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Nuclear Structure Study of ^{34}S, ^{34}Ar and ^{34}Cl Nuclei in D_3F_7 Shell

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Abstract

The nuclear structure of the nuclei ^{34}S, ^{34}Ar and ^{34}Cl are studied in the framework of the shell model. The model space is consists of two configurations $0d_{3/2}$ and $0f_{7/2}$ orbits. The even-even nucleus S^{32} is assumed to form closed shell, with two nucleons outside closed shell are considered to describe the excited states and the binding energy of the nuclei under study. A computer code were written by Mathematica to perform the configuration mixing shell model calculations by taking the modified surface delta interaction (MSDI) as residual interaction. These calculations are compared with shell model code Oxbash by employing the effective interactions W0, HW and SAS as residual interactions . The computed the ground-state energies and the low-lying states for the ^{34}S, ^{34}Ar and ^{34}Cl are compared with the recent available experimental data. A reasonable agreement were obtained by comparing our theoretical work with the experimental data.

Keywords: Energy levels, Shell model, Oxbash.

1. Introduction

In recent years there has been substantial progress in the application of shell model to study nuclear structure (Caurier *et al*., 1994). The potentials of the shell model approach to the description of nuclear energy levels. The traditional shell model approach consists first in the determination of the effective Hamiltonian, either by modifying renormalized nucleon–nucleon interactions, or simply by fitting all possible two-body matrix elements and single-particle energies to the available experimental (Puddu, 2009). The nuclear shell model is one of the cornerstones for a comprehensive understanding of nuclei. Strong efforts in the field are aimed at unraveling the driving forces behind structural departures from the well established, traditional shell model, which have been observed mostly in nuclei with a large proton and neutron excess (Gadee ,2013; Srivastava and Mehrotra, 2010). The SMCM method takes into account the correlations between the closely spaced orbitals between the closed shells as exactly as possible. The SMCM hamiltonians are derived from data on ground and excited states in specific mass region (such as the sd-shell and pf-shell) which are used to determined the effective two-body interaction (Brown, 2000).

In this paper, the nuclear shell model with modified surface delta interaction (MSDI) (Brussaard and Glaudemans, 1977) as residual interaction have been used to investigate properties of the low-lying levels of ^{34}S, ^{34}Ar and ^{34}Cl in which a computer code were written using Mathematica these theoretical calculations are compared with the calculations using the computer code Oxbash for windows (Brown *et al*., 2004) by adopting W0 (Seth *et al*., 1974), HW (Hsieh *et al.,* 1986) and SAS (Sakakura *et al*., 1976) as residual interactions and with the recent available experimental data.

2.The Modified Surface Delta Interaction

Residual interaction is defined as the force that produces when nucleons collide with each other and this interaction is happen the perturbation in Hamiltonian operator that equal summing two particles potential and represent Hamiltonian operator to perturbation state from equation (Lawson, 1980):

$$H = H_{\circ} + \sum_{i<j} V_{ij} \qquad \text{.....(1)}$$

V_{ij} is the residual two-body interaction , H_0 is represent Hamilton operator without perturbation. To calculate the spectrum of these nuclei we assume the that the residual interaction V_{ij} is given in eq.(2) (Brussaard and Glaudemans, 1977):

$$V^{MSDI}(1,2) = -4\pi A'_T \delta(r(1)-r(2))\delta(r(1)-R_{\circ}) + B'(\tau(1).\tau(2)) + C' \quad \text{.....(2)}$$

The antisymmetrized matrix element of $V^{MSDI}{}_{(1,2)}$ is given by eq.(3):

$$\langle j_1 j_2 | V_{12} | j_3 j_4 \rangle_{JT} = (-1)^{n_1+n_2+n3+n4} \frac{A_T}{2(2I+1)} \left\{ \frac{(2j_1+1)(2j_2+1)(2j_3+1)(2j_4+1)}{(1+\delta_{12})(1+\delta_{34})} \right\} \{(-1)^{j_2+j_3+l_2+l_4}$$

$$\langle j_1 \tfrac{1}{2}\, j_2 -\tfrac{1}{2} | I0 \rangle \langle j_3 \tfrac{1}{2}\, j_4 -\tfrac{1}{2} | I0 \rangle [1-(-1)^{l_1+l_2+I+T}] - \langle j_1 \tfrac{1}{2}\, j_2 \tfrac{1}{2} | I1 \rangle \langle j_3 \tfrac{1}{2}\, j_4 \tfrac{1}{2} | I1 \rangle [1+(-1)^T] \}$$

$$+[2T(T+1)-3]B + C \qquad \text{.....(3)}$$

Where $\langle j_1 \tfrac{1}{2}\, j_2 -\tfrac{1}{2} | JM \rangle$ are Clebsch- Gordan coefficients and $j_1 j_2 j_3 j_4$ are the spin states of particles .J and T are indicat to the spin and isospin of two particle state. Where A_T,B,C are strength parameters of (MSDI).

3. Shell Model Calculations

The large-scale shell model calculations were carried out in the D3F7 model space . with modified surface delta interactions (MSDI) as residual interaction in eq.(3). And with shell model code Oxbash by employing the effective interactions W0, HW and SAS as residual interactions. The mixing configuration is used of the nuclei ^{34}S, ^{34}Ar and ^{34}Cl to calculate low-lying states by taken ^{32}S nuclei as core with two nucleon outside core. The theoretical results compare with experimental data and the previous theoretical work in Ref.(Hasan and Hussain, 2013).

4. Results and Discussion

The low-lying energies have been calculated of d3f7 Shell region of ^{34}S, ^{34}Ar and ^{34}Cl nuclei for the isovector T=1,0. In nucleus ^{34}Cl have isovector part T=1 and isoscalar T=0 , but in ^{34}S, ^{34}Ar have isovector T=1.

The low-lying energies of even-even nucleus ^{34}S are shown in Fig.1. The comparison between our calculations and experimental data (Leaderar and Shirley, 1978; Endt and Firestone,1998; . Nica and Singh, 2012). and with the previous theoretical work in Ref. (Hasan and Hussain, 2013) using (SDI) interaction, is given the first excitation level 2^+_1(2.335Mev) at MSDI relative to that obtained with the W0, HW and SAS and with SDI is nearest to the experimental value (2.127Mev). The negative parity states (5^-,3^-) at the values (6.102,5.592MeV) in interaction SAS are good agreement with the experimental values from interactions used and previous work. As spins that obtain for high spectra 6^+_1,2^-_2,0^+_2, 2^+_3,4^+_2 are in a good agreement with data for interaction MSDI . In this the comparison, we find our results in MSDI interaction for the positive and negative parity states much better than W0,HW,SAS and previous theoretical work in Ref.(Hasan and Hussain, 2013).

Fig-1. Comparison of calculated spectra with experimental data from Refs. (Leaderar and Shirley, 1978; Endt and Firestone,1998; . Nica and Singh, 2012) for **^{34}S** nucleus and the previous work from Ref.(Hasan and Hussain, 2013).

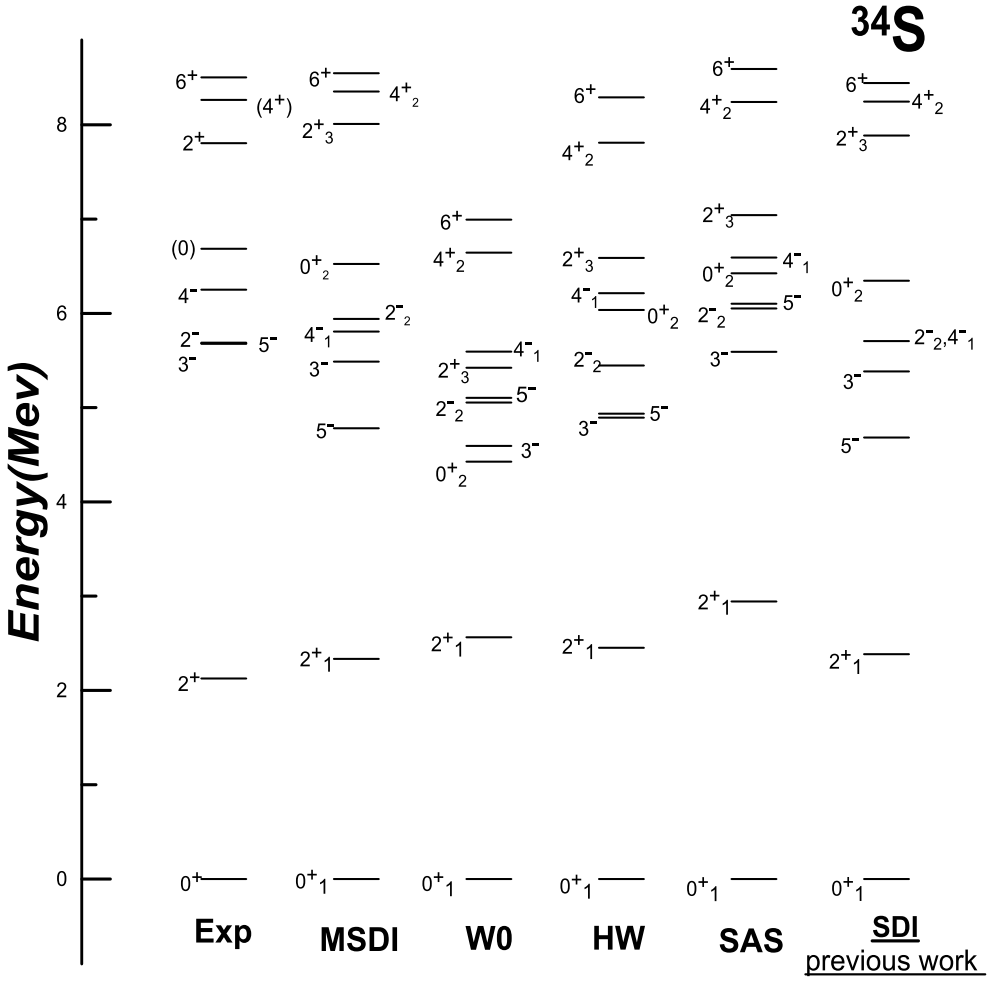
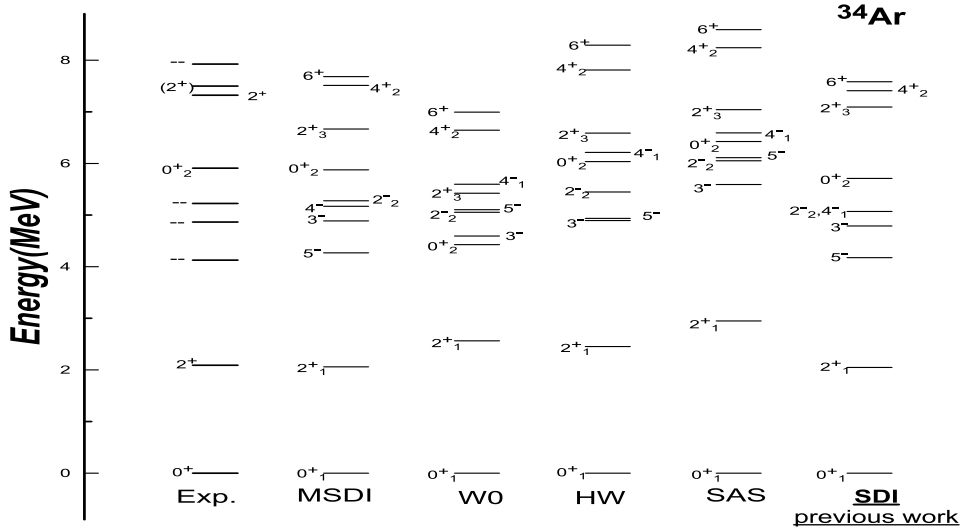


Fig.2. shows plot the energy spectrum of even-even nucleus ^{34}Ar . When compared our calculations with data (Leaderar and Shirley, 1978; Endt and Firestone,1998; . Nica and Singh, 2012), and with the previous theoretical work in Ref.[12] using (SDI) interaction. We see the first 2^{+}_{1} is predicted at 2.09MeV in MSDI interaction which is very close to the previous work in Ref.(Hasan and Hussain, 2013). and their compare with data are in excellent agreement. Most of the theory results of employed HW in oxbash interactions are in agreement experimental data. As well as the excitation energies computed in MSDI interaction an excellent agreement with data. From comparison proves unequivocally that MSDI interaction is a better form Oxbash interactions. Experimental values (4.865,5.22,7.499,7.925MeV) have been predicted and confirmed by angular momenta (3^{-},2^{-}_{2},4^{+}_{2},6^{+}).

The adopted values in MSDI interaction for odd-odd nucleus ^{34}Cl are shown graphically in Fig .3. have been compared with the experimental data (Leaderar and Shirley, 1978; Endt and Firestone,1998; . Nica and Singh, 2012) and with the previous theoretical work in Ref.(Hasan and Hussain, 2013) using (SDI) interaction . In our calculations the prediction values of ground band (1^{+}_{1},2^{+}_{1}) in reasonable agreement with data from previous theoretical work. The positive and negative parity states in MSDI interaction are very close to the previous results in Ref.(Hasan and Hussain, 2013) as well as some Experimental values have been predicted and confirmed by theoretical angular momenta. From compare between our results and experimental data are in reasonable agreement. This agreement between the results indicate to the role of mixing between d3f7shell orbits. We notice the shell model configuration mixing has been successfully evolved to study these energy levels.

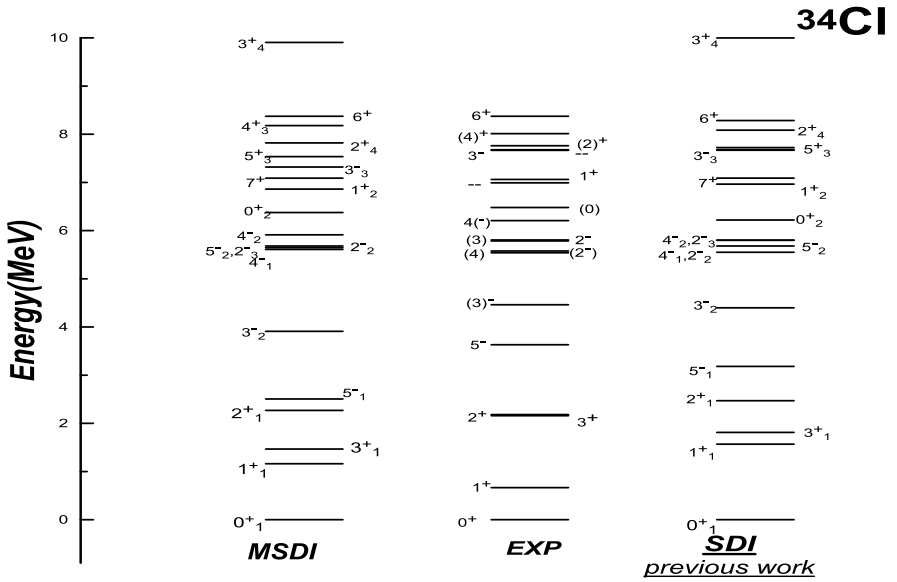
Fig-2. Comparison of calculated spectra with experimental data fromRefs. (Leaderar and Shirley, 1978; Endt and Firestone,1998; Nica and Singh, 2012) for **^{34}Ar** nucleus. and the previous work from Ref.(Hasan and Hussain, 2013).



5. Conclusions

Unrestricted large-scale shell model calculations were performed using model space d3f7. The MSDI interaction and the shell model code Oxbash for Windows were employed and taken nucleus ^{32}S as close core for ^{34}S, ^{34}Ar and ^{34}Cl. The MSDI interaction is better from code Oxbash interactions in description of energy levels which goes back to fitting the parameters to experimental spectra in the mass region A=34. The results of this work are compared with the recently available experimental data and with the previous theoretical work in good agreement. We concluded the shell model configuration mixing in this region is very successful.

Fig- 3. Comparison of calculated spectra with experimental dara from Refs. (Leaderar and Shirley, 1978; Endt and Firestone,1998; . Nica and Singh, 2012) for ^{34}Cl nucleus . and the previous work from Ref.(Hasan and Hussain, 2013).



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