HIGH SPIN STRUCTURES IN $A \approx$ 100 AND 140 MASS REGIONS*

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High spin structures were studied in the ^{105}Rh and ^{136}La nuclei using the ^{100}Mo(^{11}B,$\alpha 2n$)^{105}Rh and ^{128}Te(^{11}B,xn)^{136}La reactions respectively. DCO ratios, α–γ–γ and γ–γ coincidences were measured. Four new bands were identified in ^{105}Rh and three in ^{136}La. The results were interpreted with the CSM.

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1. Introduction

In the $A \approx 100$ and 130–140 mass regions the neutron and proton, which occupy high-j subshells show similar characteristics. Valence nucleons which lie at the top of the subshell exert a driving force towards a collectively rotating oblate shape, while those at the bottom tend towards collective prolate deformations. The competition between driving forces results in a variety of nuclear shapes and shape transitions. The Gamma Spectroscopy Group of the University of São Paulo has been studying the odd and odd–odd nuclei for $Z = 45$, 47, 57 and 59. The results of this research have been presented in references [1] and [2]. Recently, a renewal of interest in these mass regions has appeared due to the theoretical predictions based on the Tilted Axis Cranking model, which indicate a possible existence of chiral bands in triaxial nuclei ($A \approx 130$) [3] and magnetic rotational bands [4], which appear in nearly spherical nuclei such as in the $A \approx 100$ regions.

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Experimentally the former are observed as two nearly degenerate bands with strong M1 and E2 transitions, while the latter as bands with very strong M1 and very weak E2 transitions. In view of the above, we have returned to study the La isotopes and also to repeat the ^{105}Rh measurements with an improved apparatus.

2. Experimental details and results

The beam was provided by the 9 MV Pelletron Tandem. The experimental setup consists of 4 GeHP Compton suppressed detectors (PERERE). Two of the detectors with 60 % efficiency were placed at 37° and 260° while the remaining ones with 20 % efficiency were set at 100° and 323° with respect to the beam. For experiments where the neutron channels are the strongest, such as ^{136}La, a multiplicity filter of 8 NaI(Tl) was placed close to the target chamber. In order to identify the charged particle evaporation channels (such as ^{105}Rh) a 4π particle ancillary scintillator system SACI was built in this laboratory. This detector consists of 11 phoswhich plastic $E - \Delta E$ telescope scintillators housed in an aluminium casing of a semi-regular polyhedral shape, with 12 pentagonal and 20 triangular sides. The BC-400 plastic 0.1mm thick was used for the ΔE and a BC-444 plastic 10 mm thick for the E detector. The overall geometrical efficiency of this system is 76 %.

The $^{100}\mathrm{Mo}(^{11}\mathrm{B}, \alpha 2n)^{105}\mathrm{Rh}$ reaction was used at 43 MeV beam energy, with a thick isotopically enriched target. The α–γ–γ coincidences and the DCO ratios were measured. The level scheme, Fig. 1, shows four previously known bands (1–4) [2], three of them (1, 2 and 4) extended to higher spins and four new bands A to D observed for the first time. The spins were assigned on the basis of DCO measurements and systematics.

The ^{136}La was produced in a $^{128}\mathrm{Te}(^{11}\mathrm{B}, xn)^{136}\mathrm{La}$ reaction at 48 MeV beam energy. A thick, isotopically enriched target, on a lead backing was used. The γ–γ coincidences and the DCO ratios were measured. Prior to this work, the nucleus ^{136}La was investigated using $(p, 3n)$ reaction [5], where the spin of 8^+ or 7^+ was assigned to the 114 ms isomeric state. Figure 2(a) shows the level scheme of the present work, composed of three bands, tentatively placed on the 114 ms isomeric state. Since the ^{136}La level scheme is very similar to that of its isotone ^{138}Pr [1] and to the other odd–odd La and Pr isotopes, the assignment of the spins to the levels and of the band configurations was based on the systematics of this mass region, as well as Cranking Shell Model (CSM) predictions and the measured DCO ratios.

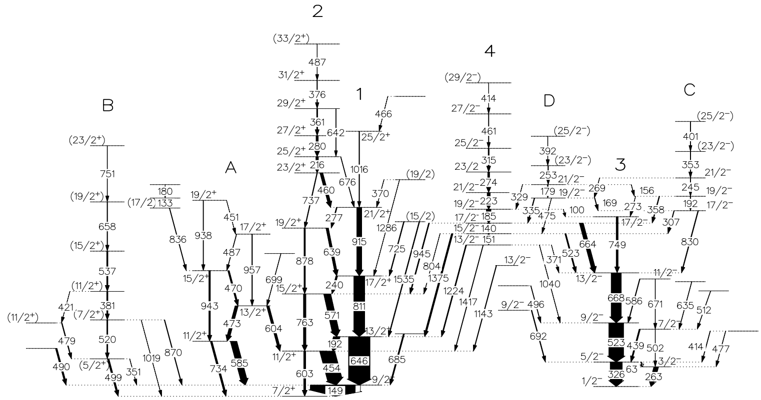
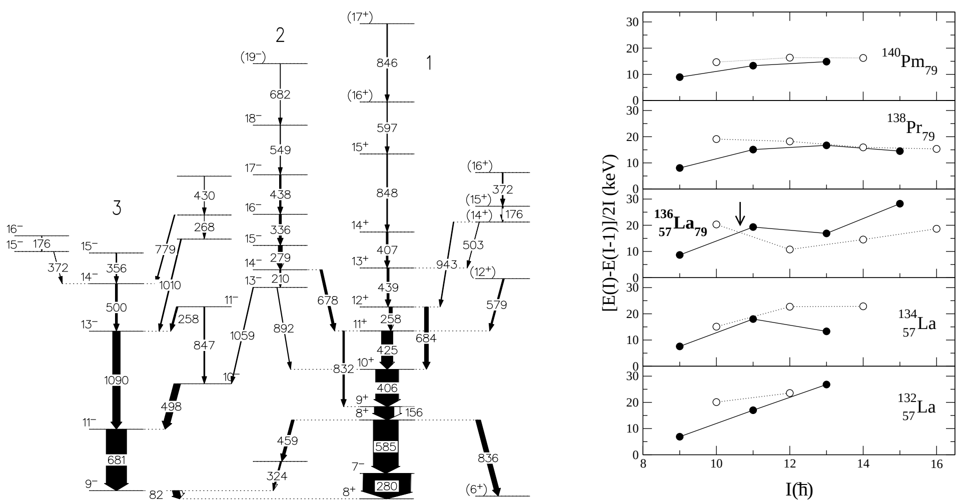


Fig. 1. ^{105}Rh level scheme showing the new bands A to D. The bands 1, 2 and 4, known from [2], were extended to higher spins.



(a) (b)

Fig. 2. (a) — ^{136}La level scheme. Bands 1, 2 and 3 were assigned the $\pi h_{11/2} \otimes \nu h_{11/2}$, $\pi[413]_{5/2} \otimes (\pi h_{11/2})^2 \otimes \nu h_{11/2}$, and $\pi[411]_{1/2} \otimes \nu h_{11/2}$ configurations, respectively. (b) — systematics of the transition energies for the $\pi h_{11/2} \otimes \nu h_{11/2}$ band. The signature inversion point in ^{136}La is indicated by an arrow.

3. Discussion

Band A in ^{105}Rh is similar to the bands based on the $7/2^+[413]$ proton state coupled to the $2^+\gamma$-phonon of the core observed in ^{107,109}Rh [6]. This can be considered as an indication of triaxiality in ^{105}Rh, contrary to the calculations presented in [6]. A possible configuration for band B is $\pi 1/2^+[431]$, but unlike in ^{107}Rh [6], the $3/2^+$ bandhead was not observed. The M1 bands in ^{105}Rh (2, 4, D and C) are candidates for magnetic rotation.

The experimental Routhians in ^{136}La exhibit a rather large and constant signature splitting of $\Delta e' = 105$ keV in the yrast band, and none in band 2. The CSM calculations performed with deformation parameters $\beta_2 = 0.14$ and $\beta_4 = 0.0$ as a function of γ-deformation for $\hbar\omega = 0.45$ MeV indicate two possibilities consistent with the observed signature splitting of band 1: a nearly oblate shape ($\gamma = -50°$) for the coupling of an $\alpha_n = -\frac{1}{2}$ neutron with the two proton signatures ($\alpha_p = \pm\frac{1}{2}$); or a nearly prolate ($\gamma = -5°$) for an $\alpha_p = -\frac{1}{2}$ proton with the two neutron signatures ($\alpha_n = \pm\frac{1}{2}$). Precise measurements of M1 + E2 mixing ratio would be helpful in order to resolve this ambiguity.

A careful examination of band 1 in the ^{136}La level scheme shows a clear signature inversion between $I^\pi = 10^+\hbar$ and $I^\pi = 11^+\hbar$, as indicated by an arrow in figure 2(b). Signature inversion has been observed [7] also for neutron deficient nuclei, such as ^{134}Pr and ^{124}La, but never below a spin of 17 $\hbar$.

4. Conclusion

The use of the SACI-PERERE array permitted the establishment of 4 new rotational bands in ^{105}Rh level scheme and an extension to higher spins of 3 other bands. Lifetime measurements for the M1 bands are necessary in order to confirm their magnetic rotation character. The level scheme for ^{136}La was established, showing three rotational bands in agreement with the sytematics of $A = 130$–140 mass region. Signature inversion was observed at very low spins in ^{136}La in contrast to the other nuclei in this region. In the present work no evidence for chiral bands was observed.

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