intensities of the 66, 70, and 75.85-kev conversion line in the spectrum of Lu^{171} ($T_{1/2}$ ~ 8 days), and of the 78.70- and 90.55-kev lines in the spectrum of Lu^{172} ($T_{1/2}$ ~ 6.7 days). The second source was used to determine the relative intensities of the γ 84.19-kev L lines in the spectrum of Lu^{170} ($T_{1/2}$ ~ 2 days), of the γ 87.30-kev L lines in the spectrum of Lu^{169} ($T_{1/2}$ ~ 2 days), and also the relative intensities of the γ 181.4-kev L lines in the spectrum of Lu^{172} (reference 3). The second source was considerably thicker than the first, and consequently the conversion lines were greatly smeared and hence difficult to separate. The data obtained with this source are consequently merely tentative.

The line energy was measured by the bias method.[4] By using a constant magnetic field in the spectrometer and varying the voltage applied between the source and the case of the spectrometer, it is possible to plot small portions of the spectrum. This method can be used to determine with great accuracy the energy distance between the conversion lines, and by measuring the energy distance between a line of known energy and the investigated line it is possible to determine accurately the energy of the latter. In our case the measurement of the energy of the conversion lines was facilitated by the fact that the lutetium fraction contained Yb^{169}, of which the spectrum has been thoroughly investigated and the energies of the γ transitions measured by the crystal-diffraction method.[5,16]

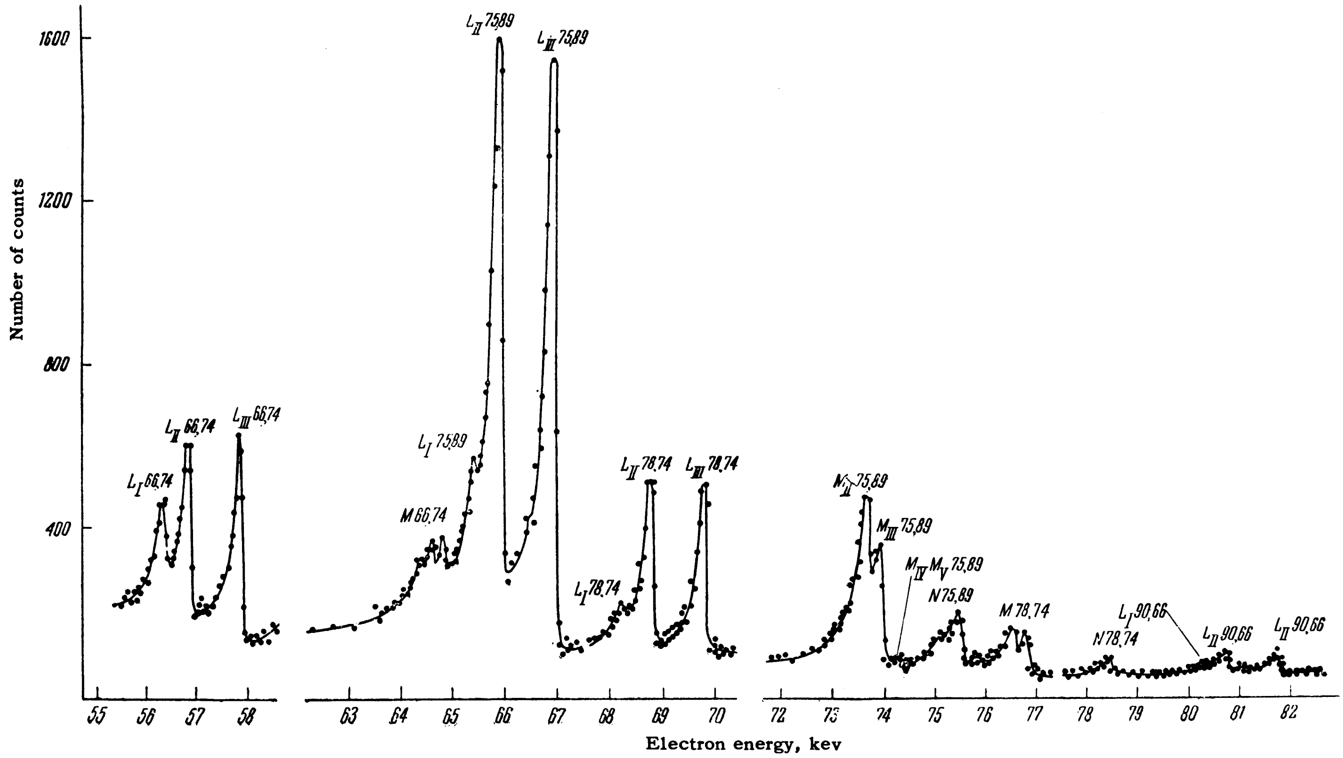
The reference line employed was $K\gamma$ (109.78 ± 0.02) kev. The binding energy of Tm on the K shell [E_K = (59.40 ± 0.01) kev] was calculated from the data of reference 6. The binding energies on the L subshells were taken from the tables (see reference 7). The bias method was used to measure directly, in volts, the energy distance from the reference line to the investigated line, and to calculate the energy of the γ transition from the values of the electron binding energies in the atom. The distance between the conversion lines was determined accurate to several volts.

Table I lists the values obtained for the energies of the conversion lines and the calculated transition energies. The energy of the 130.52 ± 0.03 and 93.60 ± 0.03 kev γ transitions in the spectrum of Yb^{169}, calculated in this manner, coincide with the values of the energy obtained with a curved-crystal spectrometer:[5] 130.53 ± 0.03

TABLE I

Line energy, kev	Identification and γ-transition energy, kev
50.38±0.02	$K\gamma$ (109.78±0.02)* in Tm
56.75±0.02	$L_{II}\gamma$ (66.74±0.02) in Yb
66.94±0.03	$L_{III}\gamma$ (75.89±0.03) in Yb
69.79±0.03	$L_{III}\gamma$ (78.74±0.03) in Yb
71.12±0.03	$K\gamma$ (130.52±0.03) in Tm
81.71±0.03	$L_{III}\gamma$ (90.66±0.03) in Yb
83.50±0.03	$L_{I}\gamma$ (93.62±0.03) in Tm

*The energy of this transition is taken from reference 5.



and 93.60 ± 0.04 kev respectively.

The diagram shows the conversion lines of the spectrum of the neutron-deficient isotopes of Lu, obtained with the first source (the instrument spectrum, without correction for Hρ and for decay). The spectrum was plotted by bias, in sections 4 — 6 kev wide, over approximately 12 days.

The ratio of the intensities of the conversion lines for the transitions from the L subshells make it possible to establish the multipolarity of the transitions with a great degree of certainty.

Table II lists the ratios of the intensities of the L-conversion lines of the 66.74- and 75.89-kev transitions in the spectrum of Lu^{171}. Both transitions occur between levels of the main rotational band of Yb^{171}. The spin of the ground state of Yb^{171} is one-half.[8] The sequence of the levels was unambiguously established in reference 9. The 66.74-kev transition is mixed (68% M1 + 32% E2). The Sliv and Band tables[10] were used to calsulate the E2 admixture, both from the L_{II}/L_I ratio and from the L_{III}/L_I ratio, accurate to ±2% (this includes the errors connected with the inaccuracy in the calculated internal-conversion coefficients). The 75.89-kev transition is of the E2 type. The intensity ratio on the L subshells excludes with great certainty all transitions with the exception of E2 and E3. The measured L_I/L_{III} ratio indicates that the transition is of the E2 type. The multipolarity of this transition was determined as E2 in reference 11, and as E3 in references 12 and 13.

The intensity ratio on the M_I, M_{II}, and M_{III} subshells is close to the ratio on the L_I, L_{II}, and L_{III} subshells. For the 66.74-kev γ transition, $M_I : M_{II} : M_{III} = 1 : 1.29 : 1.55$, while for the 75.89-kev γ transition $M_I + M_{II} : M_{III} : M_{IV} + M_V = 0.89 : 1 : 0.06$. It is interesting to compare the ratio of the intensities of the M lines of the 75.89-kev γ transition with the calculated ratios of the coefficients of internal conversion on the M subshells, given in reference 14. The calculated ratios are $M_I + M_{II} : M_{III} : M_{IV} + M_V =$ 0.96 : 1 : 0.032 and 1.08 : 1 : 0.113 for the E2 and E3 transitions respectively.

Table III lists the ratio of the intensities of the conversion lines from the L subshells for three transitions in the spectrum of Lu^{178}. The 78.74-

TABLE II

E_γ, kev	$L_I : L_{II} : L_{III}$			$L : M$
	Experiment	Theory, from E2	Theory, from E3	Experiment
66.74	1 : (2.00±0.04) : (2.02±0.02)	1 : 25.5 : 27.9	—	2.8
75.89	(0.050±0.003) : (0.97±0.01) : 1	0.053 : 0.95 : 1	0.018 : 1.04 : 1	3.1

TABLE III

E_γ, kev	$L_I : L_{II} : L_{III}$		
	Experiment	Theory, from E2	Theory, from M1
78.74	(0.09±0.02) : (0.97±0.04) : 1	0.06 : 0.96 : 1	
90.66	(0.28±0.01) : (1.11±0.03) : 1	0.09 : 1.01 : 1	1 : 0.091 : 0.013
181.4	0.52 : 1.27 : 1	0.57 : 1.32 : 1	—

and 181.4-kev transitions are E2, and represent the transitions of the principal rotation band of the even-even nucleus Yb^{172}. The L_I line of the 78.74-kev transition is somewhat too high, owing to the presence of the long-lived Lu^{173} in the source. The 78.74-kev L_I γ line in the spectrum of Lu^{172} coincides with one of the strongest lines in the spectrum of Lu^{173} (L_I γ, 78.6 kev). It is very difficult to separate these lines. The 90.66-kev transition in the spectrum of Lu^{172} is one of the transitions between the upper excited states. From the intensity ratio of the L lines one can calculate the value of the mixture of the different multipolarities (assuming that the mixture is M1 + E2). The transition was found to be 30% M1 + 70% E2. The 84.19-kev transition in the spectrum of Lu^{170} is of type E2 and is a transition from the first excited state to the ground state of the even-even nucleus Yb^{170} (reference 15). The experimental value of the $L_I : L_{II} : L_{III}$ ratio is 0.09 : 0.97 : 1, against the theoretical 0.07 : 0.98 : 1. The 87.30-kev transition in the spectrum Lu^{169} has an intensity ratio $L_I : L_{II} : L_{III}$ = 1:0.08:0.28. The calculated admixtures of E2)assuming a M1 + E2 mixture) give 9%and 4% for L_{III}/L_I and L_{II}/L_I respectively. It is obvious that the E2 admixture does not exceed 10%, although the exact value of the mixture cannot be established, for in the region of L lines of this transition there are many lines of other longer-lived isotopes, which are difficult to separate.

[1] Kel'man, Kaminskiĭ, and Romanov, Izv. Akad. Nauk SSSR, Ser. Fiz. **18**, 209 (1954).

[2] Kel'man, Metskhvarishvili, Preobrazhenskiĭ, Romanov, and Tuchkevich, JETP **37**, 639 (1959), Soviet Phys. JETP **10**, 456 (1960).

[3] Kel'man, Metskhvarishvili, Preobrazhenskiĭ, Romanov, and Tuchkevich, JETP **35**, 1309 (1958), Soviet Phys. JETP **8**, 914 (1959).

[4] V. A. Romanov, Izv. Akad. Nauk SSSR, Ser. Fiz. **22**, 191 (1958), Columbia Tech. Transl. p. 188.

[5] Hatch, Boehm, Mormier, and Du Mond, Phys. Rev. **104**, 745 (1956).

[6] Chupp, Du Mond, Gordon, Jopson, and Mark, Phys. Rev. **112**, 1183 (1958).

[7] K. Siegbahn, Beta- and Gamma-Ray Spectroscopy, Appendix VI, Amsterdam, 1955.

[8] A. H. Cooke and J. G. Park, Proc. Phys. Soc. **A69**, 282 (1956).

[9] Elbek, Nielsen, and Olesen, Phys. Rev. **108**, 406 (1957).

[10] L. A. Sliv and I. M. Band, Таблицы коэффициентов внутренней конверсии гамма-излучения, ч. 2, *L*-оболочка, (Table of Gamma-Ray Internal-Conversion Coefficients part 2, L Shell) Acad. Sci. Press, 1958.

[11] Bobrov, Gromov, Dzhelepov, and Preobrazhenskiĭ, Izv. Akad. Nauk SSSR, Ser. Fiz. **21**, 940 (1957), Columbia Tech. Transl. p. 942.

[12] J. W. Mihelich and B. Harmatz, Phys. Rev. **106**, 1232 (1957).

[13] Mihelich, Harmatz, and Handley, Phys. Rev. **108**, 989 (1957).

[14] M. E. Rose, Internal Conversion Coefficients, Amsterdam, 1958.

[15] J. W. Mihelich and E. L. Church, Phys. Rev. **85**, 690 (1952).

[16] Chupp, Du Mond, Gordon, Jopson, and Mark, Phys. Rev. **112**, 518 (1958).

Translated by J. G. Adashko
207