Systematic study of signature splitting in odd-odd Ba nuclei

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Introduction:

Signature splitting is an interesting phenomenon observed in several nuclei, and it provides interesting phenomena and useful information related to the symmetry breaking under the rotation. According to the definition of the signature, the energy levels of a rotational band split into two sequences: $I\text{-}j_n\text{-}j_p$= even and $I\text{-}j_n\text{-}j_p$= odd, where I is the total angular momentum and j_n and j_p are the spins of the odd neutron and proton quasiparticles (QP), respectively [1]. The energy levels with even spin are found lower in energy compared to the odd spin states. The even spin sequence is known as favored signature, and the odd spin sequence is known as unfavored signature of the band. As a function of spin, the favored and unfavored sequences of energy states cross each other, which is known as signature inversion. This is measurable and observable parameter, represented by an energy staggering index, S(I). The energy staggering index is defined as:

$$S(I)= [E(I)–E(I-1)]-[E(I+1)-E(I)+E(I)-E(I-2)/2 \text{-------}(1)$$

Where, E(I) is the unfavoured energy state and E(I-1) is the favoured energy state. The signature quantum number (α) is associated with symmetry under π rotation (180°) of a deformed nucleus around the principal axis. For an axially deformed nucleus, the wave function for rotational motion about perpendicular to the symmetry axis remains unchanged under the π rotation and introduce a phase factor $(-1)^{I+K}$ in the energy expression [2-3]. The signature splitting is found increasing for mid- to high-shell nuclei with the involvement of high-j valance particles and introduces γ-softness in the nucleus. Hence, signature splitting is considered as a key observable for symmetry breaking and shape change. For favored signature band the signature quantum number (α) is defined as:

$$\alpha = 1/2[(-1)^{\wedge (I-1/2)}] \text{----------}(2)$$

The α determines the order of energy (favored/unfavored in energy).

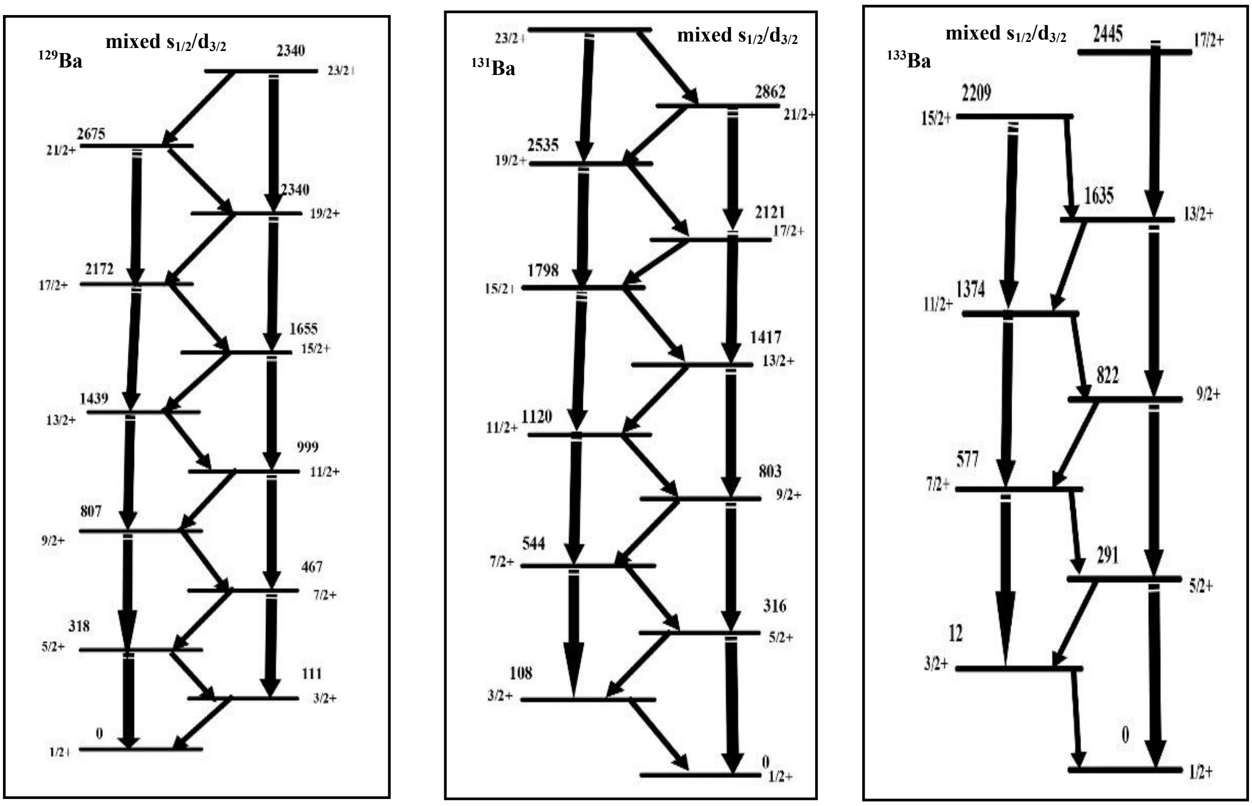

Figure 1: The bands of interests based on $I^{\pi} = ½^{+}$ states in odd-even nuclei $^{129\text{-}133}$Ba. The data is taken from references, [6-8].

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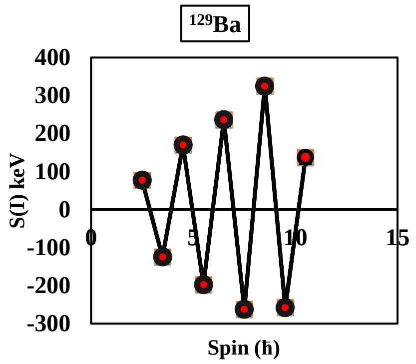

Figure 2: Signature splitting in ΔI = 2 bands based on $I^{\pi} = ½^{+}$ and $I^{\pi} = 3/2^{+}$ states in **^{129}Ba.**

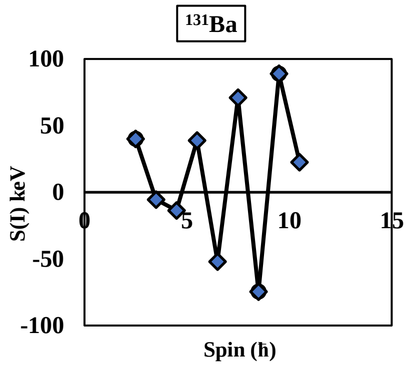

Figure 3: Signature splitting in ΔI = 2 bands based on $I^{\pi} = ½^{+}$ and $I^{\pi} = 3/2^{+}$ states in **^{131}Ba.**

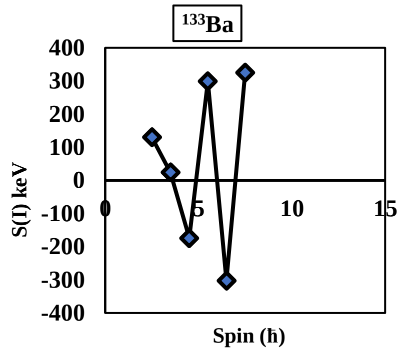

Figure 4: Signature splitting in ΔI = 2 bands based on $I^{\pi} = ½^{+}$ and $I^{\pi} = 3/2^{+}$ states in **^{133}Ba.**

The phenomenon of signature inversion in the ΔI = 2 bands associated with $\pi h_{11/2}$ and $\pi s_{1/2}$ and $\pi d_{3/2}$ orbitals was studied earlier in $^{132\text{-}136}$Ce even-even nuclei [4-5], and found to be very sensitive to the gamma degree of freedom. The present work focus on the signature splitting of the ΔI = 2 bands associated with $\nu s_{1/2}$ and $\nu d_{3/2}$ neutron orbitals in odd-even $^{129\text{-}133}$Ba nuclei inorder to understand the role of proton and neutron orbitals separately.

Result and Discussion

In the present work the signature splitting of the ΔI = 2 bands, viz. bands (I^{π}=state $1/2^{+}$ at 0 keV) and (I^{π}=$3/2^{+}$ state at 111 keV) in ^{129}Ba nucleus, the ΔI = 2 bands (I^{π}= state $1/2^{+}$ at 0 keV) and (I^{π}= $3/2^{+}$ state at 108 keV) in ^{131}Ba nucleus, and the ΔI = 2 bands (I^{π}= state 1/2+ at 0 keV) and (I^{π}= $3/2^{+}$ state at 12 keV) in the ^{133}Ba nucleus was studied. The levels of interest are shown in figure 1. The energy staggering index S(I) is plotted as a function of spin up to 12ħ for bands and found to be nearly increasing up to 10ħ in ^{129}Ba**,** shown in figure 2. The band configuration $\nu d_{3/2}/\nu s_{1/2}$ orbitals with low K are expected to lie near the Fermi surface in ^{129}Ba nuclei, hence large signature splitting is observed. However, after 10ħ signature splitting start decreasing may be due to alignment effect or may be due to other reasons. The bands with $\nu s_{1/2}/\nu d_{3/2}$ orbitals with low K in ^{131}Ba nucleus are also expected to show large signature splitting and same is observed (figure 3). In ^{133}Ba, signature splitting increases up to the spin 7ħ for bands (figure 4). The signature inversion is also observed near spin 4ħ in $^{131\text{-}133}$Ba nuclei. This may be due to the band mixing of $\nu s_{1/2}/\nu d_{3/2}$ or due to triaxiality. It seems that the neutron number (N=73, 75 and 77) in these nuclei is approaching to the N=82 shell closure and gives raise high signature splitting compare to the Ce nuclei.

Acknowledgments

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