INTERPLAY BETWEEN *K*-ISOMERISM AND γ-SOFTNESS IN ^{128}Xe*

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A partial decay scheme for ^{128}Xe is presented. The $K^{\pi} = 8^{-}$ state is isomeric with a half-life of 73(5) ns. Theoretical calculations have been performed using the configuration constrained blocking method based on a non-axial Woods–Saxon potential. Large γ-deformation and γ-softness have been predicted for the ground state. The strong shape-driving effect of the $K^{\pi} = 8^{-}$ state results in a much smaller value of γ for this configuration. This may partly explain the isomerism, despite the γ-softness. Measured hindrance factors are discussed in the context of the γ-softness of this nucleus.

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1. Motivation

The $^{128}_{54}$Xe nucleus is known to be γ-deformed and γ-soft in its ground state [1]. The K-quantum number, well defined only for axially symmetric deformed nuclei, $\gamma \sim 0$, is not expected to be such a good quantum number for γ-deformed nuclei. Nevertheless, a $K^{\pi} = 8^{-}$ isomeric state has been observed in ^{128}Xe [2], built on the combination of the two quasi-neutron $7/2^{+}[404]$ and $9/2^{-}[514]$ orbitals. This assignment is based on a measurement of the g-factor [3]. The existence of K-isomerism in this nucleus, implying the approximate conservation of K is not well understood, making

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this a particularly good testing ground. The shape polarization effect of different quasiparticle configurations may strongly affect the nuclear shape [4], and, in turn, the K-mixing.

2. Experimental details

High-spin states were populated using the fusion-evaporation reaction ^{124}Sn(^{9}Be,5n)^{128}Xe at a beam energy of 58 MeV. The time profile of the ^{9}Be beam, provided by the 14UD tandem accelerator at the Australian National University, was 2 ns pulses separated by 1.7 μs. This was incident on a 3 mg/cm^2 thick ^{124}Sn target. ^{128}Xe is produced strongly in this reaction with over 50% of the total cross-section. Time correlated γ-ray events were collected using the CAESAR array which comprises six Compton suppressed germanium detectors and two small volume unsuppressed germanium detectors (LEPS). Fig. 1 shows the partial decay scheme built in the present work.

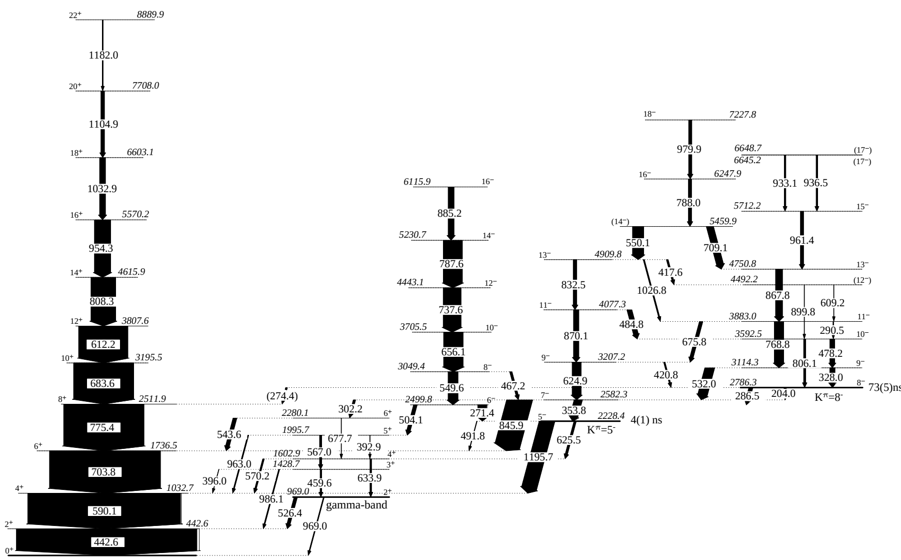

Fig. 1. Partial decay scheme of ^{128}Xe deduced from this work. The γ-ray energies are given in keV, and the thickness of the arrows represents the γ-ray intensity.

3. Shape-driving effects

^{128}Xe lies in the middle of the so-called 'transitional region', with an $E(4^+)/E(2^+)$ ratio of 2.33. Thus, the γ-degree of freedom will play an important role in any theoretical approach. Indeed, the partial ^{128}Xe decay scheme shows such a complexity with the lack of pure rotational bands, and only the yrast band shows a rotational behaviour at high angular momenta.

The configuration constrained blocking method is based on a non-axial Woods–Saxon potential, including β_2 and γ-degrees of freedom as dynamical variables [4]. Table I and Fig. 2 show the results for these calculations. Fig. 2(a) shows the PES calculation performed for the ground state (zero rotation, $\hbar\omega$=0). A triaxial shape is predicted with β_2=0.134 and γ=32.4°. The hexadecapole deformation is almost negligible. In particular, Fig. 2(left) shows that the ground state is very soft in the γ-degree of freedom. In addition, $K^\pi = 5^-$ and 8^- 2-*qp* states have been predicted at energies within 300 keV of experimentally determined ones.

TABLE I

Calculated shapes and excitation energies $E_{\rm cal}$ (in MeV) for the ground state and different 2-*qp* configurations in ^{128}Xe.

K^π	$E_{\rm exp}$	$E_{\rm cal}$	Configuration	β_2	$\mid\gamma°\mid$	β_4
0^+	0.0	0.0	ground state	0.134	32.4°	0.000
5^-	2.23	2.27	$9/2^-[514]\otimes1/2^+[400]$	0.142	26.0°	−0.002
8^-	2.78	2.49	$7/2^+[404]\otimes9/2^-[514]$	0.160	6.1°	−0.008

Evidence for the importance of the K quantum number comes from the measurement of the hindrance factors. The $K^\pi = 8^-$ state is isomeric with $t_{1/2} = 73(5)$ ns. The E1 274 keV decay to the ground state band has not been observed. However, a lower limit for the hindrance factor of 5.5×10^8 has been measured for such a branch. On the other hand, the half-life of the $K^\pi = 5^-$ state has been measured in this work as $t_{1/2} = 4(1)$ ns, and direct decays from the 5^- intrinsic state to the *gs* band ($\Delta K = 5$), 1195 and 491 keV E1 transitions, present hindrance factors of $F_{\rm W} = 3.010^7$ and $F_{\rm W} = 6.010^7$, respectively. These values are at least one order of magnitude lower than that measured for the 274 keV transition.

A possible reason for the hindrance value of the 8^- to *gsb* transition being greater than for the 5^- to *gsb* transitions is indicated in Table I and Fig. 2 (right). While the 5^- state is calculated to have $\gamma = 26°$ and therefore a possible admixture of K states, the 8^- has $\gamma = 6°$ and will have a relatively pure K-value. The low γ-deformation of the isomeric state gives an indication of the approximate conservation of the K-quantum number in the latter configuration. Therefore, the comparison between calculated shapes and measured hindrance factors leads to an interesting relation between the γ deformation of the intrinsic state and the possibility of K-isomerism.

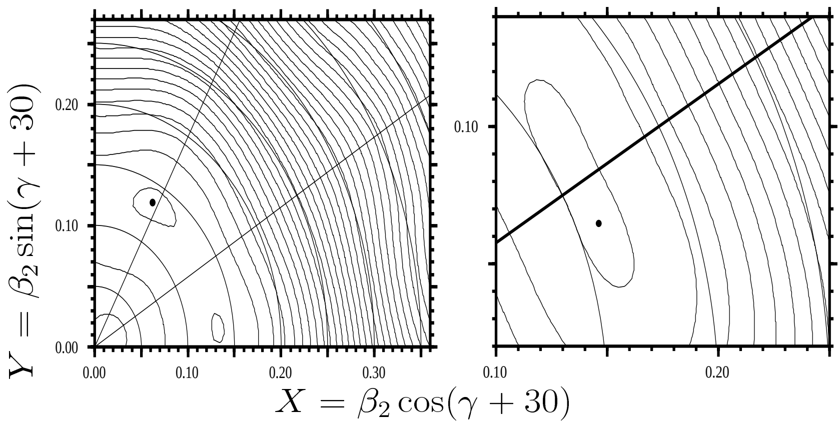

Fig. 2. The left panel shows the PES calculation for the ^{128}Xe ground state. The right panel shows the PES for the $K^\pi = 8^-$ isomeric state. The energy difference between the contours is 200 keV.

4. Conclusions

The existence of K-isomerism in such a γ-deformed and γ-soft nucleus is explained in terms of the shape driving effect of the $K^\pi = 8^-$ configuration. The comparison with the measured Weisskopf hindrance factors of E1 transitions that link the 5^- and 8^- intrinsic states to the yrast band support such a hypothesis. Further work is needed in order to study the trend of other possible intrinsic states.

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