Role of Particle-Hole Symmetry in Mirror Energy Difference

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Introduction

Charge symmetry between protons and neutrons means that they can be viewed as two states of the same particle, the nucleon, characterized by different projections of the isospin quantum number. In the hypothesis of charge-symmetry expected identical behaviour of excited states of two nuclei with the same total number of nucleons (isobaric nuclei).

The nuclei with magic number are consider to be spherical. When the number of particles/holes increase, the nucleus try towards more deformed upto mid-shell. It shows symmetry between particles and holes towards the deformation. The hypothesis of Particle-hole symmetry expected identical behaviour of excited states of two nuclei close to magic number. It is worthwhile to examine the shape of Mirror Energy Difference (MED) close to magic number nuclei, which will also an example of Particle-Hole symmetry.

Experimental observations

The mirror energy differences (MED) *vs* angular momentum, in the region of nuclei between A $\sim$ 20 to $\sim$ 60 are evaluated. Here we discussed the MED trend of isobar with mass A = 35, 43,47,49,51, 53 and 59.

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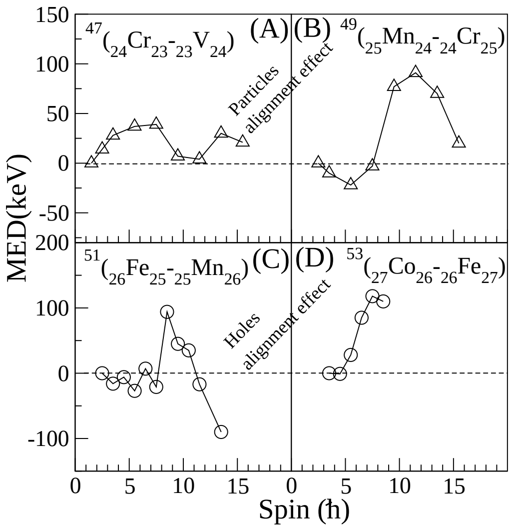

FIG. 1: Mirror energy differences *vs* spins.

Disccussion

1. Particle alignments

It is known that the Coulomb interaction between two protons coupled in time-reversed orbits is larger than for any other coupling, as the spatial overlap of their orbits is maximum. In particular, when a pair of protons aligns to the maximum value ($2j$ - 1) in a single j shell, the Coulomb energy between them reaches its minimum value as their spatial separation is largest [1, 2]. As the Coulomb interaction is repulsive, the effect of the alignment enhance the excitation energy of the nuclear state.

In Fig. 1(A), the protons pair align first in $_{24}Cr_{23}$ and so due to reduction in the Coulomb

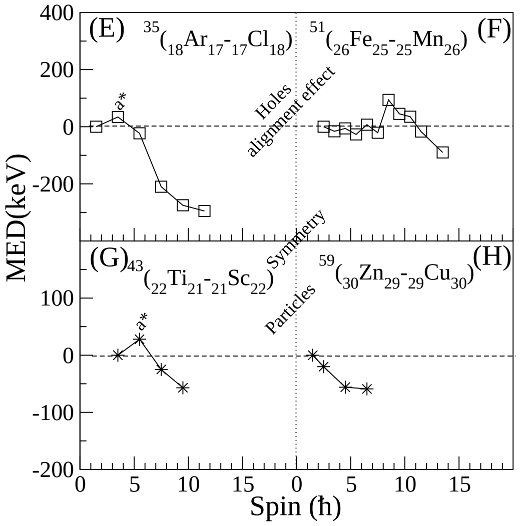

FIG. 2: Mirror energy differences *vs* spins. a*, indicates anomalous behavior [3].

energy that increases the excitation energy of states, in case of $_{23}V_{24}$ neutrons pair align first which cause no coulomb effect in excited states. Therefore an increament in MED appear in $^{47}(_{24}Cr_{23}$-$_{23}V_{24})$ upto full alignment, after it neutron pairs align in $_{24}Cr_{23}$ and protons pairs in $_{23}V_{24}$ the resultant is reduction in MED. The trend of MED in $^{49}(_{25}Mn_{24}$-$_{24}V_{25})$ could be explained in the same way in Fig. 1 (B).

2. Hole concept and Particle-hole symmetry

Owing the particles alignments, the MED trend in $^{47}(_{24}Cr_{23}$-$_{23}V_{24}$, Fig.1 (A)) and $^{51}(_{26}Fe_{25}$-$_{25}Mn_{26}$, Fig.1 (C)) must be same, because in both cases, the protons pair must be align first in $_{24}Cr_{23}$ and $_{26}Fe_{25}$, but it has been obseverd opposite to each other. Similarly, the trends of MED in $^{49}(_{25}Mn_{24}$-$_{24}V_{25}$, Fig. 1 (B)) and $^{53}(_{27}Co_{26}$-$_{26}Fe_{27}$, Fig. 1 (D)) must be same but it has been observed opposite to each other. What are the reasons which make the trend in $^{51}(_{26}Fe_{25}$-$_{25}Mn_{26})$ and $^{53}(_{27}Co_{26}$-$_{26}Fe_{27})$ opposite to the expected when Particles alignment consider? That could be the alignment of Holes.

The hole concept has been utilized for explanation to various quantum phenomena such as conductivity in semiconductor. Whenever an electron leave their state in energy band, the vacate state consider to be hole, that state has been treated as electron with positive charge. In nuclear physics the lack of nucleon to magic number (closed shell) is consider hole, therefore, in same way the hole for proton (hole-p) can be consider a state with negative charge. When the state generated by alignments of hole-p, the spatial overlap of the pair is reduced, resulting in a reduction in the Coulomb energy (due to holes *i.e* Coulomb energy with -ive sign), that such alignment cause increament in the total Coulomb energy of nucleus (due to protons) and the resultant shows the reduction in excitation energy of $_{18}Ar_{17}$, $_{26}Fe_{25}$. Therefore, MED decreases in isobar mass 35 (Fig. 2 (E)) and mass 51 (Fig. 2 (F)).

According to proton particles alignments ($_{22}Ti_{21}$, $_{30}Zn_{29}$), the MED trend must be increase in $^{43}(_{22}Ti_{21}$-$_{21}Sc_{22}$, Fig. 2 (G)) and $^{59}(_{30}Zn_{29}$-$_{29}Fe_{30}$, Fig.2 (H)). But it has been found the same trend as hole alignment in $^{35}(_{18}Ar_{17}$-$_{17}Cl_{18})$ and $^{51}(_{26}Fe_{25}$-$_{25}Mn_{26})$ *i.e.* decrease. It indicate the (hole or particle) alignment produce same results in ($_{18}Ar_{17} \equiv {}_{22}Ti_{21}$) and ($_{26}Fe_{25} \equiv {}_{30}Zn_{29}$). Therefore, this is clear indication of particle hole symmetry. On the other word it might be compitition between alignment and deformation effect on MED. In such cases (Fig. 2) the deformation pay important role than alignments.

References

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