B(E2)s of High-spin Isomers in Generalized Seniority Scheme

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Introduction

Modern experimental techniques have provided a new impetus to the exploration of nuclear isomers. Large number of isomers have been identified and measured in terms of their spectroscopic properties. The very recent "Atlas of Nuclear Isomers" presents about 2470 nuclear isomers with a half-life ≥ 10 *ns*, and sheds a light on many of their novel and unique systematic features [1]. An understanding of these features may sometimes require new physics reasons and this is the main aim of our work. In this paper, we focus on the isomers that arise due to the seniority selection rules and the role played by generalized seniority when multi-j configurations are involved. In particular, we concentrate on explaining the B(E2) values in the semi-magic isomeric chains by using a simple approach.

The semi-magic nuclei are a fertile ground to look for good seniority states and a significant amount of work already exists in this area, more so for the Z=50, Sn-isotopes. Seniority isomers arise due to the selection rules, generally relating to the E2 decays. In the previous paper [2], comparative studies of the identical and mirror behavior of the high-spin seniority isomers in the Z=50 and the Z=82 chains was presented. These were understood in terms of their seniorities and configurations by using the Large Scale Shell Model (LSSM) calculations. The seniority v = 2 and 3 isomers in both the chains were found to exhibit similar excitation energy behavior in the even-even and even-odd isotopes, respectively. The high-j $h_{11/2}$ and $i_{13/2}$ intruder orbits play an important role in these isomers. Their measured B(E2) variation has also been qualitatively understood in terms of the single-j seniority scheme by many groups.

In this paper, we study the B(E2) variation of these isomers by using the generalized seniority scheme, applicable to many-j degenerate orbits. We show that the isomers known to arise mainly from the high-j intruder orbitals, do require the configuration mixing as an essential requirement.

Formalism

We use the quasi-spin scheme to calculate the E2 transition rates in terms of seniority, which has been generalized to many-j degenerate orbits [3, 4]. The well known relation for the B(E2) between the initial and final states is given by,

$$B(E2) = \frac{1}{2J_i+1}\left|\left(J_f \left\| \sum_i r_i^2 Y^{(2)}(\theta_i,\phi_i) \right\| J_i \right)\right|^2 \quad \ldots(1)$$

where the reduced matrix elements of a resultant multi-j configuration $\tilde{j} = j \otimes j'$ can be written in terms of the seniority reduction formula as follows [4],

$$\left\langle \tilde{j}^n v l J_f \left\| \sum_i r_i^2 Y^{(2)}(\theta_i,\phi_i) \right\| \tilde{j}^n v l' J_i \right\rangle = \left(\frac{\Omega-n}{\Omega-v}\right)\left\langle \tilde{j}^v v l J_f \left\| \sum_i r_i^2 Y^{(2)}(\theta_i,\phi_i) \right\| \tilde{j}^v v l' J_i \right\rangle \quad \ldots(2)$$

Here, the total pair degeneracy is given by $\Omega = \frac{1}{2}\sum_j (2j+1) = \frac{1}{2}(2\tilde{j}+1)$ for n-particle configuration with v number of unpaired nucleons.

The B(E2) is, therefore, proportional to the $((\Omega\text{-}n)/(\Omega\text{-}v))^2$. We choose the active valence space as consisting of $h_{11/2}$, $d_{3/2}$ and $s_{1/2}$ orbitals in the Sn isotopes and $i_{13/2}$, $f_{7/2}$ and $p_{3/2}$ orbitals in the Pb isotopes. The resultant $\tilde{j}$ and Ω values become 17/2 and 9 in the odd/even Z=50 isomers, and 25/2 and 13 in the odd/even Z=82 isomers. We fix the proportionality constants by fitting the measured BE2 values for ^{116}Sn/^{198}Pb and ^{117}Sn/^{197}Pb in the two chains for the seniority v= 2, and 3 isomers, respectively. This constant carries the information about the radial matrix elements and is a very useful quantity in the LSSM calculations.

Results and discussion

We present a comparison of the experimental and calculated B(E2)s in the 10^+, Z=50 isomers and the 12^+, Z=82 isomers. Follow the upper and lower panels of Fig. 1 for the same. Fig. 2 presents a similar comparison for the $27/2^-$, Z=50 isomers and the $33/2^+$, Z=82 isomers in the upper and the lower panels, respectively. The calculated results, shown by the dashed lines in both the figures, reproduce the overall experimental trend quite well, except for the last points at the extreme right in both the chains. One can easily observe the identical behavior of B(E2)s in the high-spin isomers for both the chains in the even-even and even-odd isotopes (compare Fig.1 and Fig.2). The relative positions of the minima shift due to the different locations of $h_{11/2}$ and $i_{13/2}$ orbits in their respective valence spaces of 50-82 and 82-126.

These calculations, however, do not explain the sudden decrease in the BE2 values for the 12^+, and $33/2^+$ isomers in $^{199\text{-}206}$Pb isotopes. This may be due to the fact that these isomers also decay via an odd tensor transition (besides E2) to the low lying deformed states due to the shape coexistence in the Pb isotopes. On the other hand, the calculated results overestimate the measured values in $^{127\text{-}130}$Sn isotopes. This may be explained by using the generalized seniority scheme for the non-degenerate orbits, which may be useful to understand the observed particle-hole asymmetry due to the different rates of configuration mixing as in real wave functions.

Conclusion

The high-spin isomers in the Z=50 and 82 chains have been studied in view of the simple generalized seniority scheme for degenerate orbits. The simple formula proposed by us reproduces the experimental data quite well, and confirms the role of generalized seniority in these isomers, previously assumed to arise from the intruder orbitals only. Useful predictions can be made by using this formula. This also guides one in choosing the right space for the LSSM calculations. The involved geometric factors may further help in developing the realistic interactions. The calculated results also validate the previous results [2] behind the mirror energy trends of these isomers in the two chains due to the different relative position of the $h_{11/2}$ and $i_{13/2}$ orbitals in their respective valence spaces [2].

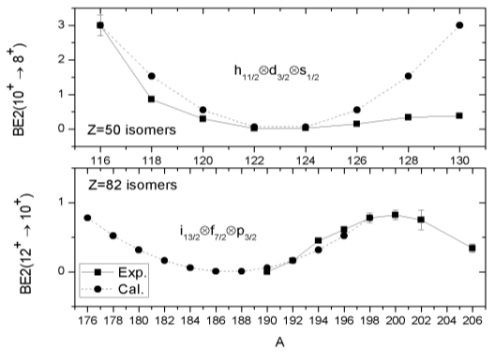

Fig. 1 Comparison of the experimental BE2s (in Weisskopf units) with the generalized seniority calculations in the even-even Z=50 and 82 isotopes. All the experimental data are taken from the ENSDF and XUNDL data sets [5].

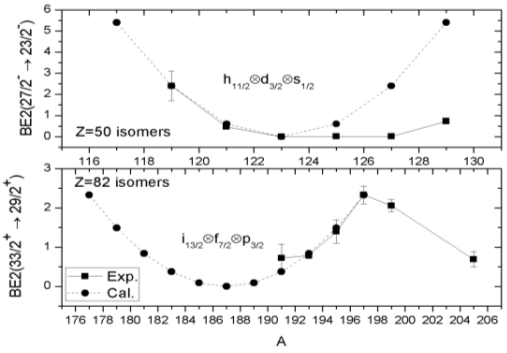

Fig. 2 Same as Fig. 1, but for the odd-A isotopes.

References

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[5] ENSDF:www.nndc.bnl.gov/ensdf/; XUNDL: www.nndc.bnl.gov/ensdf/ensdf/xundl.jsp