Vol. 34 (2003) ACTA PHYSICA POLONICA B No 4

BEHAVIOUR OF B(E2) FOR THE $h_{11/2}$ BAND TRANSITIONS IN ^{131}La*

E. Grodner, Ch. Droste, T. Morek, J. Srebrny,

Nuclear Physics Division, IEP, Warsaw University
Hoża 69, 00-681 Warsaw, Poland

A.A. Pasternak

Cyclotron Laboratory, A.F. Ioffe Physical Technical Institute
194021, St. Petersburg, Russia

A. Wasilewski, W. Płóciennik, E. Ruchowska

The Andrzej Sołtan Institute for Nuclear Studies, 05-400 Otwock-Świerk, Poland

and J. Kownacki

Heavy Ion Laboratory, Warsaw University, Pasteura 5a, 02-093 Warsaw, Poland

(Received January 21, 2003)

Lifetimes of excited states with spin $I^{\pi} = 23/2^{-} - 39/2^{-}$ belonging to the $\pi h_{11/2}$ band in ^{131}La have been measured using the DSA method. The ^{131}La nuclei were produced in the ^{122}Sn(^{14}N,5n)^{131}La reaction at $E(^{14}\mathrm{N}) = 70$ MeV. Experimental data for the $h_{11/2}$ band in ^{131}La have been compared with the CQPC and TRS model calculations. The additional experiment has been done to determine the stopping power parameters.

PACS numbers: 21.10.Tg, 23.20.Lv, 27.60.+j

1. Introduction

The energies, spins and parities of excited states of the $\pi h_{11/2}$ band in ^{131}La up to spin $43/2^{-}$ are known from [1, 2]. The lifetimes of the $11/2^{-}$, $15/2^{-}$, $19/2^{-}$, $23/2^{-}$ states were measured in [3] using the Recoil Distance Method. In our work we concentrated on the higher states with shorter lifetimes that were determined using the Doppler Shift Attenuation Method.

* Presented at the XXXVII Zakopane School of Physics "Trends in Nuclear Physics", Zakopane, Poland, September 3–10, 2002.

The properties of the $\pi h_{11/2}$ band in the odd-A nuclei are particularly interesting since chiral bands observed recently in the odd–odd La nuclei [4] have similar configuration. In these bands the odd proton also occupies $h_{11/2}$ orbital. Hence, the knowledge of the ^{131}La nucleus can be helpful in understanding the structure of the chiral bands.

2. Experimental

The ^{131}La nuclei were produced in the ^{122}Sn(^{14}N,5n)^{131}La reaction at a beam energy of 70 MeV. The beam was provided by the Warsaw University cyclotron. The target thickness was 10 mg/cm^2 which allows recoils to stop inside the target. γ–γ coincidences were collected by the OSIRIS-II multidetector array which consists of 10 Compton-suppressed HPGe detectors. Lifetimes of the excited states (with spins from $23/2^-$ to $39/2^-$) belonging to the $\pi h_{11/2}$ band were measured using the Doppler Shift Attenuation Method. The line-shape analysis has been done using codes COMPA, GAMMA and SHAPE developed by Pasternak (see [5] and references therein).

2.1. Determination of the stopping power parameters

The knowledge of the slowing down process of the recoils is the serious problem in DSA measurements. The stopping power is given by two components (see Fig. 1): electronic S_e and nuclear S_n stopping powers [6]

$$S_e = \left(\frac{d\varepsilon}{d\rho}\right)_e = f_e k_e \varepsilon^{1/2}\,, \tag{1}$$

$$S_n = \left(\frac{d\varepsilon}{d\rho}\right)_n = \frac{f_n \varepsilon^{1/2}}{0.67\phi_n + 2.07\varepsilon}\,, \tag{2}$$

where ε and ρ are energy and distance given in Lindhard's units, respectively; f_e, f_n, ϕ_n are stopping power calibration parameters. Results of Arstila *et al.*, [7] and our previous experiment [8] suggest that Ziegler values of the electronic stopping power for velocities $v/c \leq 0.015$ are too low. Therefore, we carried out the additional experiment, using the "semi-thick" method [8], to determine the stopping power parameters f_e, f_n and ϕ_n. In this experiment a 1.5 mg/cm^2 natural Sn target has been used. From the line-shape analysis of γ lines (474 keV($19/2^- \to 15/2^-$), 642 keV ($23/2^- \to 19/2^-$) and 785 keV($27/2^- \to 23/2^-$)) belonging to ^{129}La the parameters $f_e = 1.00$ and $f_n = \phi_n = 0.6$ have been obtained. These parameters are in good agreement with the Lindhard theory [6] and differ significantly from the values given by Ziegler [9] (see Fig. 1).

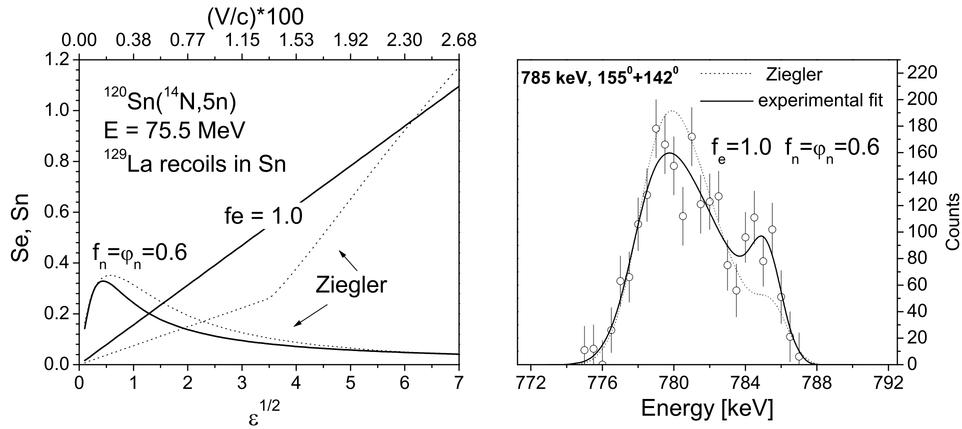

Fig. 1. Left panel: electronic S_e and nuclear S_n stopping powers of ^{129}La recoils as a function of energy ε. Solid lines represent our results, dotted lines — Ziegler's data. Right panel: results of the line-shape analysis for the 785 keV transition in ^{129}La. Solid and dotted lines stand for line-shapes obtained with stopping power parameters determined in our work and in the Ziegler study, respectively.

3. Results and interpretation

The experimental values of the reduced $B(\mathrm{E2};I \to I-2)$ transition probabilities for the states belonging to the $\pi h_{11/2}$ band measured in this work and in [3] are presented in Fig. 2. There are also shown the predictions of the Core Quasiparticle Coupling model [10]. Results marked as CQPC corresponds to the case in which the properties of even–even ^{130}Ba core have been described in the frame of the rigid triaxial rotor. The theoretical calculations do not reproduce the diminishing values of B(E2) observed in the experiment for $I^\pi > 27/2^-$. The predictions of the Total Ruthian Surface [11] calculations are also in disagreement with the experiment for $I^\pi > 27/2^-$ (line marked TRS in Fig. 2). In the approach called MOD CQPC the experimental data (energies and B(E2) values up to $I = 12$) concerning ^{130}Ba were used to replace partly the theoretical ones. It is worth adding that the experimental B(E2) values for intraband transitions between states of the yrast band in ^{130}Ba increase with spin up to $I \approx 6$ and decrease for $I \geq 8$. The standard rigid 3-axial rotor does not reproduce such behaviour. It is seen from Fig. 2, that results of the MOD CQPC calculations fit better to the measured B(E2) values. This suggests that the reduction of collectivity for $I^\pi > 27/2^-$ in ^{131}La results from the change in the structure of the even–even core.

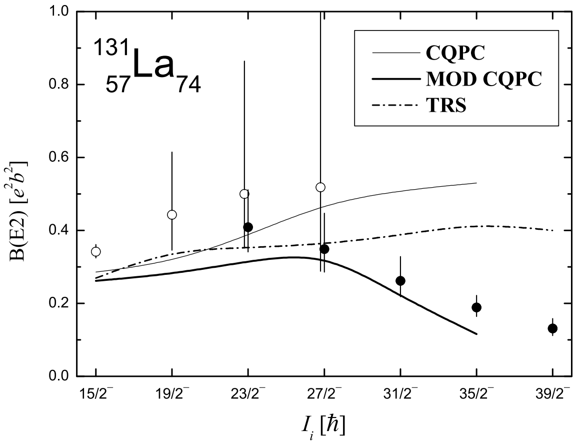

Fig. 2. Reduced transition probabilities. Open circles — experimental results obtained using the RDM method [3], full circles — results obtained in this work. Thin and thick solid lines are the results of the CQPC calculations with the core properties taken purely from the theory (rigid 3-axial rotor) and modified by the experimental data, respectively. Dot-dashed curve — the TRS calculations.

4. Conclusions

It follows from our results, that the electromagnetic properties of the $\pi h_{11/2}$ states in ^{131}La are related to properties of ^{130}Ba and a standard rigid 3-axial rotor does not represent, at high spin states, the real ^{130}Ba and ^{131}La nuclei. One expects that the B(E2) values for high spin states developed on the chiral $\pi h_{11/2} \otimes \nu h_{11/2}$ configuration may reflect the behaviour observed in the $\pi h_{11/2}$ band of ^{131}La.

REFERENCES

[1] E.S. Paul, S.A. Forbes, J. Gizon, K. Hauschild, I.M. Hibbert, D.T. Joss, P.J. Nolan, B.M. Nyakó, J.A. Sampson, A.T. Semple, R. Wadsworth, L. Walker, J.N. Wilson, L. Zolnai, *Nucl. Phys.* **A690**, 341 (2001).

[2] L. Hildingsson, C.W. Beausang, D.B. Fossan, R. Ma, E.S. Paul, W.F. Piel Jr., N. Xu, *Phys. Rev.* **C39**, 471 (1989).

[3] N.V. Zamfir, A. Dewald, K.O. Zell, P. von Brentano, *Z. Phys.* **A344**, 21 (1992).

[4] K. Starosta, C.J. Chiara, D.B. Fossan, T. Koike, T.T.S. Kuo, D.R. LaFosse, S.G. Rohoziński, Ch. Droste, T. Morek, J. Srebrny, *Phys. Rev.* **C65**, 044328 (2002).

[5] A.A. Pasternak, J. Srebrny, A.D. Efimov, V.M. Mikhajlov, E.O. Podsvirova, Ch. Droste, T. Morek, S. Juutinen, G.B. Hagemann, M. Piiparinen, S. Törmänen, A. Virtanen, *Eur. Phys. J.* **A13**, 435 (2002).

[6] J. Lindhard, M. Scharff, H.E. Schiott, *Mat. Fys. Medd. Dan. Vid. Selsk* **33**, no14, 1 (1963).

[7] K. Arstila, J. Keinonen, P. Tikkanen, *Nucl. Instrum. Methods* **B101**, 321 (1995).

[8] J. Srebrny, Ch. Droste, T. Morek, K. Starosta, A.A. Wasilewski, A.A. Pasternak, E.O. Podsvirova, Yu.N. Lobach, G.B. Hagemann, S. Juutinen, M. Piiparinen, S. Törmänen, A. Virtanen, *Nucl. Phys.* **A683**, 21 (2001).

[9] J.F. Ziegler, J.P. Biersack, U. Littmark, *The Stopping Powers and Ranges of Ions in Matter*, Pergamon, New York 1985, Vol. 1; softweare TRIM1991, SRIM2000.

[10] F. Dönau, U. Hagemann, *Z. Phys.* **A293**, 31 (1979).

[11] K. Starosta, Ch. Droste, T. Morek, J. Srebrny, D.B. Fossan, D.R. LaFosse, H. Schnare, I. Thorslund, P. Vaska, M.P. Waring, W. Satuła, S.G. Rohoziński, R. Wyss, I.M. Hibbert, R. Wadsworth, K. Hauschild, C.W. Beausang, S.A. Forbes, P.J. Nolan, E.S. Paul, *Phys. Rev.* **C53**, 137 (1995).