Shell Model Calculation of Cluster correlation in ^{36}Ar and ^{34}S

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Introduction

Knowledge on α-clustering plays an important role to understand the structure of nuclei as it has a strong connection to different areas of nuclear structure like nuclear molecules [1], nuclear deformation [2,3]. In light mass region, the cluster properties were studied to some extent for α-conjugate nuclei ^{40}Ca [2], ^{36}Ar [3], ^{28}Si [4] using different cluster models like antisymmetrized molecular dynamics (AMD) [5] and orthogonality condition model (OCM) [6]. Recently, α-cluster configuration has also been observed in non α-conjugate ^{35}Cl [7] and ^{34}S [8]. The cluster structures of these nuclei were explained in terms of one nucleon transfer spectroscopic factors obtained from large basis shell model (LBSM) calculation. In this present work, we have correlated the α-cluster states in ^{34}S with the α-cluster Superdeformed (SD) states and its partner un-observed negative parity states in ^{36}Ar through LBSM calculations. We have calculated the two nucleon transfer spectroscopic factor for the cluster states in ^{34}S in terms of two proton hole coupled to the cluster SD states in ^{36}Ar. The result obtained from LBSM calculation shows a strong correlation between these states.

Large Basis Shell Model Calculation

In order to investigate the cluster correlation**,** LBSM calculations have been performed for ^{34}S and ^{36}Ar, using the code OXBASH [9]. The valence space consists of $1d_{5/2}$, $1d_{3/2}$, $2s_{1/2}$, $1f_{7/2}$, $1f_{5/2}$, $2p_{3/2}$ and $2p_{1/2}$ orbitals for both neutron and protons above the ^{16}O inert core. The number of valence particles in ^{34}S is 18 and 20 for ^{36}Ar respectively. The *sdpfmw* interaction [10] was used for the calculation. Relevant details of calculations using this interaction were discussed in [11].

The negative parity states and the high spin positive parity states ($>5^+$) in ^{34}S have been generated with 1p-1h and 2p-2h excitations respectively. The details of the calculation were discussed in Ref. [8]. In ^{36}Ar, the LBSM calculation was first carried out for the observed SD band. In this calculation, 4p-4h excitations to the *pf* shell were considered. During calculation, $1d_{5/2}$ was fully closed and the single particle energies (SPE) of the *pf* orbitals have been suppressed by 3.375 MeV to reproduce the band head (0_2^+) energy. The mass normalization factor for this calculation was 32 [10]. In Fig. 1, we have compared our results with experimental energies. LBSM calculation has also been done for the unobserved negative parity partner band (3p-3h) as was predicted in Ref. [6].

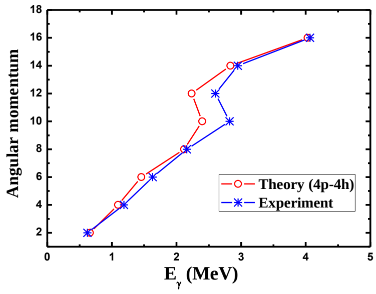

Fig-1: Comparison between the experimental and the theoretical transition energies of the SD band in ^{36}Ar.

^{34}S is two nucleon (proton) away from ^{36}Ar. Therefore, LBSM calculations have also been carried out with *sdpfmwpn* interaction to know the particle configuration of these states of interest. It shows that the positive parity (2p-2h) and negative parity (1p-1h) states in ^{34}S have been generated primarily by exciting 2 neutrons and 1 neutron into the *pf* orbaitals respectively. On the other hand, the observed SD band in ^{36}Ar have 2 proton+2 neutron configuration and the average number of proton and neutron is 1.5 for the un-observed negative parity band. Therefore, the structure of these positive and negative parity states in ^{34}S can be well described by coupling two proton holes into the *pf* shell of ^{36}Ar. Hence, we have calculated the two nucleon transfer spectroscopic factor of each states of interest in ^{34}S in terms of two proton holes coupled to the *pf* shell of the parity doublet states in ^{36}Ar as a core.

Results and Discussion

In order to estimate the parentage of the positive parity states in ^{34}S in terms of two nucleon spectroscopic factor, we have coupled two proton holes into the *pf* shell of observed SD band in ^{36}Ar. As we are considering two nucleons coupled to the *pf* shell of ^{36}Ar, number of contributions from different *pf* orbitals for different ΔJ (depending on the core angular momentum and the angular momentum of the state of interest) values have been increased. Therefore in our calculation, for a particular core angular momentum we have only considered the contributions having spectroscopic amplitude ≥ 0.05. For the contribution <0.05, the maximum value has been taken. The calculated spectroscopic factors (square of the spectroscopic amplitude) for the positive parity states in ^{34}S have been shown in Fig. 2. It shows that among all the positive parity states, 6^+, 8^+ and 10_2^+ states are primarily generated from 12^+, 14^+ and 16^+ SD states in ^{36}Ar respectively. This is consistent with one nucleon transfer calculation [8] as the $19/2^-$, $23/2^-$ and $27/2^-$ states in ^{35}Cl have large spectroscopic factors correspond to the 12^+, 14^+ and 16^+ SD states in ^{36}Ar respectively [7].

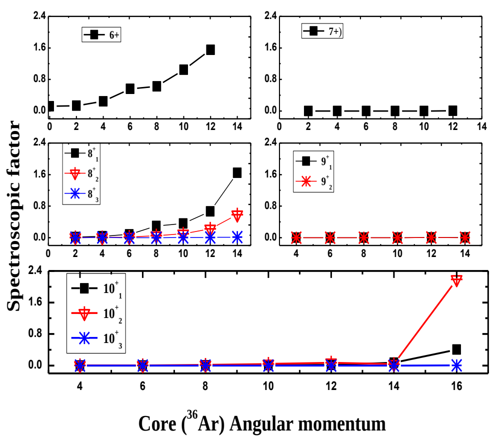

Fig.2: Calculated spectroscopic factors for the positive parity states in ^{34}S.

Two nucleon transfer spectroscopic factor calculation has also been carried out for the negative parity states in ^{34}S. From our calculation (Fig. 3), we have seen that the 5^- in ^{34}S has an average spectroscopic factor 0.4 - 0.6 correspond to the core angular momentum 5^-, 7^-, 9^- and 11^- where as the 7^- of ^{34}S was primarily generated from the 13^- of ^{36}Ar state. This is consistent with our previous calculation [8] and provide an indirect experimental evidence in favor of the existence of a negative-parity partner band of the SD band in ^{36}Ar as was predicted in Ref. [6].

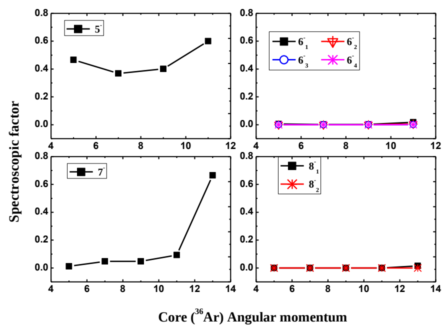

Fig.3: Calculated spectroscopic factors for the negative parity states in ^{34}S.

Therefore, our results show a strong correlation between the cluster states in ^{34}S and ^{36}Ar and also support the existence of low lying α-cluster states in ^{34}S as was reported in Ref. [6].

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