Low-lying nuclear structures of ^{59,61}Zn: a shell-model study

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Introduction

Construction of a precise theoretical model of the nucleus is very difficult because of complex relationship between the nucleons. Hence, different nuclear models have been proposed. The shell-model has been found to be important in explaining level energies, magnetic moments, quadrupole moments etc. of different nuclei lying near as well as away from magicity. It is observed that the A ≈ 60 region nuclei can have both single particle and collective excitation modes with various competing shapes, viz. prolate, oblate and triaxial. A striking interplay of single particle and collective degrees of freedom have been observed in numerous Ge [1-5] and Cu [6-10] isotopes in this region. Here, the active orbitals are $2p_{3/2}$, $1f_{5/2}$, $2p_{1/2}$, and $1g_{9/2}$. In our present work, we have taken two Zn isotopes, ^{59}Zn and ^{61}Zn lying just beyond the N=Z=28 shell closure. The nuclide ^{59}Zn is a member of the series with T_z = - 1/2. The nucleus decays to its mirror nucleus by superallowed β^+ transitions. The charge independence of the nuclear force makes these nuclei play an important role in testing nuclear models. The level structures of ^{59}Zn and ^{59}Cu exhibit similarities. This mass number is very useful in predicting unknown masses of neutron-deficient nuclei that lie far from the line of β stability.

To do calculation, one has to assume that the valance nucleons are distributed in different orbitals (model space) outside the core and all the properties of the nucleus are basically governed by the valance nucleons. One has to diagonalize the Hamiltonian within the assumed model space with a suitable choice of two body residual interaction. For performing shell-model calculations of these nuclides, we have made use of the code, Nushellx. Here the valence space, which is allowing unrestricted occupation no. of proton as well as neutron orbitals $1f_{5/2}$, $2p_{3/2}$, $2p_{1/2}$, and $1g_{9/2}$, ope rates as our model space $f_{5/2}pg_{9/2}$. The doubly closed ^{56}Ni nucleus is the insentient core. The code has been run in light of jj44b [11-12] and JUN45 [13] effective interactions,. Both the effective interactions were formed on the basis of the Bonn-C potential. Here, the effective charges of proton and neutron considered by us are 1.5e and 0.5e, respectively. It will be really very interesting to inspect the appropriateness of the model space $f_{5/2}pg_{9/2}$ and the used effective interactions in solving the nuclear structure related issues in connection with the lighter Zn nuclei, ^{59,61}Zn. we have compared the calculated level energies with the experimental data. We have calculated the occupation probabilities of the $2p_{3/2}$, $1f_{5/2}$, $2p_{1/2}$ and $1g_{9/2}$ proton and neutron orbitals for many positive and negative parity states, B(E2) values, electric quadrupole moments of both the nuclei that will be discussed briefly in the conference.

Results and Discussion

Shell-model level schemes obtained from both the interactions are compared with the experimental levels in the Fig. 1 and 2. In the case of ^{59}Zn, the ground state spin is correctly predicted by the interactions. The observed energy of the $5/2^-$ state is in moderate agreement with jj44b interaction. It is overestimated by jun45 interaction by 761 keV, which is too high. The $7/2^-$ state is very well reproduced by either interaction. For the $13/2^-$ state, the deviation in energy is not high (around 130 keV). For ^{61}Zn nuclide, the energy value of the ground state is correctly reproduced by jj44b interaction. The $9/2^-$ state is almost equally overestimated (by nearly 100 keV) in both calculations. Regarding the remaining states, the calculations with jj44b interaction estimates much closer results than that with jun45 to the observed outcomes.

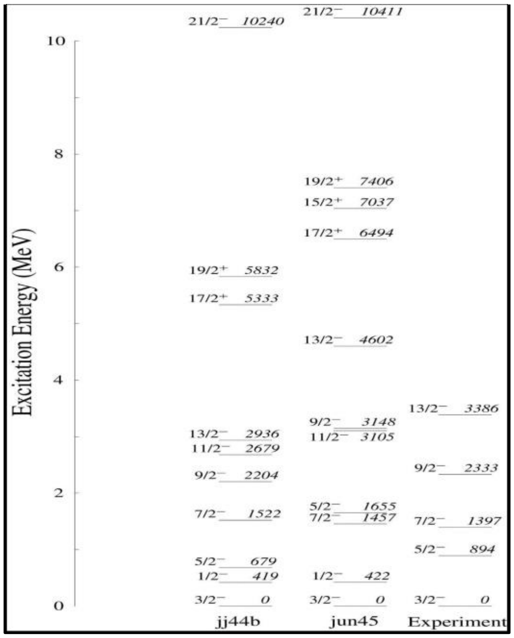

Fig. 1 ^{59}Zn level schemes

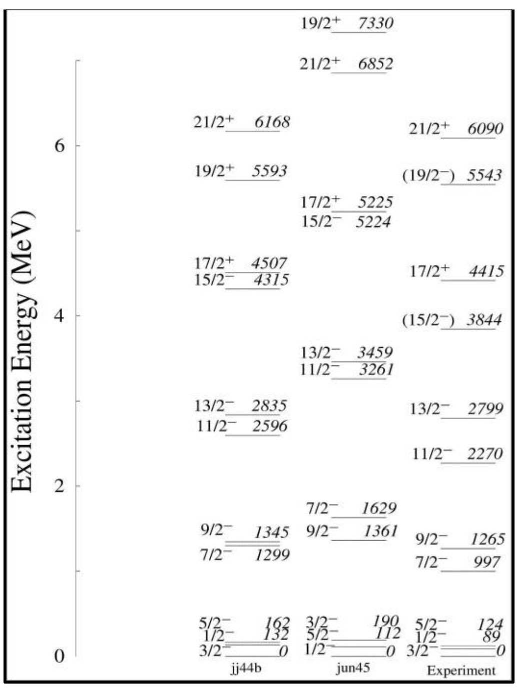

Fig. 2 ^{61}Zn level schemes

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