

Study of odd-even staggering in γ -band of ^{154}Gd

Rajesh Kumar^{1*}, M. Singh¹ and S. Sharma^{2**}

¹Department of Physics, Noida Institute of Engineering & Technology, Greater Noida-201306, INDIA

²Department of Physics, Yobe State University, Damaturu, NIGERIA

*Email: rajeshkr573@gmail.com **Email: satendrasharma@ysu.edu.ng

Introduction

The ^{154}Gd nucleus ($Z=64$, $N=90$) is lying at the transitional position between the deformed and spherical nuclei. The nuclear shape for $N \leq 88$ nuclei is close to spherical and for $N \geq 90$ nuclei it is close to deformed [1, 2]. For ^{154}Gd nucleus, the observed energy ratio R_4 is equal to 3.01 which is close to X(5) symmetry limiting value of R_4 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_4 in the present IBM-1 calculation is 3.2 which is slightly more than the experimental value. The theoretical studies of level energies of γ -band ($K^\pi=2^+$) of shape transitional nuclei are limited. The idea of odd-even spin staggering (OES) in γ -band was given by McCutchan et al. [6]. The structure of γ -vibrational and quasi γ -bands of even-even nuclei was investigated by Gupta et al. [7] on a global scale. The yrast and γ -bands of $^{120-130}\text{Xe}$ 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 γ -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 γ -band in ^{154}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 γ -soft or γ -rigid?

Odd-even staggering (OES)

The OES effect represents the relative displacement of the odd angular momentum levels of the γ -band with respect to their neighboring levels with even angular momentum. The band mixing interaction pushes the even spin members in γ -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]:

$$S(J) = \frac{[E(J) - E(J-1)] - [E(J-1) - E(J-2)]}{E_4^+} \quad (1)$$

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

Result and discussion

The experimental energies of γ -band for ^{154}Gd have been taken from the Ref. [11]. The values of energies of γ -band are calculated from IBM-I and RTRM. The IBM-1 Hamiltonian (with $\text{OCT}=\text{HEX}=0$) is used to reproduce the best energy spectrum (see Ref. [12] for details). The fitting parameters (in MeV) are $\text{EPS}=0.3425$, $\text{PAIR}=0.0116$, $\text{ELL}=0.0128$ and $\text{QQ}=-0.0221$. 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 (α) used for normalization of energies is 4.5×10^{-5} for γ -band. The $S(J)$ for γ -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}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 γ -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 axially symmetric rotor value of 0.33. This further supports the axial symmetric deformed rotor nature of ^{154}Gd nucleus.

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

$S(J) \rightarrow$	$S(4)$	$S(5)$	$S(6)$	$S(7)$	$S(8)$
EXP.	0.03	0.26	0.04	0.25	-
RTRM	0.34	0.17	0.50	-0.17	0.95
IBM-1	1.96	-1.78	2.75	-2.65	3.62

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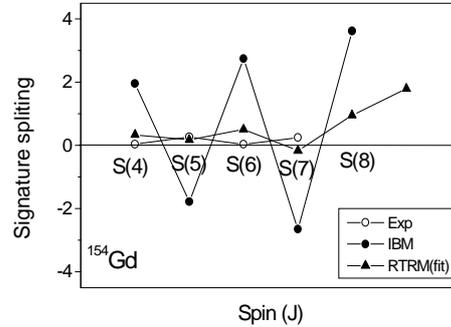


Fig.1 The variation of $S(J)$ versus spin (J).

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