

**Corresponding Member of
the Academy of Sciences
of the USSR B. S.
DZHELEPOV, M. E.
VOIKHANSKII,**

A. I. MEDVEDEV, I. F. UCHEVATKIN

1962

SovietRxiv

View the original and related papers at <https://sovietrxiv.org/items/ru-196201.73635>

Source: Math-Net.Ru and CyberLeninka. Machine translation. Verify with the original.

Abstract

Full Text

PHYSICS

Corresponding Member of the Academy of Sciences of the USSR B. S. DZHELEPOV, M. E. VOIKHANSKII,
A. I. MEDVEDEV, I. F. UCHEVATKIN

ON THE NATURE OF THE 531.8 keV LEVEL OF Er^{167}

As a result of the work (^{1,2}), it was established that in Er^{167} there is an excited state with an excitation energy of 531.8 keV and quantum characteristics $3/2^+$.

The decay scheme of $\text{Tm}^{167} \rightarrow \text{Er}^{167}$ is shown in Fig. 1. The question arises: why are transitions to the levels $1/2^-$ [521] 207.9 keV and $3/2^-$ [521] 265.0 keV not observed (dashed transitions in Fig. 1)? After all, these are transitions of type $E1$ and should successfully compete with a transition of type $E2$.

1. Predictions of the theory. If one compares the intensities of the $E2$ transition with energy 531.8 keV and of the $E1$ transitions with energies 323.9 and 266.8 keV by the Weisskopf-Moshkovsky formulas (³)*, one obtains:

$$\begin{aligned} 531.8 \text{ keV, } E2 : \quad \lambda &= 0.74 \cdot 10^8 A^{4/3} E_\gamma^5 = 2.8 \cdot 10^9 \text{ s}^{-1}, \\ 323.9 \text{ keV, } E1 : \quad \lambda &= 1.03 \cdot 10^{14} A^{2/3} E_\gamma^3 = 1.1 \cdot 10^{14} \text{ s}^{-1}, \\ 266.8 \text{ keV, } E1 : \quad \lambda &= 1.03 \cdot 10^{14} A^{2/3} E_\gamma^3 = 5.7 \cdot 10^{13} \text{ s}^{-1}. \end{aligned}$$

i.e., the $E1$ transitions should be more than 10^4 times as intense as the 531.8 keV transition.

One may try to refine the transition probabilities by assigning definite asymptotic quantum numbers to the $3/2^+$ level and using the Nilsson wave functions.

Table 1

Energy and type of tran- si- tion	$\lambda_{\gamma},$ s^{-1}	I_K	$\lambda_{\gamma},$ s^{-1}	I_K	$\lambda_{\gamma},$ s^{-1}	I_K	$\lambda_{\gamma},$ s^{-1}	I_K
Energy and type of tran- si- tion	651	651	402	402	642	642	631	631
531.8 keV, <i>E2</i>	$7.6 \cdot 10^7$	1	$3.2 \cdot 10^3$	1	$2.9 \cdot 10^7$	1	$2.2 \cdot 10^8$	1
323.9 keV, <i>E1</i>	$3.6 \cdot 10^9$	47	$4.9 \cdot 10^{10}$	$1.5 \cdot 10^7$	$7.7 \cdot 10^{11}$	$2.7 \cdot 10^4$	$7.0 \cdot 10^{10}$	320
266.8 keV, <i>E1</i>	$1.6 \cdot 10^9$	34	$2.2 \cdot 10^{10}$	$1.1 \cdot 10^7$	$3.4 \cdot 10^{11}$	$1.9 \cdot 10^4$	$3.2 \cdot 10^{10}$	230

On the Nilsson diagram ⁽⁵⁾, in the immediate vicinity of the level $7/2^+$ [633] (the ground state of Er^{167}) there are no levels with spin $3/2^+$. The levels $3/2^+$ [402] and $3/2^+$ [651] are located 4-5 levels below the ground state, and therefore their excitation seems unlikely. The levels $3/2^+$ [642] and $3/2^+$ [631] are located, respectively, above the ground state. In the original Nilsson diagram ⁽⁵⁾ they were situated very high, but in the variant proposed by Griffin and Rich ⁽⁶⁾ they were shifted somewhat downward. Nevertheless, at a deformation of ~ 0.3 (the probable value for Er^{167}), the level $3/2^+$ [642] is the seventh excited one, and the level $3/2^+$ [631] lies still higher. For all four sets of asymptotic—

* The numerical coefficients in λ are smaller than in the generally accepted formulas ⁽⁴⁾ by factors of 2.2 and 1.4 because of the change in the nuclear radius: $r = 1.2 \cdot 10^{-13} A^{1/3}$ cm instead of $1.45 \cdot 10^{-13} A^{1/3}$ cm.

for the level $3/2^+$ 531.8 keV, the probabilities of the transitions under discussion (λ) and the relative intensities of the corresponding K -conversion lines (I_K) were calculated. The results are given in Table 1. In all four cases the prohibitions by asymptotic quantum numbers weaken transitions of the $E1$ type, but nevertheless they should be very intense and easily observable. This is a consequence of the assumption that the $3/2^+$ level is a one-particle level.

Fig. 1. Decay scheme of ^{167}Tm . Double lines denote Coulomb excitation;

Fig. 1. Decay scheme of ^{167}Tm . Double lines denote Coulomb excitation; dashed lines denote transitions sought in the present work.

Figure 1: Fig. 1. Decay scheme of ^{167}Tm . Double lines denote Coulomb excitation; dashed lines denote transitions sought in the present work.

Fig. 2

Figure 2: Fig. 2

dashed lines denote transitions that were sought in the present work.

2. Experimental part. We undertook a search for the weak K 323.9 and K 266.8 lines of ^{167}Er . For this purpose we used a spectrometer with double focusing at an angle $\pi\sqrt{2}$ ⁽⁷⁾, having a very low background, which is especially important in searches for weak lines. Strict requirements were also imposed on the ^{167}Tm preparation: it had to contain as few impurities as possible; the impurity ^{168}Tm (85 days), whose conversion spectrum contains very many lines, was especially dangerous. In view of this, ^{167}Tm was obtained as a decay product of ^{167}Lu , produced in the reaction $\text{Ta} + p$ (660 MeV) (chromatographic separation of thulium from the decay products of the lutetium fraction).

Table 2

Conversion line	Counting rate, counts/min	Relative intensities of conversion lines
L 265.0	< 0.05	< 0.04
K 266.8	< 0.05	< 0.04
L 266.8	< 0.10	< 0.07
K 323.9	< 0.05	< 0.04
K 531.8	3	1.00

Figure 2 and Table 2 present the results of the experiments. On the K 531.8 line the counting rate reached 3 counts/min. In the places where the K 323.9 and L 266.8 lines should be located, the counting rate was less than 0.05 and 0.10 counts/min, respectively; these values determine the limits indicated in Table 2.

In the energy region 250–400 keV the counting rate nevertheless does not fall below 0.02 counts/min, although the background is < 0.0004 counts/min (< 1 count in 40 h). Apparently the source contains some unremoved impurity.

It is difficult to search for the K 266.8 line, since it is located near the steep fall-off of the strong (on this scale) N 207.9 line; nevertheless, here too, as can be seen

from Fig. 3, one can establish a limit for the counting rate: < 0.05 counts/min. In order to pass from the counting rate to the intensities of the lines, it is necessary to know the efficiency of the instrument. In our instrument it depends on the energy of the electrons; we used a linear interpolation of the efficiency between the N 207.9 and K 531.8 lines.

Machine Translation

Fig. 2. Portions of the spectrum of conversion electrons in the energy interval 253–275 keV and 468–476 keV

Fig. 3

Figure 3: Fig. 3

The results given in Table 2 show that the transitions with energies 323.9 and 266.8 keV are at least 25 times weaker than the 531.8-keV transition.

3. Conclusions concerning the 531.8-keV level. Transitions with energies 323.9 and 266.8 keV are very strongly hindered—by not less than 10^6 times in comparison with single-particle transitions described by the Weisskopf-Moshkowsky formula, and by not less than 10^3 times in comparison with single-particle transitions described by Nilsson's formulas. In view of this, it seems necessary to us to conclude that the $3/2^+$ 541.8-keV level of Er^{167} is a collective level. Levels of this type occur in odd nuclei, but rarely; one may expect that for them transitions of type $E1$ will be strongly hindered.

Fig. 3. Portion of the spectrum of conversion electrons in the energy interval 202–212 keV.

4. On the transition with energy 265.0 keV. At the same time we determined an upper limit for the intensity of the L 265.0 line—the L -line of the transition $3/2^- [521] 265.0 \text{ keV} \rightarrow 7/2^+ [633]$ ground state of Er^{167} (see Fig. 1). Judging by spin and parity, this transition is of type $M2$, and if the Er^{167} nucleus were not deformed, it could occur in 0.1% of the decays (according to Weisskopf-Moshkowsky, $\lambda = 1.2 \cdot 10^8 A^{2/3} E_\gamma^5 = 3.2 \cdot 10^6 \text{ s}^{-1}$). However, the $3/2^-$ level is rotational, and the transition must be of the same type as for the $1/2^-$ level, i.e., $E3$; in this case it can no longer compete with rota-

transition $3/2^- \rightarrow 1/2^-$. Moreover, the $E3$ transition ($3/2^- \rightarrow 7/2^+$) is forbidden by the asymptotic quantum numbers. Thus, the absence of the line L 265.0 in our spectrum is understandable.

The authors express their gratitude to G. S. Novikov for preparing the source; to V. D. Vitman, A. Meshter, V. A. Balalaev, and K. M. Shperling for assistance in the measurements; and to G. A. Mtvrlashvili for participation in the measurements and in the processing of their results.

All-Union Scientific Research Institute of Metrology
named after D. I. Mendeleev

Received
30 VI 1962

CITED LITERATURE

1. K. Ya. Gromov, B. S. Dzhelepov et al., *Izv. AN SSSR, ser. fiz.*, **26**, No. 8 (1962).

2. Yu. P. Gangrsky, I. Kh. Lemberg, *Izv. AN SSSR, ser. fiz.*, **26**, No. 8 (1962).
3. M. E. Voikhanskii, in: *Gamma Rays*, Publishing House of the USSR Academy of Sciences, 1961, p. 20.
4. S. A. Moshkovskii, in: *Beta- and Gamma-Spectroscopy*, 1959, p. 369.
5. S. Nilsson, *Deformed Atomic Nuclei*, II, 1958, p. 276.
6. J. Griffin, M. Rich, *Phys. Rev.*, **118**, 850 (1960).
7. S. A. Shestopalova, *Izv. AN SSSR, ser. fiz.*, **25**, 1302 (1961).

Note: Figure translations are in progress. See original paper for figures.

Source: Math-Net.Ru and CyberLeninka. Machine translation. Verify with the original.