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Short note

New investigation of the decay of the high-spin isomer in ^{151}Er

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Abstract. The decay of the $T_{1/2} = 420$ ns isomer in ^{151}Er has been reinvestigated. The multipolarities of the decaying transitions have been established by measuring the electron conversion coefficients. An $I^\pi = 67/2^-$ assignment is proposed for this isomer with a $\pi[h^4_{11/2}d^1_{3/2}d^{-1}_{5/2}]\otimes\nu[f_{7/2}h_{9/2}h^{-1}_{11/2}]$ configuration.

PACS. 21.10.Pc Single-particle levels – 23.20.Lv Gamma transitions and level energies – 23.20.Nx Internal conversion and extranuclear effects – 27.70.+q 150≤A≤189

1 Introduction

Many studies on high-spin isomers have been reported for the $N = 83$ isotones since the first observation of a long-lived state in ^{147}Gd [1] and the predictive theoretical calculations [2]. Later, using various fusion reactions induced by heavy ions, the level schemes of $N = 83$ isotones have been extended to higher excitation energies, revealing complex and different situations along the yrast cascades. The only similarity concerns yrast states with spin $I = 27/2$ and negative parity known as isomers in the isotopes ^{147}Gd [1], ^{149}Dy [3], ^{151}Er [4], and ^{153}Yb [5]. These isomers were all interpreted by a $[\pi h^2_{11/2} \otimes \nu f_{7/2}]$ configuration.

In ^{151}Er, the $I^\pi = 27/2^-$ state (^{151m_1}Er) is located at 2586 keV excitation energy with $T_{1/2} = 0.6$ s. Its gamma decay modes proceed mainly via a 57.7 keV $E3$ transition [6]. Recently, in a more detailed study of this de-excitation [7], several weakly fed excited states have been observed in agreement with complementary results reported on the ^{151}Tm $11/2^-$ β-decay [8]. From all these data, the first $11/2^+$ excited state at 1721 keV in ^{151}Er can be firmly characterized as a member of the $(\nu f_{7/2} \otimes 3^-)$ septet and included in systematics for $N = 83$ isotones from $^{143}_{60}$Nd to $^{153}_{70}$Yb.

Though high-spin states are expected to arise mainly from the alignment of $h_{11/2}$ protons and $f_{7/2}$, $h_{9/2}$ and $i_{13/2}$ neutrons, the level patterns developed above the $I^\pi = 27/2^-$ isomeric states exhibit very different behaviours in the $N = 83$ isotones. One long-lived isomer $T_{1/2} = 420$ ns with a probable spin $I = (67/2, 71/2)$ has been observed in ^{151}Er at around 10.3 MeV excitation energy [9].

It decays dominantly through one γ-ray cascade. On the contrary, long-lived isomeric states with spins ranging from 45/2 to 49/2 have been reported at 8.6 MeV in ^{147}Gd [10–12] and 7.4 MeV in ^{149}Dy [13]. Their γ-decay modes are more complex than in ^{151}Er, including parallel cascades. Above these isomers, the high-spin level structures remain complex, without any other long-lived isomeric state up to 16.9 MeV in ^{147}Gd [12] or 12.2 MeV in ^{149}Dy [13].

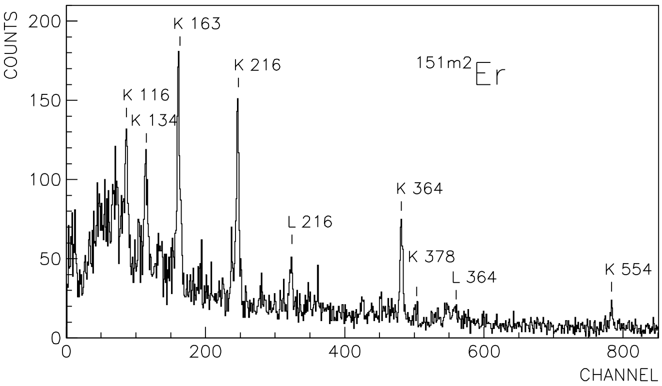

Fig. 1. Conversion electron spectrum in coincidence with the strongest γ-rays decaying from the ^{151m_2}Er isomer.

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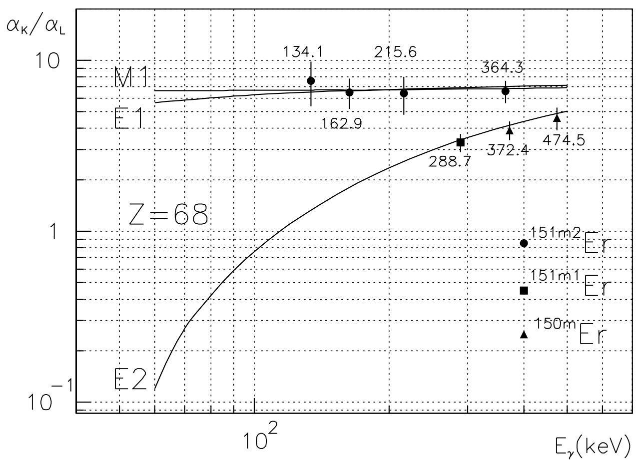

Fig. 2. α_K/α_L ratios for the strongest converted transitions decaying from the ^{151m_2}Er isomer. Some others values for transitions of known multipolarity, in ^{151m_1}Er and ^{150m}Er, are also reported.

In a previous work on ^{151}Er [9] the order of the transitions along the decay-cascade was deduced from two independent experiments using a 175 MeV ^{12}C beam on ^{144}Sm and a 220 MeV ^{40}Ca beam on ^{116}Sn.

The highest isomeric state (^{151m_2}Er) and the three γ-rays at 364.3, 1011.7 and 894.6 keV placed at the top of the level scheme were not excited in the ^{12}C reaction. The tentative spin-parity assignments proposed above the $I^\pi = 27/2^-$ state were based essentially on angular distribution results, those relative to the highest transitions being imprecise. The $M1$ character of the low-energy transitions at 116.3, 134.1, 162.9 and 215.6 keV was deduced from intensity balance considerations.

In view of this situation, we have reinvestigated the γ-decay of the 420 ns high-spin yrast isomer ^{151m_2}Er, adding conversion electron measurements needed to establish spin-parity assignments.

2 Experimental set-up and results

High-spin states were populated with the^{116}Sn(^{40}Ca,2p3n) reaction. The 220 MeV ^{40}Ca beams provided by the Grenoble variable energy cyclotron bombarded thin self-supporting Sn targets of enriched to 98% in ^{116}Sn. The recoil shadow method was used. The complete experimental set up has been recently described in detail [14]. The target was placed in front of a catcher collecting the recoil products of the reaction, at a sufficient distance of the beam axis. Simultaneously conversion electron and γ-ray measurements have been performed at the catcher position. The Bétatronc [15], an electron-guide equipped with a cooled Si(Li) detector and a 80% efficient Ge detector were installed in close geometry, on each side of the catcher, both at 90° to the beam direction. Target and catcher thicknesses were carefully adjusted to obtain a reasonable energy resolution for electron lines.

To get a large enough production with a limited energy distribution of the recoil products, the target thickness was kept between 500 μg cm^{-2} and 1 mg cm^{-2}. The catcher, placed at 45° with respect to the Bétatronc axis, was made of a mylar foil whose thickness (1.3 mg.cm^{-2}) was ajusted in order to stop the recoil products just at the back of the catcher and preserve the best energy resolution for electrons. During the measurements, the solid angle aperture of the electron-guide was 3% of 4π and electrons with energies from 0 to 1.2 MeV were recorded. The effective energy resolutions of electron lines were typically 2.5 keV at high energy and 3 keV at 100 keV. The time of flight of the recoil products was 20 ns, value which eliminates the flux of δ-electrons. A partial conversion electron spectrum in coincidence with the strongest γ-rays decaying from the ^{151m_2}Er isomer is shown in fig. 1.

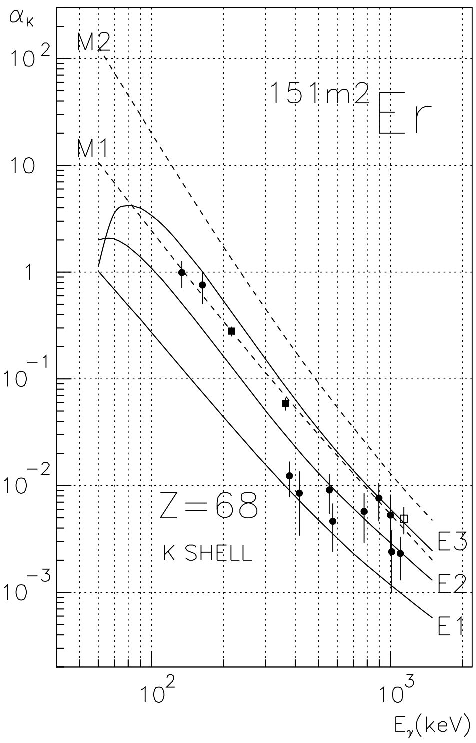

Fig. 3. Absolute α_K conversion coefficients of transitions in the yrast cascade decaying from the ^{151m_2}Er isomer. α_K of the $E3$ transition at 1140 keV in ^{151m_1}Er is shown by an open square.

The aim of the present study is the determination of the multipolarity of γ-rays which belong to a large range in energy, from a few tens of keV to 1.2 MeV. Consequently, the data analysis is difficult because for the majority of the transitions the α_K conversion coefficients are less than 10^{-2}.

One has also to take into account the oscillations known in the electron-guide efficiency curve [15] which are attenuated by the size of the source collected on the catcher. Prior the analysis of electron spectra, an efficiency curve of the Bétatronc has been experimentally adjusted, using the transitions known in all the neighbouring isotopes produced simultaneously in the nuclear reaction as ^{151m_1}Er, ^{148m}Dy, ^{150m}Er, ^{149m}Dy and in ^{150}Dy obtained by β-decay of ^{150}Ho.

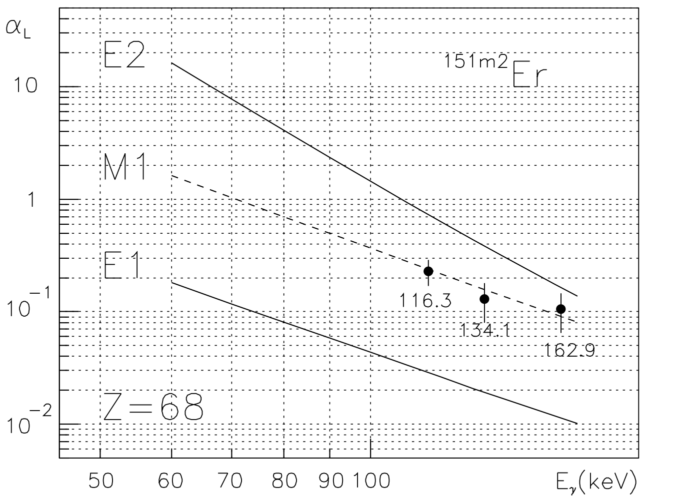

Fig. 4. Absolute α_L conversion coefficients of transitions at 116.3, 134.1 and 162.9 keV.

Several treatments of the electron and γ spectra have been combined to establish the multipolarities of ^{151m_2}Er γ-rays, as indicated below:

– From electron spectra in coincidence with γ-rays of the cascade, several α_K/α_L ratios have been deduced for the strongly converted lines. The results reproduced in fig. 2 show that the transitions at 134.1, 162.9, 215.6 and 364.3 keV have α_K/α_L ratios compatible with $L = 1$ multipolarity, *i.e.* $M1$ or $E1$ characters.

– From both electron singles and γ-singles spectra, absolute α_K coefficients have been estimated for only two transitions at 215.6 and 364.3 keV. The $E2$ transitions at 288.7 keV in ^{151m_1}Er and 653.3 keV in ^{150}Dy obtained by β-decay of ^{150}Ho have been used as normalization. The values $\alpha_K(215.6) = 0.28 \pm 0.06$ and $\alpha_K(364.3) = 0.056 \pm 0.007$ are included in fig. 3. The $M1$ multipolarity is unambiguously assigned to these transitions considering their α_K/α_L ratios.

– α_K coefficients of other transitions have been extracted from electron-γ-sum spectra using a mean value $\alpha_K = 0.059 \pm 0.008$ of the 364.3 keV transition as a reference. The γ-sum spectra contained all the γ-rays except the transition studied and the one at 364.3 keV. The values obtained by this method are reported in fig. 3. The three transitions at 378.1, 416.1 and 574.7 keV are identified as $E1$. The α_K coefficient of the 116.3 keV line is not shown in fig. 3 because the K-conversion line, located at 58.8 keV, is not well resolved in the coincident electron spectrum. The conversion coefficient α_L has been estimated. As shown in fig. 4 this value fits perfectly with a $M1$ multipolarity as for the transitions at 134.1 and 162.9 keV.

3 Discussion

The γ-decay scheme of the 420 ns ^{151m_2}Er isomer presented in fig. 5 is based on the transition multipolarities deduced from the present work.

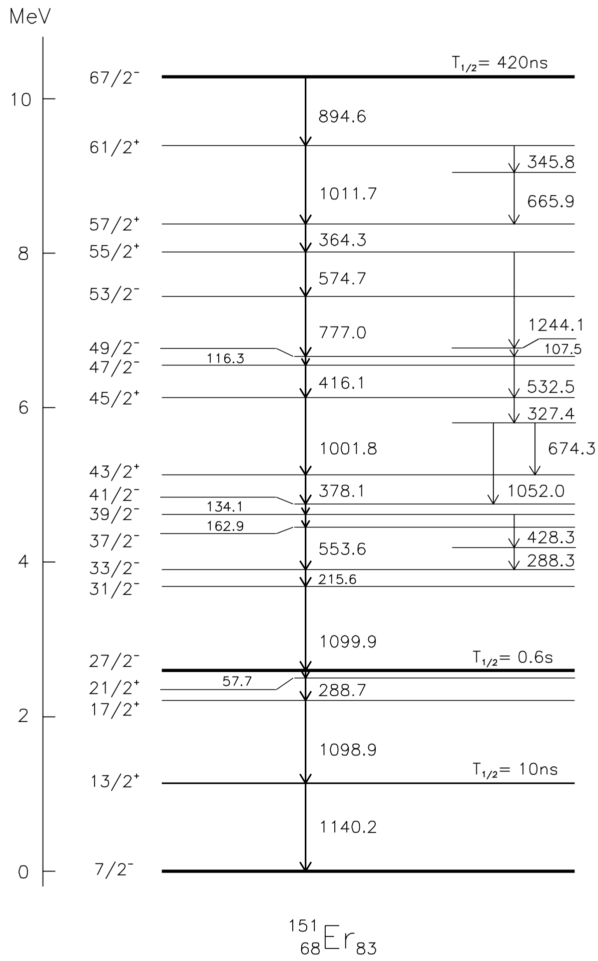

Fig. 5. γ-decay scheme of the ^{151m_2}Er isomer.

The placements of the γ-lines in the main cascade as well in the weakly fed parallel branches are similar to those already published [9]. The agreement between new conversion coefficients and previous angular distribution measurements is acceptable except for the transitions at 1099.9 and 364.3 keV. As no new low-energy transition was identified in the electron spectra, it is necessary to discuss if one of the three transitions (364.3, 894.6 and 1011.7 keV) placed at the top of the cascade could explain the long-lived isomer of 420 ns. From the results shown in figs. 2 and 3, the transitions at 1011.7 and 364.3 keV fit with $E2$ and $M1$ multipolarities, respectively. The transition at 894.6 keV which has a $\alpha_K = (7.7 \pm 3.0)10^{-3}$ value is compatible with $E3$ or $M1$ characters. In the present study the value of the α_K/α_L ratio of the 894.6 keV line which could solve this problem cannot be estimated due to the weakness of the α_L coefficient. However, an $E3$ multipolarity could explain the existence of the long-lived isomeric state, the value $B(E3; 894.6) = 4.6 \pm 0.6$ W.u. being characteristic of a single-particle transition. Finally the $T_{1/2} = 420$ ns isomer in ^{151}Er is very likely located at 10.286 MeV with $I^\pi = 67/2^-$. Its decay to the $I^\pi = 27/2^-$ isomer at 2.586 MeV remains quite simple compared to the complex situations known in the $N = 83$ isotones.

To describe the high-spin states identified in ^{151}Er a comparison has been made with the level schemes of the two neighbouring cores ^{150}Er [16] and ^{152}Er [17]. On this basis, a probable $(\pi h^4_{11/2})_{16^+} \otimes (\nu f_{7/2})_{7/2^-}$ configuration can be associated with the $39/2^-$ state at 4.62 MeV, starting from the 16^+ states located at 5.22 MeV in ^{150}Er and 4.68 MeV in ^{152}Er, respectively. Tentative assignment for the high-spin isomer has been based on Nilsson-Strutinsky cranking calculations of single-particle levels for ^{152}Er [18] at $\beta_2 = -0.06$. Using proton and neutron sloping Fermi surface diagrams, a possible configuration $\pi[h^4_{11/2} d^1_{3/2} d^{-1}_{5/2}]_{20^+} \otimes \nu[f_{7/2} h_{9/2} h^{-1}_{11/2}]_{27/2^-}$ can be associated to the $I^\pi = 67/2^-$ isomeric state identified at 10.286 MeV in ^{151}Er.

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