Low energy cluster states in ^{34}S

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Introduction

Knowledge on α-clustering is important to understand the structure of light nuclei. In upper *sd* region, different cluster model calculations [1] have shown that experimentally observed deformed or superdeformed (SD) bands have α-cluster configurations. In the recent years, improvement of computational facilities made it possible to study the structure of these SD bands through large basis shell model (LBSM) calculations [2,3] also. Therefore, it is also possible to study the cluster properties of these SD bands by calculating the cluster overlaps or one nucleon transfer spectroscopic factors through LBSM calculations.

In light mass region, the cluster properties have been studied to some extent for α-conjugate nuclei (n.α nuclei where n is an integer). It is of current interest to explore how the cluster properties are manifested for non- α-conjugate nuclei. Superdeformation along with α-clustering has recently been observed in non- α-conjugate ^{35}Cl [3] at ~6 MeV. ^{34}S has one proton less than ^{35}Cl. So ^{34}S nucleus may also be an interesting candidate for such study.

The threshold energy (E_{th}) needed for ^{34}S to appear as a composite of $^{30}Si + \alpha$ clusters is around 7.9 MeV. Recently, ^{34}S has been studied experimentally by M. Norrby *et. al.* through $^{30}Si + \alpha$ elastic scattering reaction [4]. They observed highly excited α-cluster ($^{30}Si + \alpha$) states at an excitation energy ≥12 MeV. Although presence of cluster states in its excitation spectra below 12 MeV is highly probable, they could not find them due to the restriction imposed by the penetrability factors limiting the observance of high-spin resonances at low energies.

Therefore, in the present work the structure of ^{34}S has been investigated theoretically by calculating the one nucleon transfer (^{35}Cl + 1 hole) spectroscopic factor using LBSM calculations to identify the $^{30}Si + \alpha$ cluster structure at lower excitation energies (> 5 MeV).

Experimental Observation

If a nucleus clusters into fragments of different charge-to-mass ratios, an apparent ΔI=1 rotational band with alternating parity states are found. The similar parity consecutive states are connected by strong E2 transitions indicating large quadrupole deformation [5]. On the other hand opposite parity consecutive states are connected by strong E1 transitions.

High spin states of ^{34}S have been populated up to excitation energy of 16.64 MeV [6] through heavy ion induced reaction. In the level scheme, few strong E2 (2147 keV: $8^+\rightarrow6^+$, 2680 keV: $7^-\rightarrow5^-$) and E1 transitions (2281 keV: $8^+\rightarrow7^-$ and 2813 keV: $6^+\rightarrow5^-$) having transition strengths B(E2): 7-27 W.u and B(E1): $<0.8\times10^{-3}$ W.u. have been reported. For all these transitions, the transition strengths have been calculated from their reported level lifetimes, branching ratios and the multipole mixings (δ) if available [7]. These alternating parity states appear to form a rotational band like structure evident from the linear dependence of their energies on I(I+1) (Fig.1).

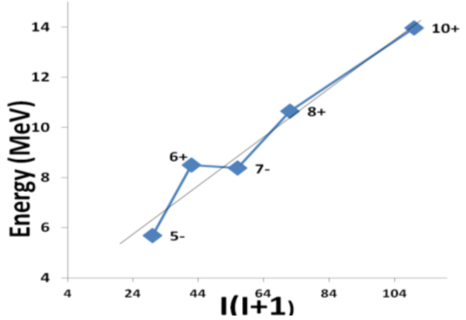

Fig 1 The energies of relevant states are plotted as function of $I\,(I+1)$.

Therefore, a strong evidence of existence of cluster states (above 5 MeV) in ^{34}S is already present in the available data.

Theoretical Calculation

To know the microscopic origin of the states of interest in ^{34}S, LBSM calculations have been performed for both ^{34}S and ^{35}Cl nuclei, using the code OXBASH [8]. 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 19 for ^{35}Cl respectively. The *sdpfmw* interaction [9] was used for the calculation. The relevant details of this interaction are discussed in [10].

Results and Discussion

The positive and negative parity states of interest in ^{34}S have been reproduced with 0p-0h (upto 4+), 2p-2h and 1p-1h particle configuration respectively and compared well with the experimental level scheme. In ^{35}Cl, for high spin positive parity states 2p-2h excitation and for negative parity SD states mixed nħω calculation with $(1d_{5/2})^{12}(2s_{1/2}1d_{3/2})^{6}(pf)^{1}\times(1d_{5/2})^{12}(2s_{1/2}1d_{3/2})^{4}(pf)^{3}$ particle configuration has been considered [3]. During the calculation, the mass normalization factor was considered accordingly and the $1d_{5/2}$ orbital was fully truncated for n>1 excitation.

Now in order to extract one nucleon transfer spectroscopic factors for the positive parity states, we have coupled a proton hole in the *pf* shell to each of the negative parity yrast state in ^{35}Cl. From our calculations, we have seen that the 6^+_1 , 8^+_1 and 10^+_2 states in ^{34}S have large spectroscopic factors correspond to the core angular momentum SD states $19/2^-$, $23/2^-$ and $27/2^-$ respectively (Fig.1). Similarly for the negative parity states, we have found that the 5^-_1 and 7^-_1 states in ^{34}S were primarily generated from the parity doublet positive parity states, $17/2^+$ and $21/2^+$ in ^{35}Cl respectively (Fig.1). Since, states below angular momentum 5 could not be generated by coupling a proton hole into the observed parity doublet positive parity states in ^{35}Cl (minimum possible angular momentum I = 17/2 - 7/2 = 5). The calculations have been carried out only for the states having angular momentum $\geq 5^-$.

Conclusion

The structure of ^{34}S has been studied using large basis shell model calculation. Different particle truncations have been used to reproduce the experimental level scheme of ^{34}S and ^{35}Cl. The parentage of the positive and the negative-parity states in ^{34}S in terms of a proton hole coupled in the *pf* shell of the parity doublet SD states in ^{35}Cl core have been obtained from the calculated spectroscopic factors. Large B(E2) values, strong decay out E1 transitions and the calculated spectroscopic factors indicate the presence of cluster states at low excitation energy (above 5 MeV) in ^{34}S.

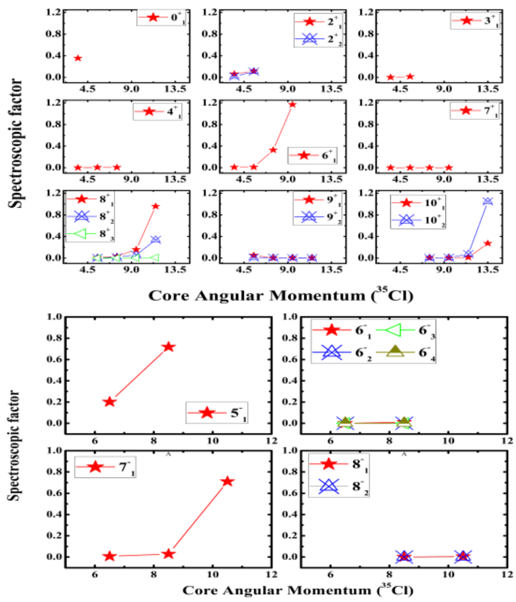

Fig.1: Calculated spectroscopic factors for the positive and negative parity states in ^{34}S.

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