An exclusive level scheme in ^{193}Pb

P. Jain[1*] and Y. Kumar[2]
[1]Department of Physics, Sri Aurobindo College,
University of Delhi, Malviya Nagar, New Delhi-110017, INDIA and
[2]Department of Physics, Deshbandhu College,
University of Delhi, Kalkaji, New Delhi-110019, INDIA

Introduction

The discovery of the high spin superdeformed (SD) bands in the ^{152}Dy nucleus [1] for the first time led to the observation of a large number of SD bands in various mass regions A $\sim 150, 190, 130, 80, 90, 60$ and 40 [2–4]. Each SD region has its own characteristics. In A $\sim$ 190 mass region, SD states have been observed at quite low spin so this region is of special interest. More than 85 bands were explored in A $\sim$ 190 mass region. The band-head and level spins in SD bands were not determined experimentally for ^{193}Pb(b7-b9) because there is no linkage between the SD states and the low lying normal deformed (ND) states. Therefore, it motivates us to determine the band-head and level spins, transition energies and a exceptional level scheme for ^{193}Pb(b9). Various models were presented for the spin assignments in SD bands [5, 6]. The main objective of the present work is bifold. The first is to estimate the unknown band-head spin and to assign the unknown level spins for SD bands in ^{193}Pb(b7-b9) and then calculate transition energies using Variable Moment of Inertia (VMI) model. The second is to propose the exclusive level scheme which will be helpful for the physicist to investigate various properties of ^{193}Pb(b9).

Formalism

In the model the rotational energy is given as the sum of the potential energy term $(\mathcal{J}_I - \mathcal{J}_0)^2$ and rotational energy term $[\hbar^2.I(I+1)/\mathcal{J}_I]$. For $I_0 \neq 0$, the band head energies for rotational bands of odd-odd nuclei can be defined as [7, 8]:

$$E_I = E_0 + \frac{1}{2\mathcal{J}_I}[I(I+1) - I_0(I_0+1)] + \frac{1}{2}C(\mathcal{J}_I - \mathcal{J}_0)^2. \quad (1)$$

Here, E_0 is band head energy of rotational band, $\mathcal{J}_0$ is the band head moment of inertia, the variable $\mathcal{J}_I$ is the moment of inertia of the nucleus for each spin value and C is the stiffness parameter. Modified VMI equation for SDRB's is expressed as:

$$E_\gamma(I \longrightarrow I-2) = \frac{1}{2J_o}[I(I+1) - (I-2)(I-1)] + \frac{1}{8CJ_o^4}\left([I(I+1)]^2 - [(I-2)(I-1)]^2\right) \quad (2)$$

The Best-Fit Method (BFM) is used to determine the parameters $\mathcal{J}_0$ and C by fitting the experimentally known transition energies. The root mean square deviations (rms) are calculated for different I_0 values for transition energies. The rms value is least for band-head spin value of a band. If I_0 shifts away from the accurate value by ±1, rapid shift in rms deviation χ can be observed. The rms deviation is defined as [7, 8]:

$$\chi = \left[\frac{1}{n}\Sigma\left|\frac{E_\gamma^{cal}(I_i) - E_\gamma^{exp}(I_i)}{E_\gamma^{exp}(I_i)}\right|^2\right]^{\frac{1}{2}}. \quad (3)$$

Where n is the total number of transitions involved in the fitting. Lowest spin I_0 is estimated and as I_0 is known, all the level spin values of the SD band can be determined. The experimental transition energies, calculated transition energies and the estimated

*Electronic address: poonam.jn1@gmail.com

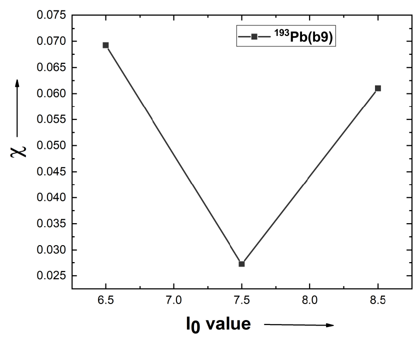

FIG. 1: The RMS deviation plots for spin assignment in ^{193}Pb(b9) SD band is given. I_0 is the spin value prescribed to the lowest level observed.

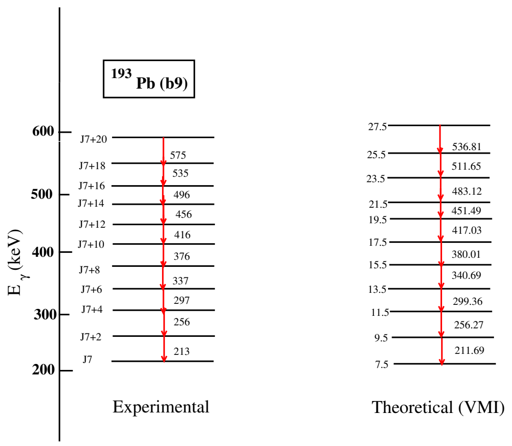

FIG. 2: Comparison of experimental and theoretical Level Scheme of ^{193}Pb(b9).

band head spin I_0 of ^{193}Pb(b7-b9) SD bands are given in the tabular form.

Results and Discussion

In this section the band head spin I_0 and level spins of ^{193}Pb(b7-b9) SD bands are estimated using VMI model. VMI model depends on two parameters stiffness constant (C) and band head moment of inertia ($\mathcal{J}_0$). Values for these two parameters were obtained from known experimental transition energies and spin values using fitting procedures. The calculated transition energies are in good agreement with the observed spectrum of experimentally known transition energies. The results are presented in Table 1. The band head spins are estimated successfully for the bands ^{193}Pb(b7-b9) where the experimental band-head spins are not known and we have compared these with other work [9] as well. In Figure 1, we showed rms deviation plot to estimate the band head spins for these three bands. Then, we have predicted the level spins on the basis of band-head spin and we are able to propose an exclusive level scheme for ^{193}Pb(b9) as shown in Figure 2 which is beneficial for the future physicist. Overall, the calculated results agree with experimental data very significantly. This method provides consistently good spin assignment of SD bands which could help in designing future experiments for these bands.

TABLE I: SD bands in ^{193}Pb(b7-b9) having experimental and calculated transition energies along with the estimated band head spin I_0.

SD Band	$E_\gamma Exp.$ (keV)	$E_\gamma VMI$ (keV)	Estimated I_0 VMI	χ
^{193}Pb (b7)	261	261.66	11.5	0.009318
^{193}Pb (b8)	282	281.68	11.5	0.008747
^{193}Pb (b9)	213	211.69	7.5	0.027254

References

[1] P. J. Twin et al., Phys. Rev. Lett. **57**, 811 (1986).
[2] B. Singh et al., Nucl. Data Sheet. **97**, 241 (2002).
[3] E. Idguchi et al., Phys. lett. B **86**, 18 (2010).
[4] The ENSDF and XUNDL at BNL Website [http://www.nndc.bnl.gov].
[5] A. M. Khalaf et al., Turk. J.Phys. **37**, 49 (2013).
[6] J. A. Becker et al., Nucl. Phys. A **520**, 187C (1990).
[7] M. A. J. Marisscotti et al., Phys. Rev. **178**, 1864 (1969).
[8] P. Jain et al., Eur. Phys. J. Plus **134**, 72 (2019).
[9] A. Dadwal et al., Eur. Phys. J. A **12**, 55 (2019).