Multi-quasiparticle structure of ^{80}Se

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Introduction

In the A≈ 80 mass region, low-lying energy states in several isotopes have been studied with higher precision. A large amount of interesting effects occur in this mass region. In recent years, the study of low- and high-spin phenomena in the proton-rich mass-80 nuclei have attracted considerable interest. This has come up by the increasing power of experimental facilities and improved theoretical descriptions, as well as by the requirement in understanding the structure of these unstable nuclei. In comparison to the rare-earth region where the change in nuclear structure properties is quite smooth, the structure of the proton-rich mass-80 nuclei shows considerable variations when going from one nucleus to another. This is mainly due to the fact that the available shell model configuration space in the mass-80 region is much smaller than in the rare-earth region. The low single-particle level density implies that a drastic change near the Fermi surfaces can occur among neighboring nuclei. Among the known nuclei in the medium to heavy mass region, the nuclear deformation has been observed for both neutron-rich and neutron-deficient isotopes in the mass region A ≈ 80 and ≈ 100 [1]. Another fact is that in these medium-mass proton-rich nuclei, neutrons and protons occupy the same single-particle orbits. As the nucleus rotates, pair alignments of neutrons and protons compete with each other and in certain circumstances they can align simultaneously. Some extensive measurements of the transition quadrupole-moments have also been extracted for various isotopes. These measurements have revealed large variations in nuclear structure of these isotopes with respect to the angular momentum. It has been observed that alignment of proton- and neutron-pairs at higher angular momenta can change the nuclear shape from prolate to triaxial and to oblate. The early mean-field approaches were devoted to a general study of the structure in the mass-80 region. Besides the work using the Woods–Saxon approach, there were studies using the Nilsson model and the Skyrme Hartree–Fock + BCS theory. The large-scale spherical shell model diagonalization calculations have been recently proved to be successful in describing the pf -shell nuclei [2], but the configuration space required for studying the well-deformed mass-80 nuclei is far beyond what the modern computers can handle. The projected shell model (PSM) has become quite popular to study the structure of deformed nuclei. The advantage in this method is that the numerical requirement is minimal and, therefore, it is possible to perform nuclear structure study on any complex nucleus in a reasonable time frame.

Theory of Projected Shell Model (PSM)

The detailed description of applied framework Projected Shell Model (PSM) can be found in a review article [3]. Projected Shell Model is the natural extension of the Shell Model, which basically begins with the deformed Nilsson single-particle states at a deformation ε_2. It uses angular-momentum projection technique in order to project out energies from the deformed Nilsson basis and hence makes Shell Model type of calculations possible for deformed nuclei. A brief account on the Hamiltonian along with the important input parameters used in the present calculations is given hereunder. The Hamiltonian used for the present PSM calculations is

$$\hat{H} = \mathrm{H}_{\circ} - \frac{1}{2}\chi\sum_{\mu} \hat{Q}^{\dagger}_{\mu}\hat{Q}_{\mu} - G_{M}\hat{P}^{\dagger}\hat{P} - G_{Q}\sum_{\mu}\hat{P}^{\dagger}_{\mu}\hat{P}_{\mu}$$

where H_{o} represents the spherical single particle Shell Model Hamiltonian, involving spin-orbit interactions while the second, third and fourth terms represent the quadrupole-quadrupole, monopole and quadrupole pairing interactions respectively. χ denotes the strength of quadrupole-quadrupole two-body interaction and is adjusted with the quadrupole deformation parameter, ε_2. For the present set of PSM calculations, three major shells (N = 2, 3, 4) for both protons and neutrons have been used. The Shell Model space is truncated at deformation parameters, $\varepsilon_2 \sim 0.210$ and $\varepsilon_4 \sim 0.000$ for ^{80}Se nucleus.

Results and Discussions

To gain the physical insights and to extract the valuable information regarding the nuclear structure from the PSM calculations, it is necessary to investigate and discuss the energies in terms of band diagram, which is an ensemble of projected configurations being plotted together. Band diagram plays a crucial role for the interpretation of the yrast states, which is the lowest band and is obtained after configuration mixing of various multi quasi-particle configurations. In the present study, the yrast levels have been investigated and also compared with experimental results as well as with the JUN45 and jj44b interactions for ^{80}Se nucleus.

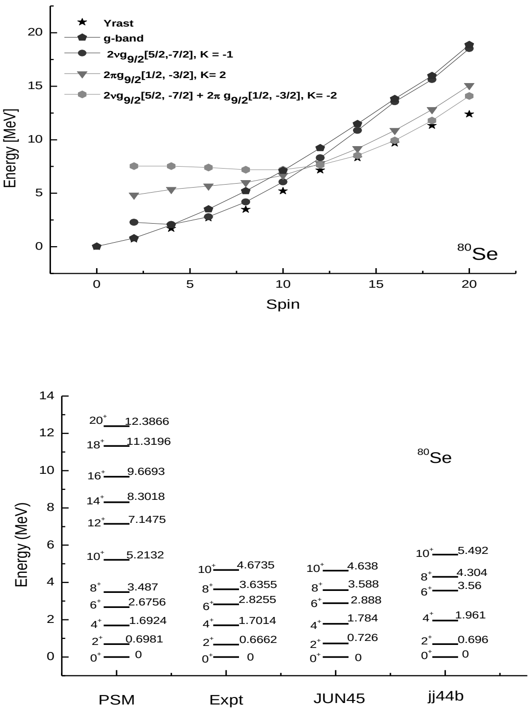

Fig. 1 (a) Band diagram of ^{80}Se (b) Yrast energy states of the ^{80}Se nucleus.

From fig. 1 (a), one finds that the yrast spectrum upto 4^+ coincides with the g-band arising from 0-qp intrinsic state. At spin 4^+, the g-band is crossed by 2-qp neutron band having configuration $2\nu g_{9/2}[5/2,-7/2]$,K = -1, which becomes yrast upto 12^+. At spin 12^+, the 4-qp band having configuration $2\nu g_{9/2}[5/2, -7/2] + 2\pi g_{9/2}[1/2, -3/2]$, K= -2 crosses the 2-qp neutron and proton bands and becomes yrast from spin 12^+ upto the last calculated spin 20^+. Furthermore, Fig. 1(b) presents the yrast spectra of ^{80}Se. The experimental data as well as other theoretical JUN45 and jj44b data [4] has been reproduced with an overall good agreement by the calculated values of energy for ^{80}Se. The g-factor and back-bending in moment of inertia have also been plotted and compared with the experimental value for ^{80}Se isotope and are shown in Figs. 2(a) and 2(b) respectively. The figures depict an overall good agreement in both forms of data.

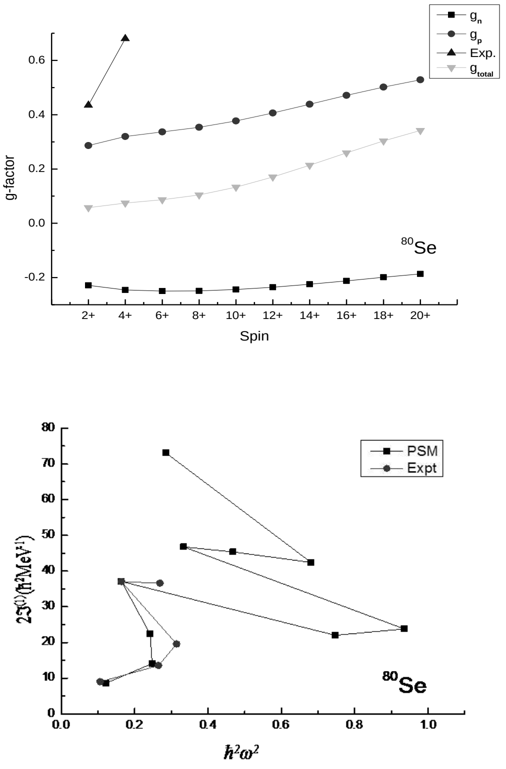

Fig. 2 (a) g-factor versus spin plot of ^{80}Se (b) Back-bending in moment of inertia ^{80}Se nucleus.

Summary:

The even-even ^{80}Se isotope has been studied within theoretical Projected Shell Model framework. The yrast level arising from multi-quasi particle configuration has been well described. Also the back bending, band diagram and g-factor shows good agreement with the available experimental results.

References:

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