A new 350 ms isomer in ^{125}La and low energy intrinsic states in A=133,131,129,127,125 La isotopes

G. Canchel, R. Béraud, E. Chabanat, A. Emsallem, N. Redon, P. Dendooven, J. Huikari, A. Jokinen, G. Lhersonneau, M. Oinonen, et al.

Institut
de Physique
Nucléaire
de Lyon

Université Claude Bernard

IN2P3 - CNRS

LYCEN 9866
September 1998

A new 350 ms isomer in ^{125}La and low energy intrinsic states in A=133,131,129,127,125 La isotopes

Presented to the International Conference « Nuclear Physics Close to the Barrier »
Warsaw (Poland) - 30 June - 4 July 1998
to be published in Acta Polonica B

43, Boulevard du 11 Novembre 1918 - 69622 VILLEURBANNE Cedex - France

A NEW 350 MS ISOMER IN ^{125}La AND LOW ENERGY INTRINSIC STATES IN A=133,131,129,127,125 La ISOTOPES

G. CANCHEL[1,2], R. BÉRAUD[1], E. CHABANAT[1], A. EMSALLEM[1], N. REDON[1], P. DENDOOVEN[2], A. HONKANEN[2], J. HUIKARI[2], A. JOKINEN[2], G. LHERSONNEAU[2], M. OINONEN[2], H. PENTILLÄ[2], K. PERÄJÄRVI[2], A. POPOV[3], J.C. WANG[2], J. ÄYSTÖ[2].

[1] IPN Lyon IN2P3/CNRS and Université Claude Bernard, F-69622 Villeurbanne Cedex, France.
[2] Department of Physics, University of Jyväskylä, P.O. Box 35, 40351 Jyväskylä, Finland.
[3] St. Petersburg Nuclear Physics Institute, Gatchina, 188350 St. Petersburg, Russia.

(Received August 31, 1998)

By means of the HIGISOL technique, the A=125 mass chain was studied via β^+/EC decay of ^{125}Ce and a new (350^{+60}_{-40})ms isomer was definitely assigned to ^{125}La based on conversion electron measurements.

PACS numbers: 23.20.Lv

1. Introduction

This work belongs to a series of investigations initiated at SARA [1, 2, 3] and devoted to the study of low-lying excited levels in neutron-deficient odd La fed via β^+/EC decay of Ce isotopes. Although a wealth of data on the rotational bands has been obtained from in-beam spectroscopy using heavy ion induced reactions, the levels at low excitation energy with low spin remain poorly known. The nuclei of this so called transition region around A=130 have a prolate-triaxial shape which has been rather well interpreted with different theoretical models. Recently, lifetime measurements [4] of levels of the decoupled $\pi h_{11/2}$ band [5], both in ^{127}La and ^{125}La, have reinforced the picture of a quasiparticle coupled to a rigid triaxial core ($\beta_2 \simeq 0.28$, $\gamma \simeq 20$ deg). The ground state is the bandhead $11/2^-$ in ^{127}La whereas in ^{125}La it has $I^\pi = 3/2^+$, similar to ^{129,131}La.

At first, two γ transitions were observed in the β^+/EC decay of 10 s ^{125}Ce [1] and then a preliminary level scheme was constructed as reported in [6]. More recently, we have suggested the existence of a (0.4 ± 0.2)s isomer in the A=125 mass chain [7]. The aim of the present work was mainly, by means of conversion electron and coincidence measurements, to assign the Z of this isomer and to try to shed light on the ^{125}La level scheme at low energy.

2. Experiment

The ^{125}Ce activity was produced via the ^{94}Mo(^{36}Ar,3p2n) reaction followed by β^+/EC decay and studied on-line after mass-separation. The ^{94}Mo target, a self-supporting foil of 3.0 mg/cm^2 and 97.6% enrichment, was bombarded with 175 MeV $^{36}Ar^{8+}$ ions (300 part.nA) from the K=130 Jyväskylä cyclotron. Reaction products were mass-separated using the HIGISOL technique developed originally at SARA for heavy ions induced fusion-evaporation reactions [8]. The system recently implemented at the Jyväskylä IGISOL facility gives readily a mass-separated yield of about 1 ion/s/mbarn/10 part.nA [9] independent of the chemical and physical properties of the elements. The 40 keV beam of A=125 radioactive ions was impinging on a 6.4 mm wide movable tape at the center of the first coil of the ELLI spectrometer described in more details in reference [10]. ELLI is a hybrid design combining the features of a magnetic transporter and a high resolution, 4 mm thick and 300 mm^2 area Si(Li) detector placed at the center of the second coil. The electron energy calibration was carried out with a ^{133}Ba source and the energy resolution was typically 2.5 keV at 320 keV. A low energy Ge detector (10 mm x 1000 mm^2, resolution 530 eV at 53 keV) was placed outside the vacuum chamber, on the symmetry axis of the spectrometer and only 10 mm from the implantation spot.

To allow growth and decay sequences of the activities, the cyclotron beam was pulsed ($T_{ON} = T_{OFF} = 10$ s). Both time-sequenced singles spectra (e-T, X-T) and e-X-t coincidence data were acquired and stored on exabyte tape using the VENLA data acquisition system [11].

3. Results

A typical conversion electron spectrum measured with the ELLI spectrometer is shown in figure 1. Most of the lines of the A=125 mass chain were identified, except three lines at 68.2, 101.7 and 106.2 keV energies. From e-X data, there is clear evidence of a coincidence between the 68.1 keV electron line and both K_α- and K_β-La X rays indicating that conversion takes place in the elements La. Therefore this line can be attributed to the K conversion of the 107.0 keV transition since the K-binding energy is 38.9 keV. The two other lines (101.7 and 106.2 keV) can be assigned to L- and M-conversion

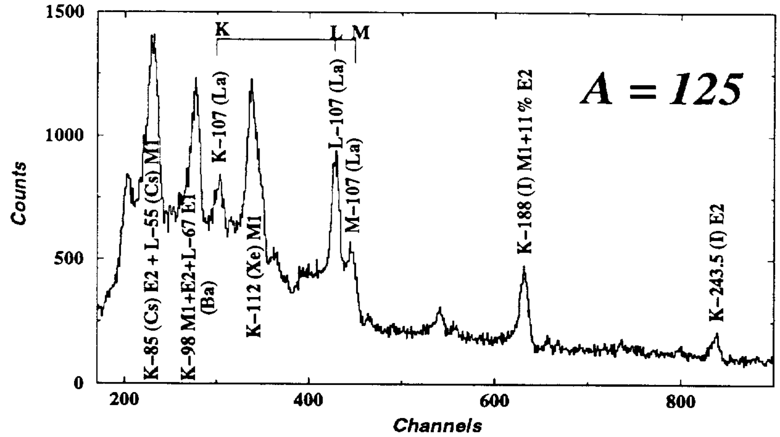

Fig. 1. Partial conversion electron spectrum measured with the ELLI spectrometer.

lines of the same transition on the basis of similar arguments. Moreover, an accurate determination of energy differences between these electron lines gives $E_K - E_L = (33.5 \pm 0.3)$ keV and $E_L - E_M = (4.5 \pm 0.3)$ keV in perfect agreement with theoretical values, 33.24 and 4.53 keV respectively in case of La.

To achieve a precise determination of internal conversion coefficients (ICC), it is of crucial importance to get with good accuracy the intensities of both γ rays and conversion electrons. The efficiency of ELLI being very sensitive to the localisation of the beam spot of HIGISOL, we have used an internal calibration procedure by means of transitions of well known multipolarities in the A=125 mass chain. The efficiency curves were then constrained to these particular points.

For the 107 keV transition we could deduce the following ICC values : $\alpha_K = 2.5 \pm 1.5$, $\alpha_L = 8.1 \pm 3.2$, $\alpha_M = 2.4 \pm 1.0$ and associated subshell ratios. Comparing with theoretical values calculated from reference [12] and [13], the E3 nature can be assigned unambiguously to this transition.

From the e-T data, we could extract the time distributions (growth and decay) for all conversion electron lines of the spectrum presented in figure 1. The K-, L- and M-lines of the 107 keV transition exhibit similar time behaviour, they have been analysed separately considering feeding of the isomer from both ^{125}Ce β^+/EC decay and direct reaction production. The half-life deduced from the fitting procedure of the sum spectrum shown in figure 2, gives for ^{125m}La, $T_{1/2} = (350^{+60}_{-40})$ ms corroborating the result we got from K_α-La X rays analysis [7]. For the slow component the half-life value $T_{1/2} = (9.9 \pm 0.5)$ s is also in good agreement with previous results [14].

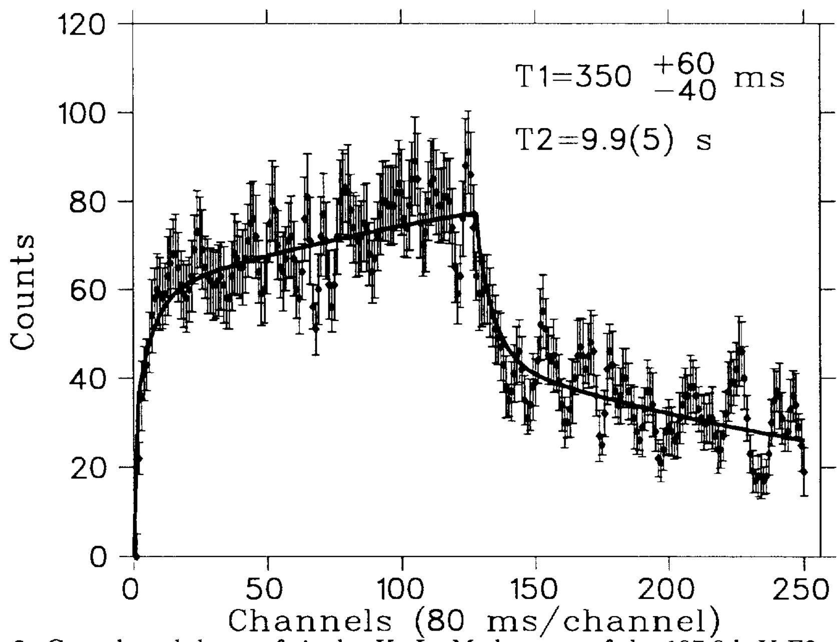

Fig. 2. Growth and decay of singles K+L+M electrons of the 107.0 keV E3 transition. The curve is calculated with two components + long-lived contamination.

4. Discussion

Unless creating a new level at an excitation energy slightly above 107 keV, it is at present not possible to place this isomeric transition in the existing level schemes deduced either from in beam work [4] or from β^+/EC decay of 10 s ^{125}Ce [6]. From β-delayed proton emission [14], $I^\pi = 5/2^+$ was suggested for the g.s. of ^{125}Ce contrary to the Nilsson model which predicts the last neutron to occupy the $1/2^+[411]$ deformed orbit for $\beta_2 = 0.28$. As in ^{127}Ce and ^{129}Ce, we may also have a close lying $7/2^-$ state and therefore more data are needed, especially on β branches and coincidences between electrons and low energy γ rays, to shed light on the β decay scheme. For the 107 keV transition, the hindrance factor value which can be derived from the ratio of experimental half-life to its Weisskopf estimate is $F_W = 1.3 \pm 0.2$.

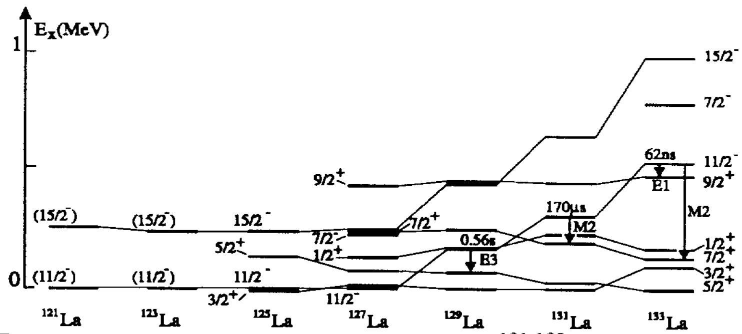

Fig. 3. Experimental low lying levels in odd La. In ^{121,123}La, the g.s. is assumed $(11/2^-)$ and the $9/2^+$ is not reported (excitation energy unknown) [2, 3, 4, 15] and refs therein.

This is a typical value for an E3 transition in this nuclear region and this indicates that we are dealing with a rather pure single particle transition $\pi 11/2^- \rightarrow \pi 5/2^+$ (e.g. $F_W = 2.0$ in ^{129}La and $F_W = 2.1$ in ^{123}Cs).

Some low lying states of odd La ($121 \leq A \leq 133$) are presented in figure 3. The systematics shows the gradual increase of deformation with decreasing neutron number down to N=70, which is reflected by the $15/2^- - 11/2^-$ energy spacing. For lighter isotopes the deformation seems to stabilize and there is no obvious fingerprint of subshell closure at N=64 for ^{121}La.

In ^{129,131,133}La, isomerism is due to the interplay between the $\pi h_{11/2}$ orbital and the positive parity orbitals $\pi 1g_{7/2}$, $\pi 2d_{5/2}$ and $\pi 2d_{3/2}$. The g.s. of ^{125}La is proposed to have $I^\pi = 3/2^+$ [4] (as in ^{129}La and ^{131}La) and its structure is strongly mixed with a dominant $d_{5/2}$ component as was shown from both IBMF-2 calculations [3] and the core quasiparticle coupling model [4]. In this isotope, the $11/2^-$ level is proposed at an excitation energy of $\simeq 9$ keV and thus β decay would strongly compete with the isomeric transition. It is expected that because valence protons are filling the lower part of the $h_{11/2}$ shell and valence neutrons are at the $h_{11/2}$ midshell, conflicting shape driving forces will result. Therefore the downsloping of the $11/2^-$ level with decreasing N could be interrupted around N=70 as it is the case in the odd Pr isotopes.

Additionnal data on ^{125}La are needed and the continuation of β^+/EC decay studies on more n-deficient isotopes i.e. ^{123}La and ^{121}La is also highly desirable to gain information on absolute excitation energies of the positive and negative close lying intrinsic levels in these isotopes.

Acknowledgements

This work has been supported by the Access to Large Scale Facility program under the Training and Mobility of Researchers program of the European Union. The authors would like to thank J.P. Richaud (ISN Grenoble) for the preparation of windows and targets, the accelerator crew at the Jyväskylä Accelerator laboratory and Dr. A. Gizon (ISN Grenoble) for fruitful discussions.

REFERENCES

[1] J. Genevey et al., contrib. Proc. 5th Int. Conf. Nuclei far from Stability, Rosseau Lake, Canada, AIP 164, Ed. I.S. Towner, 1987, p.419.

[2] J. Genevey et al., *Z. Phys.* **A356** (1996) 7.

[3] A. Gizon et al., *Z. Phys.* **A359** (1997) 11.

[4] K. Starosta et al.,*Phys. Rev.* **C53** (1996) 137.

[5] J.R. Leigh et al., *Nucl. Phys.* **A213** (1973) 1.

[6] M. Asai et al., JAERI TIARA, Annual Report, 1993.

[7] R. Béraud et al., APH N.S. Heavy Ion Physics 7 (1998) 115.

[8] R. Béraud et al., *Nucl. Instr. & Meth. in Phys. Res.* **A346** (1994) 196.

[9] P. Dendooven et al., *Nucl. Instr. & Meth. in Phys. Res.* **B125** (1997).

[10] J.M. Parmonen et al., *Nucl. Instr & Meth. in Phys. Res.* **A306** (1991) 504.

[11] K.T. Loberg et al., *IEEE Trans. on Nucl. Sci.* **42** (1995) 17.

[12] R.S. Hager et al., *Nucl. Data Tables* A4 (1968) 1.

[13] O. Dragoun et al., *Nucl. Data Tables* A6 (1969) 235.

[14] J.M. Nitschke et al., *Z. Phys.* A316 (1984) 249.

[15] C. Foin et al., *Eur. phys. J.* A1 (1998) 117.