Search of identical superdeformed bands in ^{195}Tl and ^{197}Bi possessing same F_0 symmetry

H. M. Mittal* and Honey Sharma
Department of Physics,
Dr. B. R. Ambedkar National Institute of Technology,
Jalandhar, Punjab, India

Introduction

The phenomenon of identical bands is one of the most interesting discoveries in SD spectroscopy. Two superdeformed bands (SD) are known to be identical if they have same dynamic moment of inertia $J^{(2)}$ and same transition energies within (1-3keV). Transition energies E_γ are directly associated to their corresponding $J^{(2)}$ obeying $A^{5/3}$ dependence. Baktash et al. [1] found the identical bands in deformed and SD nuclei. Soon after, Byrski et al. [2] found the identical bands in $A \sim 150$ mass region. Similarly in $A \sim 190$ mass region [3] many SD bands are grouped into the families of identical bands w.r.t the central nuclei. Nazarewicz et al. [4] highlighted the identical transition energies sequences in ^{152}Dy and ^{151}Tb as well as in ^{150}Dy and ^{150}Tb. Thus, this discovery proves to be the most important fingerprint of the pseudospin symmetry at extreme deformation and angular momenta. In general, the occurrence of identical bands helps to understand the moment of inertia as the function of N and Z. Systematic study of $J^{(1)}$ and $J^{(2)}$ of SD bands with N_pN_n scheme is studied by Sharma et al. [5]. Mittal and Sharma [6] studied the F_0 symmetry and identical bands in $72 \leq$ N ≤ 86 region. In this present work we have studied the identical bands in ^{195}Tl and ^{197}Bi SD bands possessing same F_0 values by using nuclear softness formula.

Formalism

Nuclear softness formula [7] was used to study the energy levels of ground state bands. In this formula the variation of moment of inertia with spin was taken into the account. The rigid rotor energy formula was given as

$$E = \frac{\hbar^2}{2\Im} I(I+1), \tag{1}$$

when the moment of inertia with spin was taken into account, equation (1) can be modified as

$$E = \frac{\hbar^2}{2\Im_I} I(I+1). \tag{2}$$

Applying Taylor series about its ground state values $\Im_0$ for I=0 we get

$$E_I = \frac{\hbar^2}{2}\left(\left[\frac{1}{\Im_0} - \left(\frac{1}{\Im_I^2}\frac{\partial \Im_I}{\partial I}\right)\right]_{I=0} I + \left[\frac{2}{\Im_I^3}\right.\right. \left.\left.\left(\frac{\partial \Im_I}{\partial I}\right)^2 - \frac{1}{\Im^2}\frac{\partial^2 \Im_I}{\partial I^2}\right]_{I=0}\frac{I^2}{2!} + ...\right) I(I+1). \tag{3}$$

As the spin of nuclei increases, the moment of inertia approaches the rigid rotor value. Therefore, as the deformation increases the nucleus tends to acquire more rigidity. Therefore, equation (3) becomes

$$E_I = \frac{\hbar I(I+1)}{2\Im_0}\frac{1}{1+\sigma_1 I} \times \left(1 - \frac{\sigma_2 I^2}{1+\sigma_1 I + \sigma_2 I^2} - ....\right), \tag{4}$$

putting σ_1,σ_2 =0 i. e. keeping the nuclear softness to only first order, equation (4) becomes

$$E = \frac{\hbar^2}{2\Im_0} \times \frac{I(I+1)}{1+\sigma I}, \tag{5}$$

*Electronic address: mittal.hm@lycos.com

where $\Im_0$ and σ are the fitting parameters. The only information available for SD bands are their intraband energies and intensities. Hence, one may apply fitting of E_γ transitions.

$$E_\gamma(I) = E(I) - E(I-2). \quad (6)$$

Using equations (5) and(6), E_γ transitions energies for SD bands is expressed as

$$E_\gamma = \frac{\hbar^2}{2\Im_0} \times \left[\frac{I(I+1)}{1+\sigma I} - \frac{(I-2)(I-1)}{1+\sigma(I-2)}\right]. \quad (7)$$

Results and Discussion

Identical bands are those which have same transition energies and the $J^{(2)}$. Following this definition, we have applied nuclear softness formula to fit the transition energies of ^{195}Tl and ^{197}Bi SD bands. The data has been taken from the SD tables of Singh et al. [8] and continuously updated data from Ref. [9]. It is found that the transition energies of ^{195}Tl and ^{197}Bi SD bands come out to be identical within 0.6 keV over the significant range of spin (see Table I). $J^{(2)}$ has been linked with the nucleons pair occupying high N intruder orbital (namely $j_{15/2}$ neutrons and $i_{13/2}$ protons) in the presence of pairing correlations [10]. Therefore, the $J^{(2)}$ of ^{195}Tl and ^{197}Bi SD bands is also similar (see Table II). The ^{195}Tl and ^{197}Bi SD bands may have the same contents in intruder orbital. Thus, it very well implies that the ^{195}Tl and ^{197}Bi SD bands are identical.

TABLE I: The calculated transition energies E_γ and difference in E_γ for ^{195}Tl and ^{197}Bi SD bands in (keV).

Spin I	E_γ for ^{195}Tl	E_γ for ^{197}Bi	Δ E_γ
9.5	191.2	190.6	0.6
11.5	229.2	228.6	0.6
13.5	268.2	267.9	0.3
15.5	308.3	308.3	0
17.5	349.5	350.0	-0.5
19.5	391.9	393.0	-1.1

TABLE II: The dynamic moment of inertia $J^{(2)}$ for ^{195}Tl and ^{197}Bi SD bands in ($\hbar^2$ MeV^{-1}).

Spin I	$J^{(2)}$ for ^{195}Tl	$J^{(2)}$ for ^{197}Bi
9.5	105.2	105.2
11.5	102.5	102.5
13.5	100	100
15.5	97.5	97.5
17.5	94.3	94

Conclusion

In this present work, we have applied the nuclear softness formula to check the identical SD bands in ^{195}Tl and ^{197}Bi. It is highly interesting to note that similar values are obtained for the transition energies and the $J^{(2)}$. The results further prove that the two SD bands (^{195}Tl and ^{197}Bi) are identical.

References

[1] C. Baktash et al., Annual Review of Nuclear Science, Vol. 45 (1995) 485-541.
[2] T. Byrski et al., Phys. Rev. Lett., 64 (1990) 1650-1653.
[3] F. Stephens et al., Phys. Rev. Lett 65 (1990) 301-304.
[4] W. Nazarewicz et al., Phys. Rev. Lett 64 (1990) 1654-1657.
[5] H. Sharma et al., Chinese physics C 41 (2017) 084104.
[6] H. M. Mittal and N. Sharma, Armenian Journal of Physics 5 (2012) 165-175.
[7] R. K. Gupta, Phys. Lett. B 36 (1971) 173.
[8] B. Singh et al., Nucl. Data sheets 97 (2002) 241-592.
[9] www.nndc.bnl.gov.
[10] M. A. Riley et al., Nucl. Phys. A 512 (1990) 178.