Forbidden E1 transitions and isospin mixing in self-conjugate *sd*-shell nuclei

Abhijit Bisoi[1,2*], S. Sarkar[1] and M. Saha Sarkar[2]
[1]Indian Institute of Engineering Science and Technology, Shibpur, Howrah - 711103, INDIA
[2]*Saha Institute of Nuclear Physics, Kolkata-700064, INDIA*
**Email: abijitbisoi@gmail.com*

Introduction

The isospin T is a good quantum number under the fundamental assumptions of charge symmetry and charge independence of strong nuclear force. However, violation of isospin symmetry due to Coulomb force has been observed [1]. Therefore, exploring the limit of validity of the isospin symmetry, understanding the mechanism of isospin mixing in nuclei close to the N = Z line and their variations with mass number A is now one of the major challenges of modern nuclear physics.

In self-conjugate nuclei, the isovector contribution vanishes in ΔT=0 transitions and leaves only the isoscalar contribution [2]. However, in the long wave length limit, one can neglect the isoscalar contribution. Thus the matrix element of the nuclear E1 operator vanishes when both the initial and final states have same isospin and T_3=0. So, at lower excitation energy, electric dipole (E1) transitions are forbidden in self-conjugate nuclei. However, due to the presence of Coulomb force, admixture between low-lying T=0 and T=1 states with same angular momentum (J) is possible. As a result, E1 transition between T=0 (T=1) component of initial state and T=1 (T=0) component of final state may be observed in these nuclei. Therefore, the observed E1 transitions in self-conjugate nuclei are signatures of isospin mixing. Isospin symmetry breaking effect can be studied from these forbidden E1 transition rates as they are very sensitive to small admixture of isospin mixing in the corresponding wave functions.

Several intense E1 transitions are observed in mid-*sd* shell self-conjugate nuclei [3] which provide signatures of isospin mixing. The strengths of these E1 transitions are of the order of 10^{-5} - 10^{-7} W.u. In heavier mass region, isospin mixing calculation has already been carried out to extract the amount of isospin mixing from multipole mixing ratio (δ) [4] or forbidden E1 transition rates [5]. Recently, Pattabiraman *et. al.* [6] investigated the amount of isospin mixing in A=31 and A=35 mirror nuclei from the relative strengths of E1 transitions. They have estimated < 1% isospin mixing in A=35 mirror nuclei. However till now no such measurements have been performed for low lying states in *sd* shell N=Z nuclei. So, in the present work, we are reporting the amount of isospin mixing for a few low lying forbidden E1 transitions in N=Z *sd* shell nuclei, for the first time.

The Model

In mass 60 region, Farnea *et al.* [5] have already studied the isospin mixing in self-conjugate ^{64}Ge by using a schematic model based on the experimental E1 transition rates of the corresponding transitions in T=0 ^{64}Ge and T=1 ^{66}Ge nuclei. They have already discussed some limitations in their prescribed model [5]. Therefore, in the present work, we have used a different approach to extract the isospin mixing in self-conjugate nuclei. A simple model based on the experimental and theoretical E1 strengths, has been proposed to extract the amount of isospin mixing in *sd* shell self-conjugate nuclei. The experimental E1 strengths of these transitions have been calculated from their level lifetimes, branching and the multipole mixing ratios (δ) [3]. Large basis shell model calculations have been performed using the code OXBASH [7] to extract the theoretical E1 transition strengths between ΔT=1 states. The *sdpfmw* interaction was used for the calculation. This interaction has been taken from WBMB *sd-pf* shell Hamiltonian [8]. In our calculations, different truncations have been adopted to reproduce the T=0 states and their corresponding T=1 states in N=Z ^{30}P, ^{32}S, ^{34}Cl and ^{36}Ar nuclei (Fig. 1).

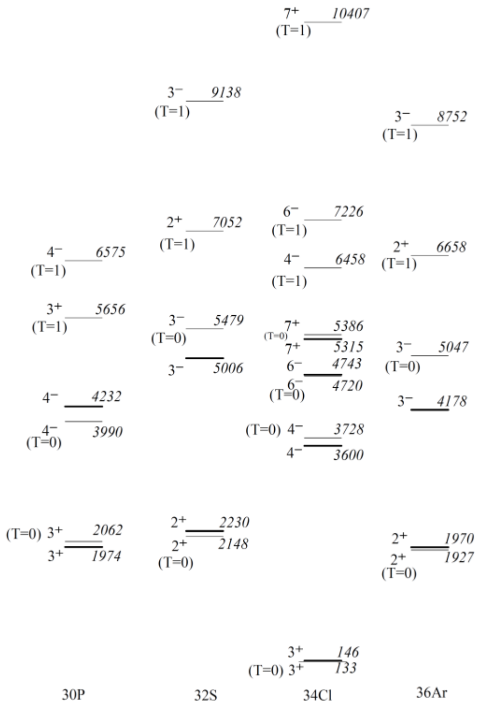

Fig. 1: Comparison between the experimental and shell model states of ^{30}P, ^{32}S, ^{34}Cl and ^{36}Ar. The experimental excitation energies are represented by thick line.

Results and Discussion

In order to estimate the amount of isospin mixing in self-conjugate *sd* shell nuclei, we have investigated few intense E1 transitions in N=Z nuclei such as 2259 keV ($4^- \rightarrow 3^+$) in ^{30}P, 2776 keV ($3^- \rightarrow 2^+$) in ^{32}S, 572 ($7^+ \rightarrow 6^-$) and 3454 keV ($4^- \rightarrow 3^+$) in ^{34}Cl and 2208 keV ($3^- \rightarrow 2^+$) in ^{36}Ar. The results obtained from our model calculations, have been plotted in Fig. 2. The extracted isospin mixings obtained from the schematic model prescribed by Farnea *et.al* [5] have also been plotted in Fig. 2. The uncertainties in calculated isospin mixing probabilities are primarily due to the experimental errors in the corresponding lifetimes [3]. The results show that except for 572 and 2776 keV transitions, results from our model calculations have good agreement with the results obtained from previous model [5]. These values of isospin mixing are consistent with the observed typical isospin mixing (of the order of few percentage) for low lying E1 transitions (ΔT = 0) in self-conjugate nuclei in other mass regions [9]. However, previous model calculation estimates ~15-25% isospin mixings for 572 keV and 2776 keV transitions.

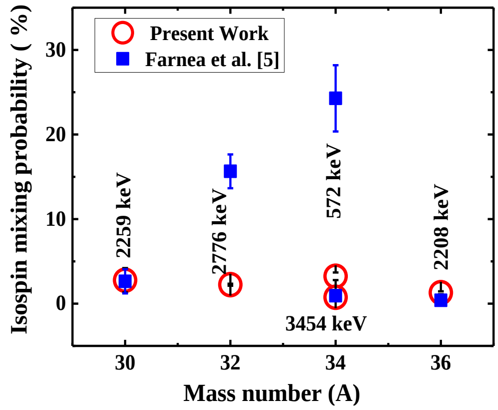

Fig. 2: Isospin mixing probabilities for different excited states in N=Z *sd* shell nuclei.

It has been discussed [5,9], that the earlier model was valid only when the corresponding states in T=0 and T=1 nuclei have identical wave functions. The large unrealistic mixings obtained for these transitions are therefore due to the presence of non-identical wave functions of corresponding states in T=0 and T=1 nuclei. The advantage of our model is that it only depends on the wave functions of the corresponding states of T=0 nucleus and does not depends on the conjugate T=1 nucleus. Therefore, it also works better for non-identical wave function situations as discussed above.

One of the authors (A.B) acknowledges CSIR for financial support.

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