Determination of band head spin of SD bands in ^{194}Tl nuclei

Annanya Mahajan and H. M. Mittal*

Dr. B. R. Ambedkar National Institute of Technology, Jalandhar, Punjab (144008) – India

** email: mittalhm@nitj.ac.in*

Introduction

The superdeformation has been one of the most remarkable discoveries since 1956. The first superdeformed band was observed in ^{152}Dy by Twin [1] and thereafter SD bands were observed in A~80,100,120,150 and 190 mass regions. The superdeformed nucleus is defined as a nucleus which is far away from spherical symmetry and approximates to an ellipsoidal with an axes ratio 2:1:1 [1]. The interactions of valence nucleons with the core of the nucleus distort the shape of nucleus leads to deformation [2-3]. The gamma transition energies and intensities are only globally available information for understanding the nuclear structure in SD bands. Therefore, there are many features of the nuclei which are unknown. The nucleus is a many body complex quantum system. Therefore, to understand the structure of nuclei, the knowledge of spin, angular momentum and parities is necessary. There is a missing transitions link between normal (ND) and superdeformed (SD) bands, due to this spins and energies are unknown. Many physicists have proposed various methods like VMI [4] and Harris expansion [5] etc. to assign correct band head spin to SD nuclei. We have used IBM model to obtain band spin of SD bands in ^{194}Tl. Previously A. Dawdal et al.,[6] have obtained the band head spins using other formula for SD bands in ^{194}Tl.

Formalism

The Hamiltonian of the VMI inspired IBM is:

$$H = E_0 + \kappa \hat{Q}^2 . Q^2 + \frac{C_0}{1+f \hat{L}.\hat{L}} \hat{L}.\hat{L} \quad (1)$$

where $\hat{Q}^2$ and $\hat{L}$ are the quadrupole and angular momentum operator respectively. The parameter "f" is called YOSA coefficient. This coefficient is important to describe the change in dynamic moment of inertia ($\Im^{(2)}$). The energy expression of VMI inspired IBM model is [7]:

$$E = E_0(N_B, N_F) + \frac{C_0}{1+ f_1 I(I+1) + f_2 I^2 (I+1)^2} I(I+1) \quad (2)$$

The SD rotational bands are regular cascades of experimental γ– transition energies and spins as:

$E_\gamma(I_0+2n)$, $E_\gamma(I_0+2n-2)$,……, $E_\gamma(I_0+4)$, $E_\gamma(I_0+2)$,

$I_0+2n \rightarrow I_0+2n-2 \rightarrow$………, $\rightarrow I_0+4 \rightarrow I_0+2 \rightarrow I_0$,

The calculated gamma transition energies are obtained using equation which is as follows:

$$E_\gamma = E(I) - E(I-2) \quad (3)$$

The root mean square deviation (RMS) is obtained using the values of experimental and calculated gamma transition energies.

$$\chi = [\frac{1}{n} \sum_{i=1}^{n} (\frac{E_\gamma^{cal}(I_i) - E_\gamma^{expt}(I_i)}{E_\gamma^{expt}(I_i)})] \quad (4)$$

where "n" is the total no. of γ- transitions involved in the fitting. This formula involves the differences of calculated and experimental transitions energies. Whenever correct band head spin (I_0) is assigned, RMS is minimum. The value of RMS deviation is almost same for I= 12 and 13 for SD bands in ^{194}Tl(1) and I= 10 and 11 for SD band in ^{194}Tl(3) respectively. Therefore, to assign unique I_0 for the SD bands in ^{194}Tl(1) and ^{194}Tl(3), the ratio-R method [8] (spin independent) is used, as an additional support to the spin assignment. The ratio- R is evaluated as:

$$R = \Im^{(0)} = \sqrt{\frac{(\Im^{(1)})^3}{\Im^{(2)}}} \quad (5)$$

"$\Im^{(0)}$" is a band head MOI gives horizontal line when correct I_0 is assigned and if the band head spin varies by $I_0 \pm 1$, $\Im^{(0)}$ changes immediately and give hyperbolic trajectory. The $\Im^{(1)}$ and $\Im^{(2)}$ are kinematic and dynamic moment of inertia respectively, is obtained from the calculated γ – transition energies using eq. (2) and (3).

Results and Discussion

In this paper, we have calculated the band head spin of SD bands in ^{194}Tl(1) and ^{194}Tl(3) using VMI-IBM model. C_0, f_1 and f_2 are parameters obtained through computer based program. The expt. value of I_0 ^{194}Tl(1) is 12 (see Ref [9]) and from RMS and the ratio-R, I_0=12 (see fig. 1 and 2), the expt. and calculated value of I_0 are in agreement. The expt. value of I_0 ^{194}Tl(3) is 10 (see Ref [9]) and from RMS and the ratio-R, I_0=10 (see fig. 3 and 4), the expt. and calculated value of I_0 are in agreement. This may be because of pairing and anti-pairing effects on $\Im^{(2)}$ which is demonstrated by YOSA coefficients. The f_1 and f_2 can be > 0, f_1 and f_2 can be < 0 and $f_1 > 0$ and $f_2 < 0$ or vice-versa. The positive and negative value of f parameter signifies the pairing effect and anti-pairing effects on $\Im^{(2)}$ respectively. In this case, f_1 and f_2 are negative.

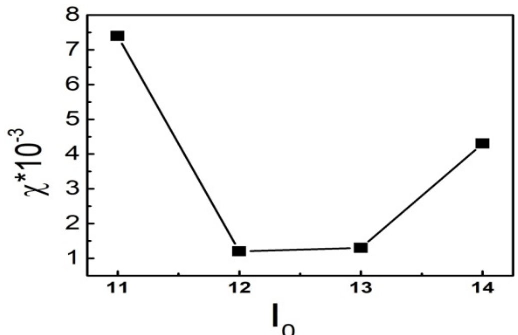

Figure 1: χ vs. I_0 for ^{194}Tl(1)

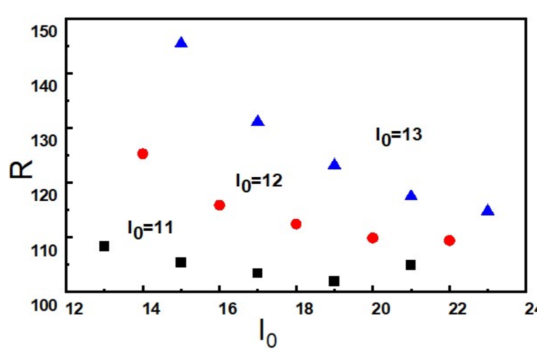

Figure 2: The ratio-R vs. I_0 for ^{194}Tl(1)

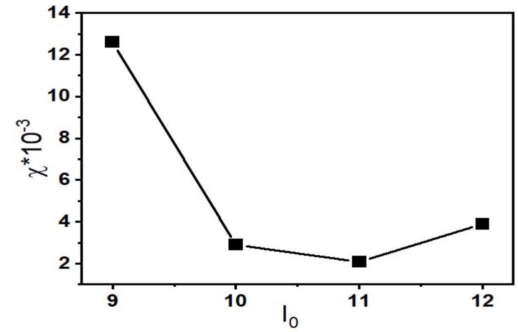

Figure 3: χ vs. I_0 for ^{194}Tl(3)

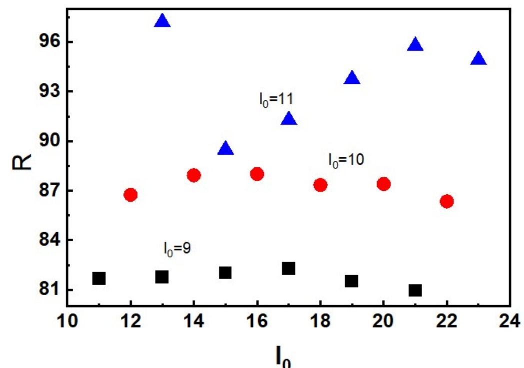

Figure 4: The ratio-R vs. I_0 for ^{194}Tl(3)

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