Mystery of ^{151}Ho isotope

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Introduction

Excitation spectra of ^{151}Ho [1] and ^{153}Ho [2] populated in heavy ion induced reactions reveal interesting differences when compared. In ^{153}Ho, we see the parallel evolution of both negative and positive parity bands at low energies. A positive parity band is built on $15/2^+$ state (1091 keV) in ^{153}Ho where the $31/2^+$ is an isomeric state [2]. They are interpreted to be originated from the coupling of $\pi(h_{11/2})$ orbital to the 3^- and 11^- octupole states of ^{152}Dy core, respectively [2]. However, surprisingly in the next odd mass Ho isotope in decreasing order, i.e. ^{151}Ho, this positive parity band has not been reported so far. Moreover, several other isomeric states have been reported in ^{153}Ho [2] at low and medium spins. However, in ^{151}Ho, only two isomers of 1ns and 9 ns are reported tentatively at very high spin [1].

Both 3^- and 11^- octupole states [3] are observed in ^{150}Dy (Fig. 1) and in other neighboring even isotopes of Dy. However, the analogous positive parity states are absent in ^{151}Ho. Recently, energies as well as transition probabilities of ^{153}Ho have been interpreted quite satisfactorily within a version of particle-rotor model (PRM) [4] by our group [5].

In the present work, we want to extend our study of this surprising fact in more detail theoretically within PRM. This work has been initiated earlier and some preliminary results have been reported in the recent past [6].

Results

The parameters for PRM calculation are mostly determined from the available experimental data. They are : $\mu_p = 0.591$, $\kappa_p = 0.065$, $\delta = 0.1$, Δ=1.52 MeV, λ=44.2MeV and Coriolis attenuation coefficient = 1. Our result for –ve parity states is shown in Fig 2.

We have interpreted the –ve parity states in ^{151}Ho, as the coupling of the positive states of ^{150}Dy core and average single particle spin 5.48ħ (corresponding single particle orbital is $h_{11/2}$).

Theoretically we find the possibility of a +ve parity band in ^{151}Ho, not shown here. Energy of the band head depends on the Nilsson parameters (μ, κ), and deformation (δ) parameters. It is seen that proper intraband spacing can be obtained without fine tuning of the parameters, but it is then difficult to decide the relative spacing between the +ve and –ve parity bands .

In order to overcome this problem, we have considered the theoretical energy of $49/2^+$ state same as the experimental value, since this is the only state experimentally assigned as positive parity (tentatively). Moreover, we have matched some theoretical +ve parity levels with some of the experimental states (i.e. 2616 keV, 2880 keV) which have unassigned or ambiguous spin and/or parity. However, to have a definite conclusion we need to find the multipolarity of a number of transitions (i.e. 517, 653, 275, 367, 264-keV etc.). Unfortunately due to the lack of adequate data, currently we are unable to do that.

For the +ve parity band, we found that from $21/2^+$ onwards major single particle contribution arises from $d_{5/2}$ and $g_{7/2}$ orbitals alternatively, which indicates to the existence of two possible positive parity bands having different signature quatum number in ^{151}Ho.

It is seen in the neighboring isotopes like ^{153}Ho, that considering the non-yrast (1st excited) energy levels of the ^{152}Dy core for certain spins based on the relation of energy and spin, we can theoretically reproduce the experimental data with better accuracy. We have checked the same possibility for ^{151}Ho by considering the energy of the 1st excited , 6^+ and 8^+ states of the core

(^{150}Dy) along with the other yrast states. But this modification is not showing any better agreement between the theoretical and experimental states. Moreover, considering the modified core energies we cannot reproduce the decoupled band like nature of the low spin states in ^{151}Ho. Fig 3 represents a preliminary result of the theoretical levels calculated by modifying some of the core states.

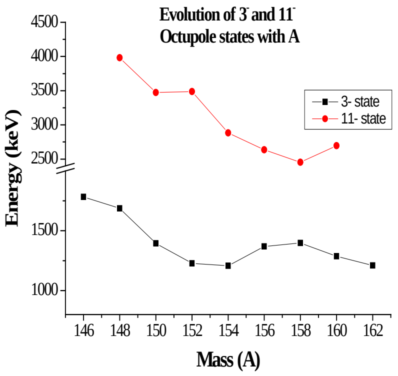

Fig 1: Evolution of 3$^-$ and 11$^-$ octupole states of with A in Dy isotopes.

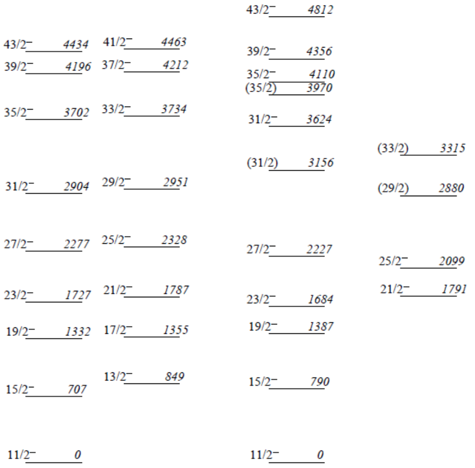

Fig 2: Comparison of theoretical (left panel) and experimental (right panel) -ve parity states in ^{151}Ho.

Conclusion

We have noticed that an appropriate choice of the core states is very important to reproduce the experimental levels of the nucleus under consideration. We are in the process to find an indicator which will help us to determine the appropriate core states. Preliminary, the core states are chosen from the E vs. I(I+1) plot which indicates the path of the main intensity branch. In case of ^{153}Ho, we are successful, but for ^{151}Ho, result is not so promising. This aspect needs more attention to be paid at and the work is in progress.

But, at least, we are able to say that we have identified some indicator to choose the relevant core states. Hopefully, by scanning over the series of the core nuclei corresponds to the neighboring isotopes of ^{151}Ho will give some light on the reasons behind the differences in the excitation spectrum of ^{151}Ho with the others.

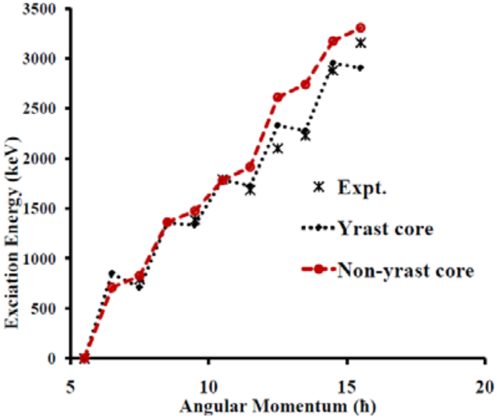

Fig 3: Comparison of theoretical (with and without modified core energies) and experimental –ve parity states of ^{151}Ho.

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