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Short note

Study of the first excited $1/2^+$ state in ^{131}La

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Abstract. Low-spin states of ^{131}La have been reinvestigated via the ^{115}In + ^{20}Ne reaction at 95 MeV with a pulsed beam and γ-ray spectroscopy. A doublet of excited states, $1/2^+$ at 230.3 keV and $7/2^+$ at 231.2 keV, has been definitely established in ^{131}La. Low-spin state systematics in Z=57 and N=74 isotopes are presented and discussed.

PACS. 23.20.Lv Gamma transitions and level energies – 27.60.+j $90 \leq A \leq 149$

Several on-line gamma spectroscopic studies have been devoted to the isotope ^{131}La. The band structures built on the low-lying $h_{11/2}$, $g_{7/2}$, or $d_{5/2}$ states have been observed up to high spins by using fusion-evaporation heavy-ion induced reactions. As expected for the transitional nuclei of this A $\sim$ 130 mass region, triaxial-prolate shapes have been established [1].
The non-yrast low-lying levels of the nucleus ^{131}La have also been investigated by means of the β/EC decay of ^{131}Ce. In a recent work, using the He-jet technique to extract and transport the recoil products of the ^{94}Mo + ^{40}Ca reaction at 255 MeV bombarding energy, a level scheme of ^{131}La has been deduced including the low-spin states up to 2 MeV [2]. Low-lying band structures have been established which agree with the bands proposed from in the beam data [1].

However, these results have not cleared up the discrepancies reported from the previous radioactive decay works [3,4]. Indeed, the existence of two long-lived states [$7/2^+$, $T_{1/2} \sim 10$ min and $1/2^+$, $T_{1/2} \sim 5$ min] in the precursor ^{131}Ce introduces a complex situation in the ^{131}Ce to ^{131}La β/EC decay studies. The most surprising puzzle concerns the decay of the $1/2^+$ partner in ^{131}Ce to the first $1/2^+$ excited state in ^{131}La which is expected at low-energy excitation. Since 1973 [3], the existence of a γ-ray at 230.4 keV was associated to the β-decay of the shortest half-life in ^{131}Ce. In 1983, a tentative decay scheme of ^{131}Ce ($1/2^+$) to low-spin states in ^{131}La was proposed [4]. It includes 3 new states at 230.4 keV ($1/2^+$), 462.9 keV (3/2, 1/2) and 595.0 keV (3/2, 1/2). The state at 230.4 keV decays to the ground state ($3/2^+$) and to the first excited state ($5/2^+$) at 26.2 keV, with I_γ (204.3) /I_γ (230.4) equal to 1.2 %.

The ^{94}Mo + ^{40}Ca reaction used for the most recent series of radioactivity measurements [2] leads to the isotopes ^{131}Nd and ^{131}Pr with large production cross-sections. Correspondingly, the $1/2^+$ low-spin state in ^{131}La is expected to be strongly populated via the A = 131 β/EC decay chains. Contrary to this expectation no $1/2^+$ excited state was observed at 230.4 keV in this study. However, a new level established from coincidence relationships was placed at 231.2 keV with probable $I^\pi = 7/2^+$. This state decays also to the ground- and the first excited states by transitions of 231.2 and 205.0 keV with an intensity ratio I_γ (205.0)/I_γ (231.2) = 4.0±1.5.

In the present paper we report on a complementary identification of the first $1/2^+$ excited state in ^{131}La. The systematics of low-spin levels in odd-A La isotopes and N=74 isotones are also presented and discussed.

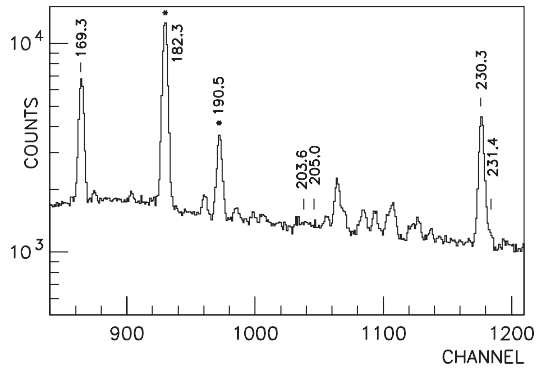

Fig. 1. Portion of a singles γ-ray spectrum recorded during the T_{OFF} period of the pulsed beam cycles. All energies are in keV. The 230.4 keV and the 231.4 keV depopulate the $1/2^+$ and the $7/2^+$ states in ^{131}La, respectively. The very weak lines at 203.6 and 205.0 keV are indicated. The *peaks marked with* $a *$ belong to ^{132}La

On-line experiments have been performed at the SARA accelerator with the ^{20}Ne + ^{115}In fusion-evaporation reaction at 95 MeV. A thin target (2.6 mg.cm^{-2}) of natural indium evaporated on gold was bombarded with a pulsed beam. Cycles with T_{ON}/T_{OFF} = 33s / 132s were produced with a mechanical chopper installed at 8m in front of the reaction chamber to favour the decay of the 5 min half-life in ^{131}Ce. Gamma and X-ray spectra were recorded in singles, multianalysis (16 x 6s) and coincidence modes.

The identification of the ^{131}Ce beta decay was based on the known γ-transitions in ^{131}La. In addition to those reported in the previous experiment [2], several new γ-rays have been clearly observed. In Fig. 1, the low-energy γ-ray spectrum shows the existence of a doublet at 230.3 - 231.4 keV and of weak gamma lines in the 203-205 keV energy range. The ratio I_γ (231.4) / I_γ (230.3) is around 6%. From a careful analysis of singles and coincident X-γ events, a doublet of excited states has been identified in ^{131}La, which has the following properties:

– The first member at 230.3 ± 0.1 keV is preferentially fed in the present measurement. It decays to the ground state and to the first excited level at 26.2 keV with a ratio I_γ (203.6) / I_γ (230.3) = 1.5%. This value is comparable to the one of 1.2% reported by Vitman et al. [4] for a tentative $1/2^+$ excited state at 230.4 keV in ^{131}La. A similar decay mode has also been reported for the first

– The second member of the doublet at 231.4 ± 0.2 keV is poorly fed in the present work ; it deexcites via two γ-rays of 231.4 keV and 205.0 keV. Taking into account that two γ-lines of 231.2 and 231.0 keV, with similar intensities, which were already placed in the ^{131}La level scheme [2], the ratio I_γ (205.0) / I_γ (231.4) equals 0.3 ± 0.2 for the excited state at 231.4 keV. In spite of the large uncertainty observed for this ratio, it can be explained by a preferential feeding of the $7/2^+$ excited level previously established in the $T_{1/2} \sim 10$ min, ^{131}Ce beta decay [2].

Several weakly populated states have been confirmed in the present measurement. Coincidence γ-ray spectra gated by lines at 169.4 and 195.5 keV, respectively, show γ-rays at 264.2 keV and 715.7 keV and agree with both the states at 459.5 keV and 911.2 keV. The placements of several weak lines at 147.7, 155.2, 276.1 and 607.6 keV have also been confirmed, in agreement with the level scheme of Vitman et al.[4]. In addition, two new excited states are established : one at 946.1 keV which deexcites via 3 γ-rays (202.0 keV to the 743.3 keV (7/2, $5/2^+$) state ; 750.6 keV to the 195.6 keV, $7/2^+$ state ; 800.7 keV to the 145.4 keV, $5/2^+$ state) and the other one at 1782 keV which decays to the 946.1 keV state by a 835.8 keV γ-transition.

The present work confirms and extends the knowledge of low-spin, low-energy states in ^{131}La. In particular, the identification of the $1/2^+$ state at 230.3 keV completes the experimental $1/2^+$ state systematics in odd-A, Z = 57 La isotopes and in N = 74 isotones of this A $\sim$ 130 mass region. As shown in Fig. 2, three groups of states "$3/2^+_1$, $7/2^+_2$", " $5/2^+_1$, $7/2^+_1$ $9/2^+_1$", "$5/2^+_2$, $9/2^+_2$", characterized respectively by dotted, dashed and dot-dash lines evolve differently while the low-lying $1/2^+$ states (solid line) exhibit a specific behaviour. This is most obvious for the N = 74 isotones (Fig. 2, right). The calculations performed with the interacting-fermion-boson model for the odd-A, odd-Z isotopes of this region [2,7] indicate a large mixing of configurations arising from the $s_{1/2}$, $d_{3/2}$, $d_{5/2}$ and $g_{7/2}$ shells. The same complexity is also obtained by applying the particle-plus-rotor model on ^{133}Pr [5]. Thus, in ^{131}La, the $5/2^+_1$, $7/2^+_1$ $9/2^+_1$ states are dominated ($\sim$ 70 %) by the $g_{7/2}$ shell, while the $3/2^+_1$, $7/2^+_2$ states contain 35 to 45 % of $d_{5/2}$ components. The first $1/2^+$ excited state in ^{131}La has also a mixed nature but, in agreement with the N = 74 systematics (Fig. 2, right) it is very likely dominated by the $\pi[420]1/2^+$ Nilsson orbital previously proposed for the $1/2^+$ states in ^{129}Cs and ^{133}Pr.

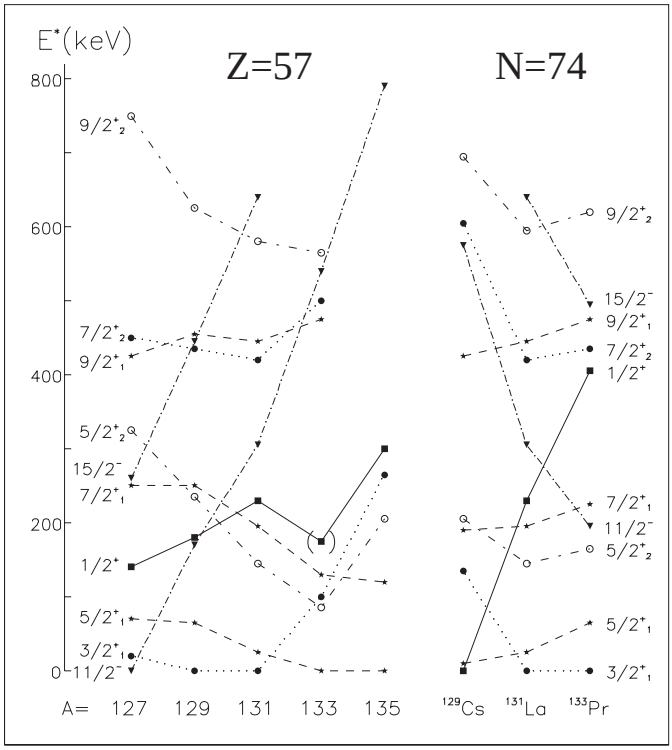

Fig. 2. Comparison between the relevant low-lying states observed in odd-A, Z=57 La isotopes (*left*) and N=74 isotones (*right*) of the A$\simeq$130 mass region. Besides the present work, the experimental data are from [6] for ^{127}La, [7 and Refs. in] for ^{129,133}La, [8] for ^{135}La, [9] for ^{129}Cs and [5] for ^{133}Pr

References

1. L. Hildingsson et al., Phys. Rev. C**39** (1989) 471
2. J. Genevey et al., Nucl. Phys. A**611** (1996) 247
3. M.A. Deleplanque et al., Phys. A**207** (1973) 565
4. V.D. Vitman et al., preprint LNPI-868 (1983); Yu. V. Sergeenkov et al., Nucl. Data Sheets **72** (1994) 487
5. J.B. Breitenbach et al., Nucl. Phys. A**595** (1995) 481
6. J. Genevey et al., Z. Phys. A**356** (1996) 7
7. A. Gizon et al., in press Z. Phys. A
8. Yu. V. Sergeenkov, Nucl. Data Sheets **52** (1987) 205
9. Y. Tendow, Nucl. Data Sheets **77** (1996) 631