Contrasting behavior of B(E3) transition rates from even-A to odd-A N=82 isotones

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Introduction

The octupole correlations in nuclei are of great importance in nuclear structure, particularly for the low-lying excitations [1]. Strong octupole coupling exists for particle numbers associated with a large $\Delta N_p = 1$ (N_p being the principal quantum number) interaction between the unique-parity intruder orbital *(l; j)* and the normal-parity orbital *(l-3; j-3)*, particularly in normally deformed nuclei not far from the beta-stability line. Here, *l* and *j* denote the orbital angular momentum and the total angular momentum, respectively. Such regions of nuclei with strong octupole correlations correspond to nucleon numbers near 34 (coupling between the $1g_{9/2}$ and $2p_{3/2}$ orbitals), 56 (coupling between the $1h_{11/2}$ and $2d_{5/2}$ orbitals), 88 (coupling between the $1i_{13/2}$ and $2f_{7/2}$ orbitals) and 134 (coupling between the $1j_{15/2}$ and $2g_{9/2}$ orbitals), just above the Fermi surface of the interacting pair of nucleons. These regions are not very far from the closed-shells resulting in complex interplay of single-particle and octupole motion. Such interplay remains a topic of great interest due to its influence on the underlying nuclear structure [2]. The B(E3) transition rates are a good measure of the octupole collectivity in nuclei. Therefore, the systematic studies of B(E3) rates are quite useful to identify the *N* and *Z* values at which maximum octupole collectivity may occur and to explain the evolution of octupole collectivity along an isotopic/isotonic chain.

Our recent works [3-5] based on the generalized seniority have been quite successful in explaining and predicting the various spectroscopic properties for the isomers and other excited states in and around semi-magic nuclei. In the present work, we apply the generalized seniority (GS) approach to understand the experimental systematics of $B(E3;3^-\rightarrow0^+)$ rates [6, 7] for the even-even N=82 isotones for the first time and to contrast them with the $B(E3;11/2^-\rightarrow5/2^+)$ rates for odd-A N=82 isotones.

Brief formalism

The B(E3) transition rates for *n* particles in multi-j $\tilde{j} = j \otimes j' \ldots$ configuration can be obtained as [5]:

$$B(E3) = \frac{1}{2J_i+1}\left|\left\langle \tilde{j}^n v l J_f \left\| \sum_i r_i^3 Y^{(3)}(\theta_i,\phi_i) \right\| \tilde{j}^n v' l' J_i \right\rangle\right|^2 \quad (1)$$

where the reduced matrix elements connect the J_i (with GS v') to J_f (with GS v) by electric octupole (E3) operator. One can deduce the corresponding reduced matrix elements by using the reduction formula for GS conserving $\Delta v = 0$ and GS changing $\Delta v = 2$ transitions, respectively, as [4, 5],

$$\left\langle \tilde{j}^n v l J_f \left\| \sum_i r_i^3 Y^{(3)}(\theta_i,\phi_i) \right\| \tilde{j}^n v l' J_i \right\rangle = \left[\frac{\Omega-n}{\Omega-v}\right] \left\langle \tilde{j}^v v l J_f \left\| \sum_i r_i^3 Y^{(3)}(\theta_i,\phi_i) \right\| \tilde{j}^v v l' J_i \right\rangle \quad \ldots(2)$$

$$\left\langle \tilde{j}^n v l J_f \left\| \sum_i r_i^3 Y^{(3)}(\theta_i,\phi_i) \right\| \tilde{j}^n, v\mp 2, l' J_i \right\rangle = \left[\sqrt{\frac{(n-v+2)(2\Omega+2-n-v)}{2(2\Omega+2-2v)}}\right] \left\langle \tilde{j}^v v l J_f \left\| \sum_i r_i^3 Y^{(3)}(\theta_i,\phi_i) \right\| \tilde{j}^v, v\mp 2, l' J_i \right\rangle \quad \ldots(3)$$

where the coefficients in the square brackets depend on the particle number $n = \sum_j n_j$, the GS $v = \sum_j v_j$, and the total pair-degeneracy, $\Omega = \frac{2\tilde{j}+1}{2} = \sum_j \frac{2j+1}{2}$.

Results and discussion

Fig. 1 (lower panel) exhibits the B(E3;$3^- \rightarrow 0^+$) variation with respect to proton number for the first-excited 3^- states in the N=82 isotonic chain. The 3^- states are assumed to be *v=2* (arising from protons) states which decay by *E3* transition to the 0^+ pair-correlated *v=0* ground-states. The GS, therefore, predicts an inverted parabolic B(E3) trend for this transition by using Eqs. (1) and (3). Indeed, we find that the N=82 semi-magic isotones satisfy this trend quite well, as GS works reasonably well in semi-magic chains. Most of the experimental data have been taken from Kibedi and Spear [6] unless otherwise adopted from the ENSDF and XUNDL database [7]. The first 3^- states can be deciphered as the good *v* =2 states due to which these states follow nearly particle number independent energy variation in various semi-magic chains.

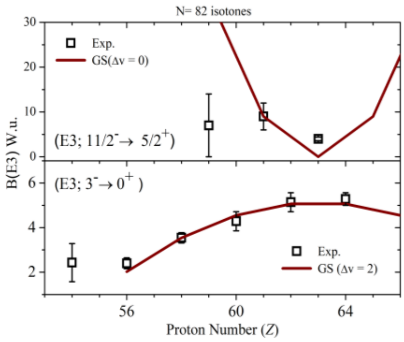

Fig. 1: Experimental B(E3) rates [6,7] in Weisskopf Units (W.u.) for the first 3^- states and $11/2^-$ states in even-A and odd-A N=82 isotones, respectively. GS stands for generalized seniority predicted trend.

Fig. 1 (upper panel) presents the B(E3;$11/2^- \rightarrow 5/2^+$) variation for the first-excited $11/2^-$ states decaying via E3 transition to the lower lying $5/2^+$ states in odd-A, N=82 isotones. Both the $11/2^-$ and $5/2^+$ states are taken to be same seniority (*v* =1) states for GS calculations. The GS scheme, hence, predicts a normal parabolic trend for these B(E3) rates. The predicted trend explains the measured values at Z=61, 63 in N=82 isotones, though the measurement at Z=59 is out of prediction range.

As one moves away from N=82, GS may persist for a couple of valence particles/ holes. Similar results have been found for the B(E3) rates in even-A and odd-A N=80, 84 isotones having two-neutron holes/particles with respect to the N=82 closed shell (and will be discussed in the full paper). Hence, the octupole evolution from even-even to odd-A nuclei has been understood for the first time in terms of generalized seniority symmetries. The GS results are of generic nature in nearly spherical nuclei. Recent measurement on ^{137}La reported the *B(E3)* enhancement [8], which also fit into the GS selection rules and explanation. A few important predictions from this work would suggest the measurement of B(E3;$11/2^- \rightarrow 5/2^+$) rates in odd-A ^{139}La (N=82) and re-measurement of B(E3) for ^{141}Pr (N=82) which has a large error bar. New measurements for these lower-lying levels may be very useful to study the competition of octupole collectivity with the GS (single-particle) estimates.

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