Study of odd-even staggering in $\gamma$-band of $^{154}\text{Gd}$

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Introduction

The $^{154}\text{Gd}$ nucleus (Z=64, N=90) is lying at the transitional position between the deformed and spherical nuclei. The nuclear shape for N=88 nuclei is close to spherical and for N=90 nuclei it is close to deformed [1, 2]. For $^{154}\text{Gd}$ nucleus, the observed energy ratio $R_s$ is equal to 3.01 which is close to X(5) symmetry limiting value of $R_s$ equal to 2.9 [3]. The existence of X(5) symmetry in the N=90 isotones (Sm-Gd-Dy) established in recent work [4] also supported by the formation of isotonic multiplets [5]. The value of $R_s$ in the present IBM-1 calculation is 3.2 which is slightly more than the experimental value. The theoretical studies of level energies of $\gamma$-band (K$^\pi$=2$^+$) of shape transitional nuclei are limited. The idea of odd-even spin staggering (OES) in $\gamma$-band was given by McCutchan et al. [6]. The structure of $\gamma$- vibrational and quasi $\gamma$- bands of even- even nuclei was investigated by Gupta et al. [7] on a global scale. The yrast and $\gamma$-bands of $^{120-136}\text{Xe}$ nuclei was studied by Singh et al. [8] using asymmetric rotor model by employing the Lipas parameter and pointed out that the reason of odd even staggering (OES) was due to the splitting of $\gamma$-band in odd and even spin sequence. Recently, Gupta et al. [9] illustrated that the values of odd-even energy staggering index $S(4)$ is small for well deformed nuclei and the odd-even spin members form a single K=2 band.

In the present work, we test the odd-even spin staggering (OES) in $\gamma$-band in $^{154}\text{Gd}$ nucleus in the framework of rigid triaxial rotor model (RTRM) [10] and interacting boson model (IBM-1) [1]. In the present empirical work, we also studied that whether this nucleus is $\gamma$-soft or $\gamma$-rigid.

Odd-even staggering (OES)

The OES effect represents the relative displacement of the odd angular momentum levels of the $\gamma$- band with respect to their neighboring levels with even angular momentum. The band mixing interaction pushes the even spin members in $\gamma$-band relative to the odd spin members, due to the interaction with even spin members of the ground band [1]. The staggering in band energies and the transition between different structural symmetries in nuclei is calculated by using the expression [4]:

$$S(J) = \frac{|E(J) - E(J-1)| - |E(J+1) - E(J-2)|}{2E^2}$$

Therefore, using equation (1) we have calculated the value of staggering index $S(J)$ for $^{154}\text{Gd}$. The index of odd-even spin staggering is a quantitative measurement of OES with spin.

Result and discussion

The experimental energies of $\gamma$-band for $^{154}\text{Gd}$ have been taken from the Ref. [11]. The values of energies of $\gamma$-band are calculated from IBM-I and RTRM. The IBM-I Hamiltonian (with OCT=HEX=0) is used to reproduce the best energy spectrum (see Ref. [12] for details). The fitting parameters (in MeV) are EPS= 0.3425, PAIR= 0.0116, ELL= 0.0128 and QQ=0.0221. The energies calculated in RTRM [10] are normalized using Lipas like relation:

$$E(\text{fit}) = \frac{E_{\text{RTRM}}}{1 + \alpha \cdot E_{\text{RTRM}}}.$$
Where, the Lipas parameter (\(\alpha\)) used for normalization of energies is 4.5x10^{-5} for \(\gamma\)-band. The S(J) for \(\gamma\)-band is calculated using equation (1) and listed in Table 1. The IBM index of odd-even spin staggering S(J) with spin (J) are much larger with corresponding experimental and RTRM values. The plot of experimental index of odd-even spin staggering S(J) with spin (J) tallies with that of our calculated RTRM values (see Fig.1). The all S(J) values of RTRM are positive and a small in magnitude except S(7) and show slightly zig-zag behavior, but increase slowly with increase in spin. This indicates that \(^{154}\text{Gd}\) nucleus is axial symmetric rotor. The staggering index S(4) is 0.33 for axially symmetric rotor and 1.67 for rigid triaxial rotor. For \(\gamma\)-soft rotor or O(6), S(4) = \(-2.0\) and for spherical vibrator it is = 1.0 [8]. In our RTRM calculations the value of S(4) is 0.34 (see Table 1) which tally with axial symmetric deformed rotor nature of \(^{154}\text{Gd}\) nucleus.

**Table 1.** The values of odd- even spin staggering in \(\gamma\)-band for \(^{154}\text{Gd}\) as estimated in the RTRM and IBM-1 along with experimental results.

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<td>-1.78</td>
<td>2.75</td>
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<td>3.62</td>
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**References**