Shell-model description of $N=Z$ pfg-shell nuclei

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[NUCLEAR STRUCTURE, shell model]

In upper pf-shell nuclei, various interesting phenomena have been discovered recently, such as the development of nuclear deformation, the coexistence of different shapes near the ground state, the formation of isomeric states, the double β decay, and so on. In neutron-rich nuclei, the shell structure can be different from that of the stable nuclei, which reveals a new aspect of the nuclear tensor force[1)]. For deeper understanding and reliable predictions of these phenomena, a unified theoretical framework has been desired.

We have developed an effective interaction JUN45 for shell-model calculations in the model space consisting of valence orbits $1p_{3/2}$, $0f_{5/2}$, $1p_{1/2}$ and $0g_{9/2}$ assuming an inert ^{56}Ni core (f5pg9-shell). Here, we modified a realistic interaction (renormalized G-matrix[2)] derived from the Bonn-C potential) through the iterative fitting calculations to a body of experimental energy data as we did in the derivation of the GXPF1 interaction for the pf-shell[3)]. In the latest iteration, we have attained the rms error of 185 keV for 400 data taken from 87 nuclei with masses A=63-96.

In $N=Z$ nuclei, since protons and neutrons occupy the same orbit, the strong proton-neutron interaction works efficiently, which can develop significant collectivity. In the derivation of the JUN45 interaction, we excluded the experimental data of nuclei around $N\sim Z\sim 40$ region for the fit in order to avoid possible difficulties for describing such collectivity due to the limited model space. Therefore, it is interesting to examine to what extent we can explore this region with the f5pg9-shell space.

As an example, we consider ^{68}Se ($N=Z=34$), for which the shape coexistence has been predicted by the deformed potential model. Experimental observation[5,6)] is in fact consistent with the oblate ground state band, which is crossed by an excited band with prolate shape at around the spin $J\sim 8$. As shown in Fig.1, we have obtained two low-lying bands on top of the 0^+_1 and the 0^+_2 states. The calculated quadrupole moment for the 2^+_1 is $+44e\mathrm{fm}^2$, and that for the 2^+_2 state is $-41e\mathrm{fm}^2$. This indicates that the ground band shows the oblate shape, while the excited band is prolate, which is consistent with the experimental findings. However, the calculated moment of inertia is

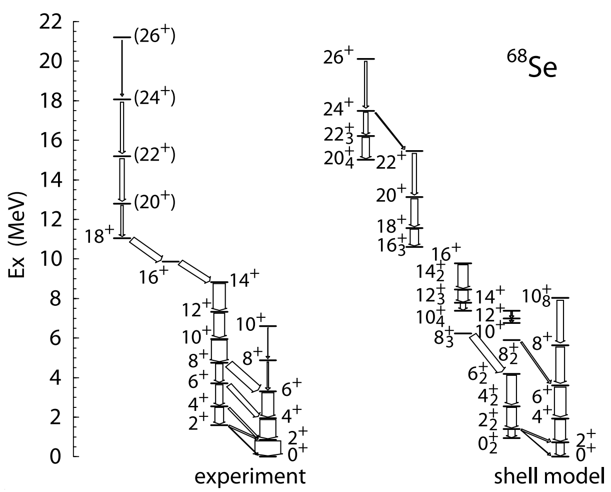

Fig. 1. Comparison of energy levels between the experimental data and the shell-model results for ^{68}Se. The width of the arrow drawn in the experimental part corresponds to the relative γ-ray intensity, while it stands for the relative B(E2) values in the theoretical part. Experimental data are taken from Refs.[5,6)]. The shell-model results are obtained by using the efficient shell-model code MSHELL[4)].

somewhat too small especially in the prolate band. As a result, the crossing with the oblate band never occurs. This indicates the insufficient collectivity for the prolate deformation within the present model space.

The calculated occupation number of the $g_{9/2}$ orbit is almost constant within each band. It is about 1.0, 2.3, and 4.1 for the low spin (J=0$\sim$8), intermediate spin (J=10$\sim$14), and high spin (J=16$\sim$22) band, respectively. Thus, the higher spin bands are generated by successive promotions of nucleons into the $g_{9/2}$ orbit. Considering the reasonable overall agreement between the experimental data and the shell-model results, we can expect that the JUN45 successfully describes the single-particle properties related to the $g_{9/2}$ orbit in the deformed mean potential.

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