Importance of $0g_{9/2}$ orbit for $^{66-70}$Zn

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Introduction

Closure shells at N=28 and 50 have strong effect on the nuclei belonging to pf and f_5pg_9 mass region and their persistence have been studied extensively in several nuclei [1,2] in last two decades where the lowest order multipole excitation *i.e.* quadrupole excitation variation achieves a minima with respect to neighbouring nuclei. It is furthermore supported by the complementary well-defined maxima of E_2^+ at N = 28 and 50. Thus, these characteristics support unlike jumps of lower placed nucleon within closed shell to upper energy level of another shell due to strong paring interaction between like nucleons, large energy gap between two shell and/or to the change in parity of single-particle energy levels [3] of two shells. However, single-particle energy levels present between N = 28 and 50 is also framed for the presence of quasi magic number that build sub-shell closure at N = 40, produced from the absence of non-central spin-orbit coupling interaction in the mean field single-particle potential which split a bunch of three odd parity states ($p_{3/2}$ $f_{5/2}$ $p_{1/2}$) to even parity intruder state ($0g_{9/2}$). Moreover, its signature analogous to shell closure nuclei has been marked in Ni isotopic chain [3]. But despite of its quasi-closure nature, its ability to reduce the excitation is less marked when few protons are added above the ^{56}Ni core. Presence of this unique orbital also plays distinct role in nucleon excitation process and development of collectivity around A~60-70 nuclei.

Hence, Zn isotopic chain is of primary interest to investigate the persistence of sub-shell closure and to determine the contribution of $\nu 0g_{9/2}$ in nucleus excitation process in medium mass Zn isotopes. In the present work, we report calculated low-lying yrast levels and B(E2) for $^{64-70}$Zn to account the aspects responsible for less persisting signature of quasi-magic number. Our calculated results are compared with existing experimental measured values [4,5].

Shell Model Calculation

We have performed our calculation from the M-scheme based Shell Model Antoine code [6] in two different sets. However, these sets have been made from combination of two different model space and two different effective interactions i.e. KB3G [7] and JUN45 [8] called set 1 and set 2. In the following calculations, the global space configuration obtained via the mixing of sub-valence space has type

$$X^{n-n0}Z^{n0} + X^{n-n0-1}Z^{n0+1} + X^{n-n0-2}Z^{n0+2} + ... + X^{n-n0-t}Z^{n0+t}$$

Here, X and Z represent lowest orbit and rest orbits of the valence space respectively. n and t are total number of nucleon in valence space and truncation number respectively. However, n_0 has non-zero value when neutrons (or protons) present in the valence space are greater than the occupancy of the lowest orbit of respective sub-space. Hence, for $t = n - n_0$ we have full space calculation $(XZ)^n$. Due to large dimension of Hilbert matrix for set1, full space calculation was not feasible for ^{64,66}Zn. Thus, we have employed truncated scheme for them where maximum 4 particles (neutrons + protons) were allowed to promote from $1f_{7/2}$ to above orbits. Moreover, core polarization effect on electrical quadrupole properties has been studied by the use of effective charge $e_\pi = 1.5$ and $e_\nu = 0.5$ in set1 and $e_\nu = 1.1$ in set2.

Results and Discussion

Our full space calculations of low-lying states of set2 are in good agreement with experimental situation, whereas results with less degree of freedom of active nucleons in set1 show large discrepancy from the experimental

systematic, as shown in Fig. 1. Here, change in slope of low lying states of ground state band for set 1 as a function of neutron number in isotopic chain varies significantly that represent individually particle-hole excitation from $f_{7/2}$ orbit into remaining fp orbits is insufficient to characterize the heavier zinc isotopes and indeed requirement of $g_{9/2}$ orbit for neutrons to excite. Moreover, validity of wave-function for each eigenvalue of each set has been studied from B(E2: $2_1^+ \rightarrow 0_1^+$) calculations. A similar behavior has been observed in B(E2) calculation, as expected in both sets, see Fig. 2. Thus, study of energy eigenvalues and B(E2) clearly reveal the significant contribution of $\nu 0g_{9/2}$ in ground state band of $^{66\text{-}70}$Zn whereas ^{64}Zn gives good results in pf space. It can be looked as the pull down of $\nu 0g_{9/2}$ by cluster of $\nu(p_{3/2}f_{5/2}p_{1/2})$ originate from T = 1 interaction on filling the valence space by active neutron near the sub-shell. Moreover, minima of B(E2) at N = 40 in Ni chain show maximum strong neutron paring interaction between active nucleon [3] in the valence space while shift in calculated values from 40 to 38 for Zn represent effect of addition of two proton. Hence, it indicates weak competence of sub-shell closure and its inept nature to keep the nucleus in spherical shape. However, at N= 38, deviation of B(E2) curve of Zn from Ni is interrupted as onset of deformation in Zn nucleus owing to the fact of decrease in strong neutron paring interaction due neutron-proton correlation. Thus, deviation in ground state band properties of set 1 represents the necessity of $0g_{9/2}$ orbit in calculations that can account the changes in strong neutron paring interaction due to addition of active proton in model space.

Conclusion

Our calculations for $^{66\text{-}70}$Zn in shell model frame shows essential requirement to add $g_{9/2}$ orbit to enlarge the configuration space and to increase the degree of freedom of valence nucleons that characterize the change appear in paring interaction when two active protons are added into the valence space. Thus, our set 2 calculations of Zn chain give good agreement with data while set1 results deviate significantly.

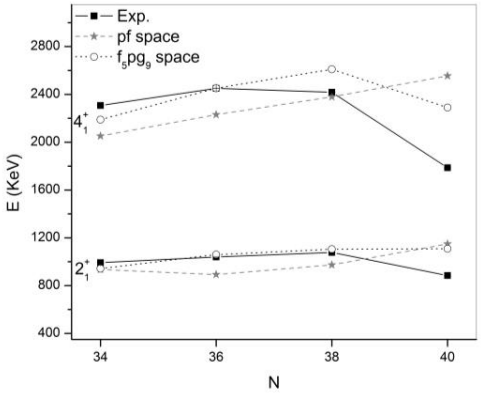

Fig. 1 Calculated E(2_1^+) and E(4_1^+) as a function of neutron number in pf and f_5pg_9 space.

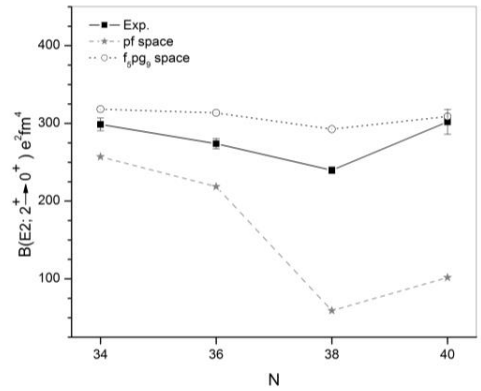

Fig. 2 Calculated B(E2) as a function of neutron number in pf and f_5pg_9 space.

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