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Shell Model Calculations for some pf Shell Nuclei

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Abstract

In this proceeding, the nuclear energy levels of the some isotopes of Cu and Ga nucleiwere investigated within the nuclear shell model. ^{56}Ni nucleus was considered as inert core for the theoretical application and pf single particle orbitals on this core were used as the model space. f5pvh nucleon-nucleon interaction were used for two-body effective interactions. $f_{5/2}$, $p_{3/2}$ and $p_{1/2}$ orbitals have been handled as active model space orbitals. KShell shell model software was used for the calculations. The results have been compared with the experimental data and they are in good agreement.

Keywords: KShell Code, Nuclear Shell Model, Nucleon-Nucleon Interaction, pf-Shell

1. INTRODUCTION

The investigation of the neutron-rich nuclei in the pf-shell is one of the interesting topics for the nuclear structure studies. Especially, the structure of the exotic nuclei in the pf-shell region displays some interesting phenomena such as the appearance of new magic numbers and disappearance of well-known ones [1]. The identification of the energy levels for given nucleus is one of the important way to describe the nuclear structure properties. One of the successful model is the nuclear shell-model (SM) establishedto understand some properties of the nuclei [2,3].

In this proceeding, we have focused on the calculations of the energy levels forsome odd-odd isotopes of Cu and Ga nuclei. These calculations were performed within Kshell code [4] applied to the nuclear shell-model calculations with M-scheme representation with the thick-restart Lanczos method. Moreover, this code can compute some other nuclear structural properties such as the magnetic and quadrupole moments, E2/M1 and one-particle spectroscopic factors.

The proceeding is structured as follows; the basic information concerning shell model and calculations is introduced in this section,the second section includes the methodology, the calculated results for the energy levels along the isotopic chains of both given nuclei are presented and discussedby comparing experimental data in the third section. The conclusion is summarized in the last section..

2. METHOD

For the shell model calculations on the energy levels of the given nuclei, Kshell computer code [4] has been used because of its power on the medium and heavy mass region. The Kshell code was applied for calculations of the energy levels for some isotopes of Cu and Ga nuclei. In pf-shell space consists of p1/2, f5/2 and p1/2 valence orbitals as shown in Fig.1. This figure illustrates the pf-model space and the core according to shell model theory. The double magic ^{56}Ni nucleus is taken as the core and the nucleons with angular momentum j=0 cannot move from the core.

In the shell model, the valance nucleons can move in a finite number of j-orbits and the Hamiltonian of the valance nucleons is given as following [5]

$$H = E_0 + \sum_i \varepsilon_i a_i^+ a_i + 1/2 \sum_{ijkl} \langle ij|V|kl\rangle a_i^+ a_j^+ a_l a_k. \quad (1)$$

Here,E_0, ε_i and $\langle ij|V|kl\rangle$ terms are the energy for the inert core, the single particle energies (SPE) for the valance orbits and two-body matrix elements (TBME) of residual interaction amongst the valance particles, respectively [6]. For the calculation process with f5pvh effective interaction, the SPE's are -9.42 MeV, -10.27 MeV and -9.05 MeV for $f_{5/2}$, $p_{3/2}$ and $p_{1/2}$ orbitals, respectively. TBMEs are fitted from the experimental data and 158 TBMEs are used for this calculations.

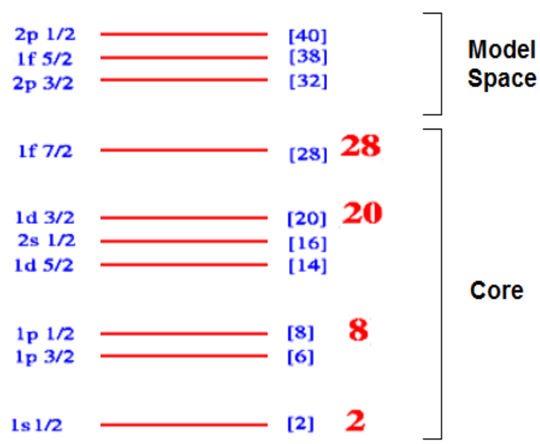

Figure 1. The core till 28 magic number and $f_{5/2}$, $p_{3/2}$ and $p_{1/2}$ orbitals of pf-model space for the calculations

3. RESULTS AND DISCUSSION

For this work, we focused on the calculations of the energy levels for some odd-odd isotopes of Cu and Ga nuclei by using Kshell code [4] of the nuclear shell-model with M-scheme representation with the thick-restart Lanczos method. The calculated results are compared with the experimental data by presenting in the figures and discussed for both Cu and Ga nuclei.

The calculated energy levels for the odd-odd Cu isotopes are presented in Fig.2. This figure shows the calculation results by comparing the experimental data obtained from the National Nuclear Data Centre (NNDC) [7]. The well agreement with the observed level scheme is very good for the case of N=Z ^{58}Cu isotope close to double magic ^{58}Ni nucleus. Also this isotope consists of only two active particles in model space. Until 1.665 MeV of 2^+ level, the results are highly compatible with the experimental spectra. But the experimental 1.647 MeV of 3^+ level is missing in shell model calculations. Moreover, the low energy levels of other odd-odd ^{60,62,64,66}Cu isotopes are well calculated with the correct spins along to this isotopic chain despite considering the fact that no adjustable parameter is used here. In the case of ^{62}Cu isotope, the 2^+ level lowered and therefore the 2^+ is calculated as the lowest level instead of 1^+. For ^{60,62,64,66}Cu isotopes, 10 levels are below than 1 MeV and several experimental spin assignments are tentative. For ^{60,62,66}Cu isotopes, 0^+ levels are experimentally unknown along to the spectra up to 1 MeV. However, these unknown levels are predicted within the shell model calculations. In between ^{60}Cu and ^{68}Cu isotopes, while the mass number is increasing, 3^+ levels are gradually going down in energy and finally become lowest for ^{68}Cu isotope. The energy levels in the ground state bands are well predicted for ^{62}Cu and ^{68}Cu isotopes.

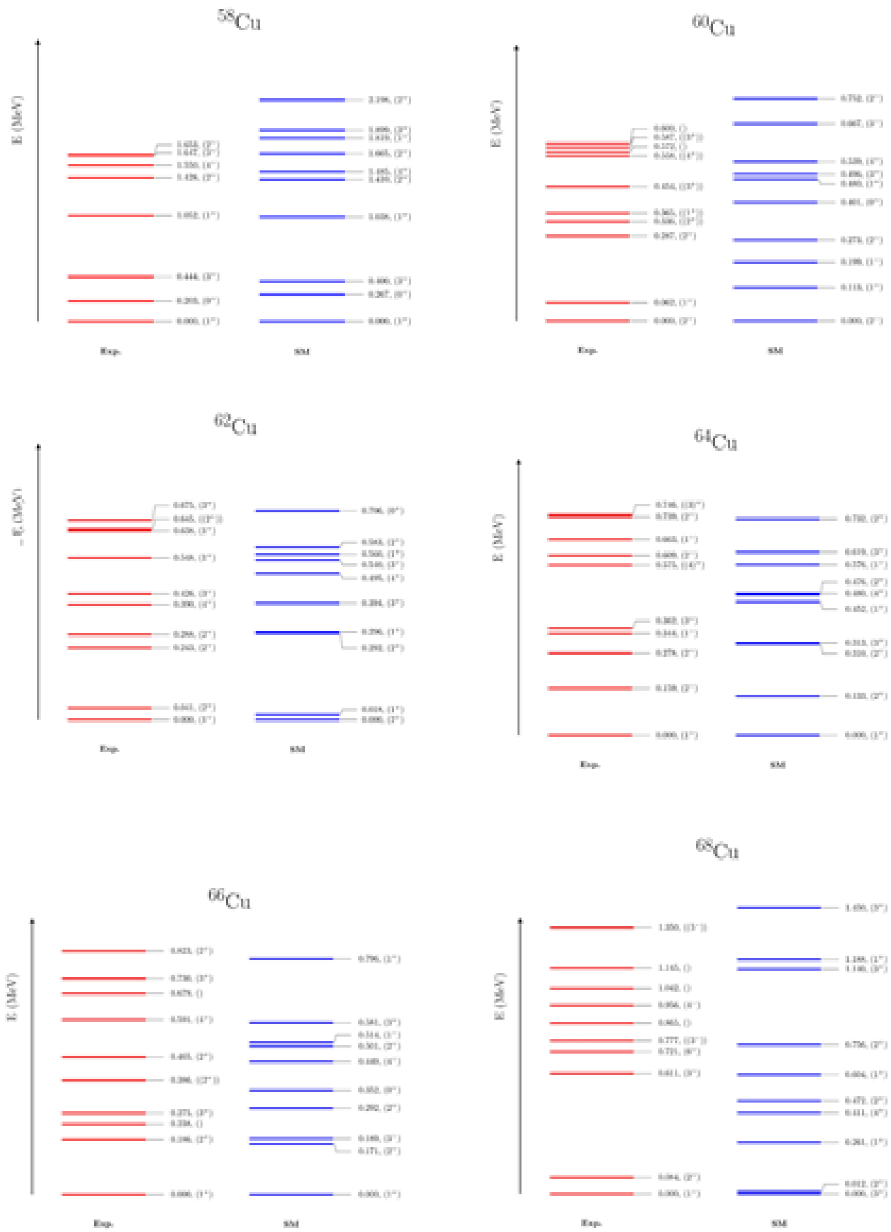

Figure 2. The experimental (red) and the calculated (blue) energy levels for odd-odd $^{58\text{-}68}$Cu isotopes.

The calculated energy levels for some odd-odd isotopes of Ga nuclei are presented in Fig. 3. This figure includes the shell model calculations and the experimental data [7]. However, shell model calculations are performed for the prediction of the unknown excited states for exotic ^{60}Ga isotope which is very close to proton dripline. For isotopic chain, the spins and parities are generally well calculated especially for the low levels in the ground state bands. Moreover, some unknown levels located in between experimental 0^+ and 1^+ states were predicted for odd-odd ^{62}Ga isotope. This N=Z isotope can supply some important information on competing T=0 and T=1 excitation modes or isospin effects. As seen figures in the panels of Fig. 3, the low energy levels in the ground state bands have good agreement in between calculated results and experimental data. However, the experimental 44 and 163 keV states are missing in the shell model calculation for ^{66}Ga isotope. The results are generally in good agreement with experimental for other Ga isotopes. In the shell model calculations, some energy levels appear up to 0.376 MeV for ^{68}Ga isotope and up to 0.508 MeV for ^{70}Ga isotope.

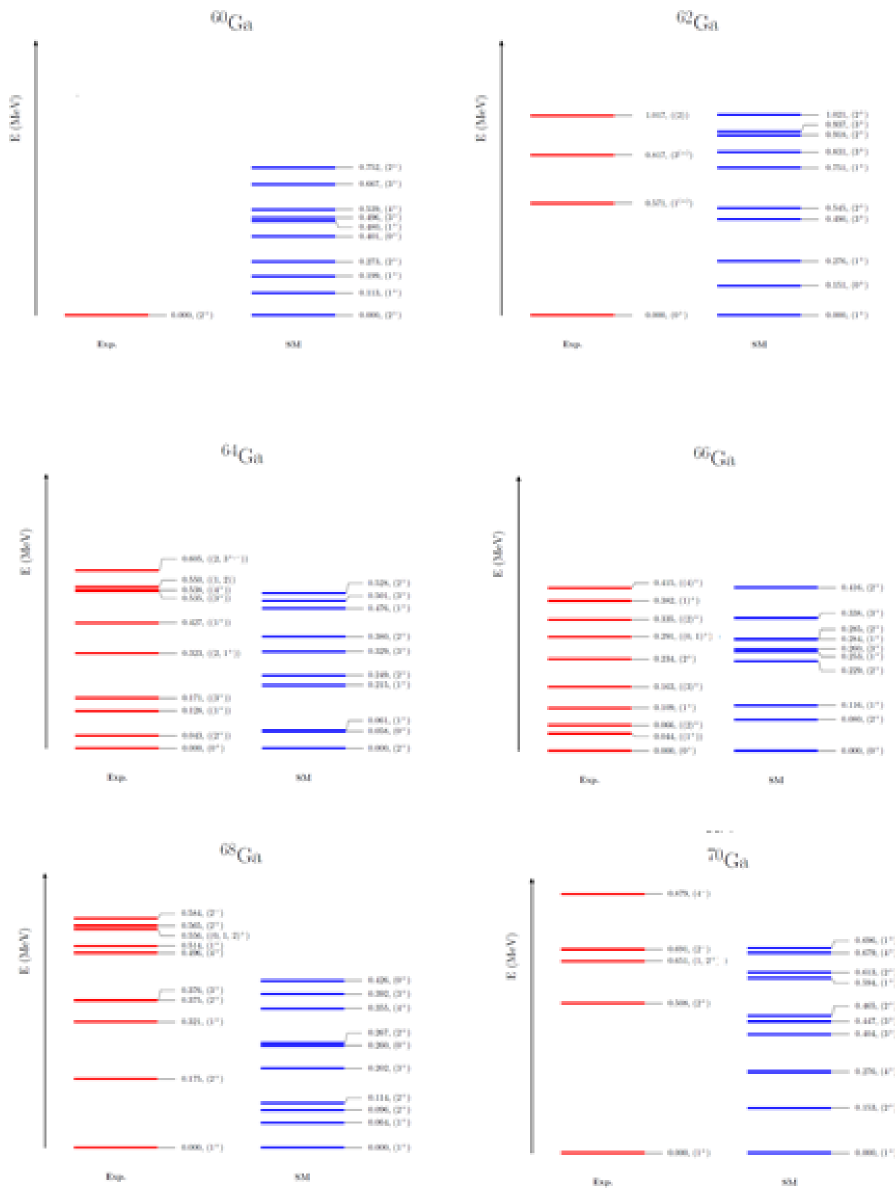

Figure 3. Similar to Fig. 2 but for odd-odd $^{60-70}$Ga isotopes

4. CONCLUSIONS

In this proceeding, the energy levels of the ground state bands some odd-odd $^{58,60,62,64,66}Cu$ and $^{60,62,64,66,68,70}Ga$ isotopes were investigated within the nuclear shell model. Kshell computer code [4] was used for the calculations on these 12 isotopes in total. The calculated results were compared with available experimental data from NNDC [7] and they are generally in good agreement. Some unknown energy levels are also predicted for some exotic isotopes. Some other nuclear structural properties such as the electromagnetic transitions probabilities, magnetic and quadrupole moments, E2/M1 ratios can be calculated for given isotopes. Since the computer performance, only the energy levels were calculated for this proceeding for the moment. We are planning to calculate the high energy levels in the ground state bands and also in the other bands with other nuclear properties by using powerful computer systems. Moreover, this work can be expanded to the neighbour odd-even isotopes for given Cu and Ga nuclei, results can be compared with experimental data and also other nuclear models' calculations

5. ACKNOWLEDGEMENTS

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