MULTIPOLARITIES OF GAMMA TRANSITIONS IN Tm^{169}

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The ratios of the internal conversion coefficients of 63, 94, 110, 130.5, 177 and 198 kev γ quanta in the L-subshells of Tm^{169} have been found. From these data, we determine the multipolarities of the transitions and, in the case of mixed radiations, the percentages of components in the mixture.

THE gamma spectrum and conversion electron spectrum of excited Tm^{169}, formed by electron capture from radioactive Yb^{169} (half-life 32 days), have been studied by many authors.[1-9] The Tm^{169} nucleus is highly deformed, and one sees very clearly in its level scheme* (Fig. 1) the rotational band with $K = \frac{1}{2}$ (the levels at 0, 8.4, 118, and 139 kev). The lowest level of this band, with spin $\frac{1}{2}$ and positive parity, is the ground state of Tm^{169}. The levels at 316 and 379 kev are associated with single-particle excitation of the nucleus, while the level at 379 together with the one at 473 kev form the rotational band with $K = 7/2$. Most of the γ transitions are mixtures of dipole and quadrupole. Up to now the composition of the mixtures has not been determined sufficiently accurately, and the data from different papers differ markedly from one another. The most accurate determination of the mixture percentages was made in reference 5. These authors used, in addition to other methods for determining the multipolarities, the measurement of the ratio of the conversion coefficients in the L-subshells. They made these measurements quite accurately for the conversion of the 130.5 kev line. For the harder γ rays at 177 and 198 kev, they made only an approximate determination of the ratio $L_I : L_{III}$.

In the present paper we give results of measurements of the ratios of conversion coefficients of γ quanta with energies 63, 94, 110, 130.5, 177, and 198 kev in the L-subshells of Tm^{169}. We have determined the multipolarities of the transitions, and the percentages of the mixture in cases of mixed radiation. The measurement of the ratio of intensities of conversion lines from the first γ ray listed was done on a double-focusing β-ray spectrometer in which the relative half-width of the line was 0.4% (in momentum). The remaining measurements were done on a β-spectrometer constructed in analogy to an optical spectrometer.[10,11] It consists of a magnetic deflection system (prism) and two magnetic lenses. The source was a thin layer of Yb^{169} placed on a strip of aluminum foil. Its dimensions were 5×1 mm^2. The preparation of the source was accomplished as follows. A tantalum target was irradiated with 680-Mev protons at the synchrocyclotron of the Joint Institute for Nuclear Studies. The rare earths produced by spallation reactions were separated by the ion exchange method on a sulfostirol cation KU-2, using ammonium lactate[12,13] as a complexing agent. The principal activity of a particular element was concentrated in 1 or 2 drops of the ammonium lactate solution (concentration 0.2 to 0.4 M in the lactate) emerging from the column.

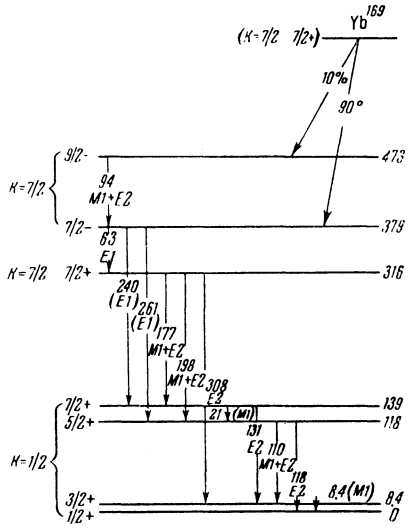

FIG. 1. Level scheme of Tm^{169}.

*This level scheme is taken from reference 4, but the multipolarity assignments have been corrected in accordance with the results of the present work.

Even careful evaporation of these drops directly onto the source results in some tarring of the lactate and formation of some residue. If the source is prepared on a thin aluminum foil or organic film, heating to burn off the residue is not possible. Therefore the lactate drops carrying the activity were first evaporated onto another backing, and then the activity was taken up in a drop of ~1% solution of acetic acid, which was placed on the source backing and evaporated. In this way the activity was almost completely transferred.

Using this method, we separated and deposited on an aluminum foil the Lu fraction, which contains Lu^{169}. The latter decays with a period of ~2 days to Yb^{169}.[14] The measurements of the conversion spectrum of Tm^{169} were begun about a month after the separation of the Lu fraction, so that the radioactive lutecium isotopes had had time to decay sufficiently and the main activity was that of Yb^{169}. The measurements of the internal conversion lines of the 130.5-kev line in the L-subshells of Tm^{169} were done three months after the separation, because the L_I conversion line is superimposed on a strong line from K-conversion of the 181.4 kev γ ray accompanying the Lu^{172} — Yb^{172} decay (Lu^{172} half-life is 6.7 days).

Because the source was quite thick, the resolving power of the spectrometer cited in reference 11 (instrumental relative half-width of line = 0.04%) could not be reached. It therefore seemed reasonable to reduce the resolution of the instrument and thus raise its luminosity. For this purpose we reduced the focal separation of the lenses from 120 to 50 cm and brought the source and detector correspondingly closer to the lenses. This reconstruction of the instrument increased the instrumental half-width by a factor of about 2.4, but the solid angle increased by a factor of 5 or 6, reaching a value of ~0.1% of 4π. The relative half-width found in the experiment, resulting from slowing down of electrons in the source, was

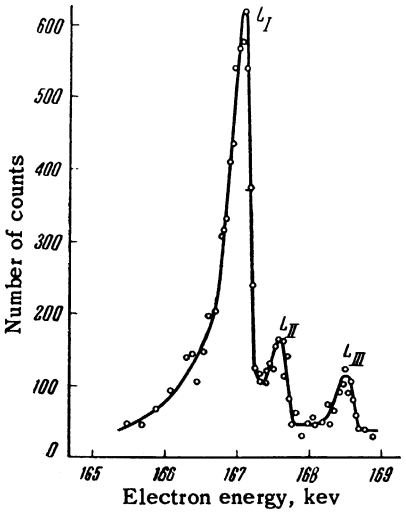

FIG. 2. Conversion lines of 177 kev radiation in the L-subshells of Tm^{169}.

0.12 — 0.20% (in momentum). In all cases the lines were resolved sufficiently well for the later graphical separation. To illustrate this, we show in Figs. 2 and 3 the conversion lines of the 177 and 198 kev radiations in the L-subshells of Tm^{169}.

The ratios of the internal conversion coefficients and the multipolarities determined from them are given in the table. The percentage composition of the mixed radiations was determined

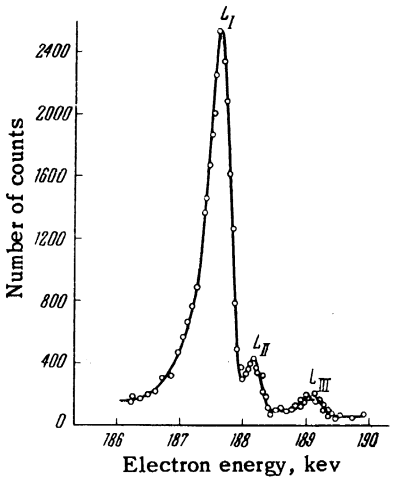

FIG. 3. Conversion lines of 198 kev radiation in the L-subshells of Tm^{169}.

Multipolarities of γ-transitions and ratios of conversion coefficients in L-subshells for Tm^{169}

Energy of transition in kev	$L_I : L_{II} : L_{III}$	Multipolarity of transition found from ratio: L_{II}/L_I	Multipolarity of transition found from ratio: L_{III}/L_I	Average value
63	1 : (0.44±0.01) : (0.50±0.02)	*E1*	*E1*	*E1*
94	1 : (0.179±0.006) : (0.085±0.005)	96.2% *M1* + +3.8% *E2*	96.9% *M1* + +3.1% *E2*	96.5% *M1* + +3.5% *E2*
110	1 : (0.133±0.003) : (0.053±0.002)	97.5% *M1* + +2.5% *E2*	97.5% *M1* + +2.5% *E2*	97.5% *M1* + +2.5% *E2*
130.5	(0.23±0.01) : (1.09±0.03) : 1	*E2*	*E2*	*E2*
177	1 : (0.24±0.01) : (0.137±0.006)	82% *M1* + +18% *E2*	82% *M1* + +18% *E2*	82% *M1* + +18% *E2*
198	1 : (0.135±0.002) : (0.063±0.001)	93% *M1* + +7% *E2*	90% *M1* + +10% *E2*	91.5% *M1* + +8.5% *E2*

independently from the ratios L_{II}/L_I and L_{III}/L_I, which were compared with the corresponding theoretical ratios.[15] The average of these two values was taken for the final result.

Our results confirm the level scheme shown in Fig. 1. An interesting point is the large admixture of E2 to the M1 radiation in the 177 and 198 kev transitions. This is apparently caused by K-forbiddenness of the transition from the 316-kev level to the lower levels.

[1] S. A. E. Johansson, Phys. Rev. **100**, 835 (1955).

[2] B. R. Mottelson and S. G. Nilsson, Z. Physik **141**, 217 (1955).

[3] Cork, Brice, Martin, Schmid, and Helmer, Phys. Rev. **101**, 1042 (1956).

[4] Hatch, Boehm, Marmier, and DuMond, Phys. Rev. **104**, 745 (1956).

[5] Mihelich, Ward, and Jacob, Phys. Rev. **103**, 1285 (1956).

[6] Baranov, Polevoĭ, Rodionov, and Shishkin, Атомная энергия (Atomic Energy) **3**, 256 (1957).

[7] Gromov, Dzhelepov, and Preobrazhenskiĭ, Izv. Akad. Nauk SSSR, Ser. Fiz. **22**, 775 (1958), Columbia Tech. Transl. p. 770.

[8] E. N. Hatch and D. E. Alburger, Phys. Rev. **110**, 1116 (1958).

[9] U. Capeller and R. Klingelhoefer, Z. Physik **150**, 375 (1958).

[10] Kel'man, Kaminskiĭ, and Romanov, Izv. Akad. Nauk SSSR, Ser. Fiz. **18**, 148, 209 (1954).

[11] Kel'man, Romanov, Metskhvarishvili, and Kolyunov, JETP **32**, 39 (1957), Soviet Phys. JETP **5**, 24 (1957).

[12] Preobrazhenskiĭ, Lilova, Dobronravova, and Teterin, Ж. неорг. химии (Journal of Inorganic Chemistry) **1**, 2294 (1956).

[13] B. K. Preobrazhenskiĭ, ibid. **3**, 119 (1958).

[14] Gorodinskiĭ, Murin, Pokrovskiĭ, and Preobrazhenskiĭ, Izv. Akad. Nauk SSSR, Ser. Fiz. **21**, 1004 (1957), Columbia Tech. Transl. p. 1005.

[15] L. A. Sliv and I. M. Band, Таблицы коэффициентов внутренней конверсии гамма-излучения (Tables of Internal Conversion Coefficients of Gamma-Radiation), vol. 2, Moscow-Leningrad, 1958.

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