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Short note

Configuration assignments and decay of ^{126}La high-spin bands

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Abstract. High spin states of ^{126}La have been populated using the reaction ^{116}Sn+^{14}N at 68 MeV. γ-rays and conversion electrons were detected with the GAREL array. Multipolarities of the lowest-lying in-band dipole transitions have been determined from the deduced internal conversion coefficients. Experimental B(M1)/B(E2) ratios have been derived for the bands and compared with calculated values using the Dönau-Frauendorf geometrical model. Configurations are proposed for the bands comparing them with cranked shell model calculations and on the basis of the measured B(M1)/B(E2) ratios. The β-decay of ^{126}La has also been revisited. The population of the ^{126}Ba levels gives a probable spin value of five for the decaying high-spin ^{126}La state with $T_{1/2}\approx$64 s which may indicate a signature inversion in the $\pi h_{11/2}\nu h_{11/2}$ band.

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It has been shown recently [1] that the $\pi h_{11/2}\nu h_{11/2}$ bands in the light Cs isotopes systematically exhibit signature inversion at relatively low spins. This phenomenon is expected when one of the valence nucleons lies in a low-Ω orbital of a high-j shell while the other nucleon is placed on a high- or medium-Ω orbital of a high-j shell. In the light La nuclei similarly to the Cs case the proton Fermi level lies just below the [550]1/2$^-$ low-Ω Nilsson orbital while the neutron Fermi level is close to the [523]7/2$^-$ orbital at the middle of the $h_{11/2}$ subshell. On the basis of this fact one can expect signature inversion for the $\pi h_{11/2}\nu h_{11/2}$ bands in the light La isotopes, too. These bands are known in the La isotopes, however till now there is no unambiguous spin-parity assignment for them, and therefore the signatures are not known either. In ^{126}La high-spin bands have been observed in [2] and their configurations have been tentatively assigned as $\pi h_{11/2}\nu h_{11/2}$ and $\pi h_{11/2}\nu g_{7/2}$ on the basis of their signature splitting. The spins and parities were tentatively derived from the assigned configurations using the Gallagher-Moszkowski rules assuming that the lowest observed levels are the bandheads.

Experiments have been performed in order to establish the spin and parity values of the levels in the high-spin bands of ^{126}La and consequently to determine the signa-

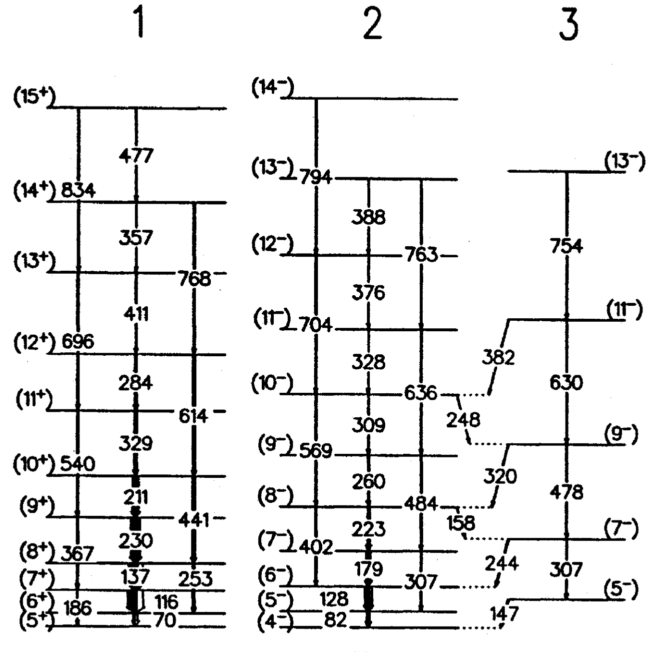

Fig. 1. Partial level scheme of ^{126}La obtained in the present work. Level and γ-ray energies are given in keV. The width of the arrows is proportional to the γ-ray intensity

tures in the $\pi h_{11/2}\nu h_{11/2}$ band. High spin states of the nucleus have been populated using the reaction ^{116}Sn+^{14}N at 68 MeV. The beam was provided by the Vivitron accelerator at IReS, Strasbourg. The γ-rays and the conversion electrons were detected with the GAREL array comprising fourteen EUROGAM2 tapered coaxial detectors, a planar Ge detector (LEPS) and the Betatronc [3], a gradient-field solenoidal electron guide equipped with a cooled Si(Li) detector of 28 mm diameter and 6 mm thickness. The γ-detectors were supported on one side of the beam line by part of the EUROGAM2 mechanical frame. Their front faces were placed at 15 cm from the target. The electron guide was installed on the other side at 90° to the beam. Its entrance face was at 11 cm from the target.

To stop the recoiling products of the nuclear reaction prior to conversion-electron emission, the targets were made of 190 μg/cm^2 of ^{116}Sn evaporated onto 200 μg/cm^2 of carbone. To reject the main part of δ-electrons created at the target by beam bombardment, a potential barrier was inserted inside the ion-guide chamber, along its axis. It was realized with an electrically isolated cylinder made of anodised aluminium of 80 mm diameter and 20cm length. Negative high voltage from 12 to 15 kV was applied.

45×10^6 γ(coaxial)-γ(coaxial), 1.3×10^6 γ(coaxial)-conversion electron and 1.4×10^6 γ(coaxial)-γ(LEPS) coincidence events were collected and stored on magnetic tapes. During the off-line analysis two-dimensional matrices were sorted from the coincidence events. The γ(coaxial)-γ(coaxial) matrix has been analysed using the Radware [4] graphical program package. The previously known ([2]) level scheme has been confirmed up to spin 14. The observed level scheme is shown in Fig. 1.

Internal conversion coefficients have been derived for the lowest-lying inband dipole transitions comparing the γ-ray and conversion-electron intensities in the spectra obtained by setting the same gates on the γ(coaxial) axis in the γ(coaxial)-γ(LEPS) and in the γ(coaxial)-conversion electron matrices. Sample γ-ray and conversion-electron spectra are shown in Fig. 2. The efficiencies of the Ge detectors and electron guide were obtained with ^{133}Ba, ^{152}Eu and ^{223}Ra radioactive sources. In the $50-400$ keV electron-energy range the absolute efficiency of the electron guide was larger than 2% with a maximum of 4.5% around 300 keV. The conversion coefficients were normalized to the 252 keV and 256 keV E2 transitions from the first excited states of ^{127}La and ^{126}Ba, respectively, which were strongly populated in the experiment. The obtained conversion coefficients give M1 or E2 multipolarity for the strong low-energy transitions. For the five lowest-energy transitions the K/L value have also been determined providing unambiguous M1 character for them. The observed conversion coefficients and K/L values are shown in Fig. 3.

It has been observed [6] and confirmed recently [7] that the β-decay of ^{126}La corresponds to two different decaying states, one populating the low-spin states while the other the high-spin (5-6) states in ^{126}Ba. From the measured β end-point energies [8] the high-spin state lies below the low-spin one by about 200 keV, however with an experimental error of about 400 keV which does not rule out strictly the opposite ordering. Assuming that the observed high-spin decaying state corresponds to the lowest state of either band 1 or band 2 a search was performed for low-energy decay-out transitions setting gates on the strongest inband γ rays in the γ(coaxial)-γ(LEPS) and in the γ(coaxial)-conversion electron matrices . No new transitions were seen in these coincidence spectra although the statistics and the purity of the spectra would enable to see E1 and M1 decay-out transitions with energies larger than 35 keV and 45 keV, respectively. This fact favours the scenario of being the high-spin decaying state below the low-spin one.

In order to confirm the previous tentative configuration assignments for the observed bands we compared

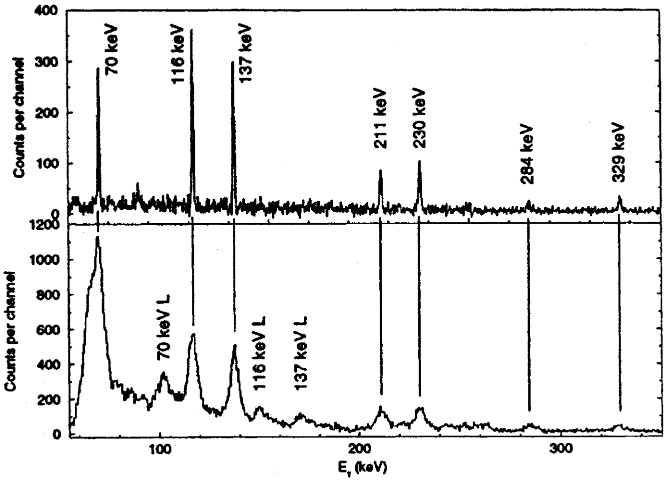

Fig. 2. Sample γ-ray (upper panel) and conversion electron (lower panel) spectra obtained in the present experiment. The vertical lines indicate the position of the K-conversion lines of the corresponding γ-rays. The gates were set on the 116, 137, 230 and 211 keV γ rays

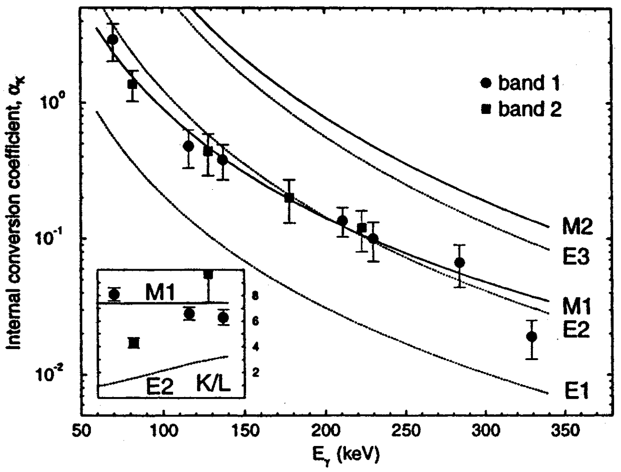

Fig. 3. Experimental (symbols with error bars) and calculated (solid and dotted curves) α_K conversion coefficients for the strongest ^{126}La transitions. The insert in the left bottom corner shows the K/L values

Table 1. Parameters used to calculate B(M1)/B(E2) ratios

Configuration	(g)-factor	(K) value	(i_x)
$(\nu d_{5/2})$	–0.33	2.5	0.5
$(\nu g_{7/2})$	0.21	2.5	1.0
$(\nu h_{11/2})$	–0.21	3.5	3.0
$(\pi h_{11/2})$	1.17	0.5	5.0

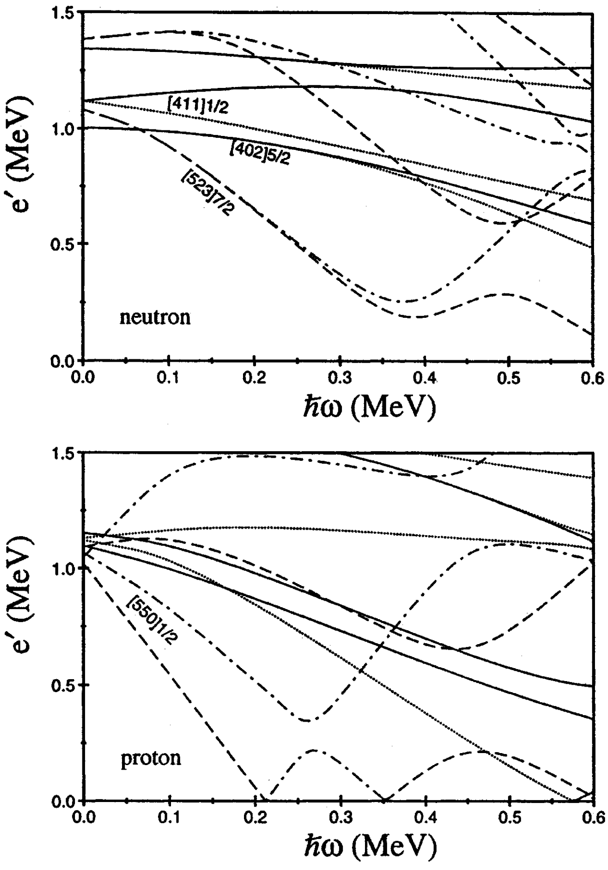

Fig. 4. Cranked shell model Routhians calculated for ^{126}La. The used parameters are given in the text

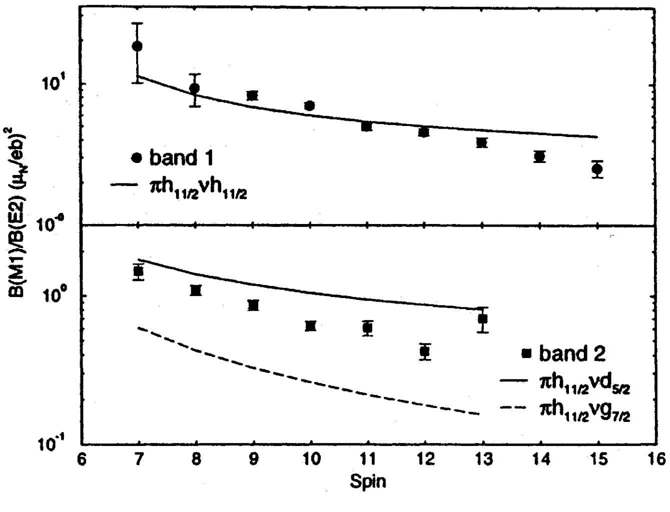

Fig. 5. Experimental and calculated B(M1)/B(E2) ratios for bands 1 and 2

them with cranked shell model calculations and we also compared the observed B(M1)/B(E2) ratios with calculated values using the Dönau-Frauendorf semiclassical formalism [5]. In Fig. 4 the calculated proton and neutron cranking Routhians are shown for the shape characterized by β_2=0.25, which is a typical value in this region, while the β_4 and γ values were set to zero. The experimental and calculated B(M1)/B(E2) ratios are shown in Fig. 5. The g-factors, K and alignment values used in the calculations are given in Table 1, g_R was taken as Z/A and the Q_0 electric quadrupole moment was calculated assuming an axially symmetric shape with β_2=0.25.

According to Fig. 4 the yrast band is expected to arise from the coupling of the α=-1/2 signature of the proton [550]1/2 Nilsson state to the two signatures of the neutron [523]7/2 orbital because of the large signature splitting of the [550]1/2 Routhians.

This band is expected to have positive parity and because of the blocking effect of the occupied [550]1/2 proton and [523]7/2 neutron orbitals neither the first proton nor the first neutron alignment is expected in this band. The next low-energy bands are expected to arise from the coupling of the proton [550]1/2 state to the bunch of three close-lying positive parity neutron orbitals comprising the two signatures of the [402]5/2 Nilsson state and the α=-1/2 signature branch of the [411]1/2 state. As the α=-1/2 signature orbitals in the bunch probably mix with each other we can expect three E2 bands coupled to each other with M1 transitions.

The experimentally observed band structures fit well to these expectations. Band 1 is built of two E2 bands coupled to each other by M1 transitions and it does not show alignment up to the 0.55 MeV rotational frequency. These facts and the agreement between the observed B(M1)/B(E2) ratios with the calculated values confirm the $\pi h_{11/2}\nu h_{11/2}$ configuration assignment for this band. Bands 2 and 3 form a coupled structure of three E2 bands. They do not show the first proton alignment expected below 0.3 MeV but show the beginning of an upband at about 0.4 MeV which is the expected frequency for the first neutron alignment. The experimental B(M1)/B(E2) ratios of band 2 lies between the calculated curves for the $\pi h_{11/2}\nu d_{5/2}$ and the $\pi h_{11/2}\nu g_{7/2}$ configurations but closer to the first one. This is in agreement with the fact that the [402]5/2 Nilsson orbital has basically $d_{5/2}$ character but mixed with $g_{7/2}$. This assignment, however, implies that in this three E2 band structure there should be two E2 band with α=1 signature and one with α=0 signature. This contradicts to the previous tentative spin assignment. In order to be in agreement with the calculations we propose (4^-) spin-parity for the lowest-energy level of band 2 which, according to the Gallagher-Moszkowski rules, should be 3^- or higher.

In a previous β-decay experiment using the He-jet technique and the ^{94}Mo + ^{35}Cl reaction [6] we observed direct population of the ^{126}Ba states from spin 0 to spin 7

Table 2. Relative population strengths of the ^{126}Ba states from the β-decay of ^{126}La assuming no direct feedings to the 0^+ states

Spin	0	2	3	4	5	6	7
Strength	[0.0]	13.2	13.2	43.8	21.5	6.8	1.5

in agreement with the scenario that there are two states in ^{126}La decaying by β^+, one with low spin and one with high spin. The observed relative global population strengths of the states is shown in Table 2 as a function of the spin. The facts that the most strongly populated spins are 4 and 5 but states with spins 6 and 7 are also directly populated suggest a probable spin of 5 for the high-spin decaying state.

Assuming that the lowest-energy high-spin state belongs to band 1 the above facts provide a most probable spin of 5 for the lowest level of band 1. According to the Gallagher-Moszkowski rules it is expected to be 4 or higher. This new spin assignment, however, changes the signature values belonging to the levels in band 1 and with the new signatures it shows signature inversion similarly to the $\pi h_{11/2}\nu h_{11/2}$ bands in the light Cs nuclei. This means that the existence of the signature inversion does not depend as strongly on the proton number in this region as it is proposed in [1].

In conclusion the ^{126}La high-spin bands and their β-decay have been investigated. Multipolarities of the strong-est transitions have been determined from conversion-elect-ron measurement. The previous tentative configuration assignments of the bands have been confirmed. New spin and signature values have been proposed for the bands on the basis of the observed β-decay properties and comparison with cranked shell model calculations. With the new signature values band 1 shows signature inversion similarly to the $\pi h_{11/2}\nu h_{11/2}$ bands in the light Cs nuclei.

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