The empirical study for superdeformed band in ^{131,133}Ce nuclei

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Introduction

The discovery of super deformation is one of the significant advances in nuclear structure physics. Super deformed (SD) bands were first observed in fission isomers in the actinide region [1]. With rapid advancements in the experimental facilities, particularly the detectors and data acquisition systems, SD shapes at higher spins were discovered in the last decade of 20th century. The first discrete line SD shapes were found in ^{152}Dy nucleus [2]. Since then vast experimental and theoretical studies have been undertaken. At present numerous SD bands have been observed in various mass region A= 30, 60, 80, 130, 150 and 190 [3]-[4].
Several phenomenological formulae have been proposed to fit the transition energies and assign spin angular momentum to the observed levels in SD bands. The transition energies, spins in identical phenomenon for SD bands in the A=150 and A=190 mass regions have been predicted by various two and three parameters viz. variable moment of inertia, ab formula, Harris expansion [1]-[6].
In present work, we aim to describe the nuclear properties and SD bands of ^{130}Ce (SD-1), ^{131}Ce(SD-1) and ^{132}Ce(SD-2) nuclei. We have employed the two-parameters ab formula and power law to calculate the transition energies of above mentioned bands.

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

(here $\Im$ and J are the moment of inertia and spin of the nuclei, respectively), and the Bohr-Mottelson energy expansion in powers of $J(J+1)$ for deformed nuclei , i.e.,

$$E = AJ(J+1) + B(J(J+1))^2 + C(J(J+1))^3. \tag{2}$$

Holmberg and Lipas [7] noted that the moment of inertia of deformed nuclei increases with level energy linearly, i.e.,

$$\Im(J) = a + bE. \tag{3}$$

By substituting Eq.(3) in Eq.(1) they obtained the two-parameter ab formula

$$E = a\left[\sqrt{1 + bJ(J+1)} - 1\right], \tag{4}$$

Brentano et. al. obtained the two-parameter formula, called the soft rotor formula (SRF)

$$E = \frac{1}{\Im_0(1+\alpha J)} J(J+1) \tag{5}$$

Gupta et. al. [8] suggested a single-term expression for ground band level energies of a soft-rotor. They replaced the concept of the arithmetic mean of the two terms used in the Bohr-Mottelson expression by the geometric mean and introduced a two-parameter formula called the power law

$$E = aJ^b \tag{6}$$

By using Eq.(6) for any spin (J) the value of b can be determined from the ratio

$$R_J = E/E(2) = (J/2)^b. \tag{7}$$

Result and Discussion

Theoretical energies so obtained for the SD-1 bands of ^{131}Ce have been compared with the corresponding experimental values in Table 1 and Table 2. It shows that the theoretical transition energies obtained for SD band of ^{133}Ce by using empirical formula, power law and ab formula show good agreement with the experimental values.

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TABLE I: Comparison of theoretical (ab and Power law) and experimental results on transition energies of SD-1 band of ^{131}Ce nuclei.

Nuclei	Exp.	power	ab	SRF	Ejiri
2	0.59	0.5568	0.575	0.4793	0.5905
4	1.2688	1.2709	1.2688	1.1684	1.2522
6	1.985	2.0594	1.9794	1.934	1.9850
8	2.789	2.9007	2.6952	2.736	2.7890
10	3.663	3.7833	3.4133	3.5582	3.6642
12	4.606	4.7005	4.1325	4.3926	4.6105
14	5.617	5.6474	4.8525	5.2352	5.6280
16	6.698	6.6206	5.5729	6.0833	6.7167
18	7.849	7.6172	6.2935	6.9355	7.8765
20	9.074	8.6352	7.0144	7.7907	9.1075

TABLE II: Comparison of theoretical (ab and Power law) and experimental results on transition energies of SD-1 band of^{133}Ce nuclei.

Nuclei	Exp.	Ejiri	ab	SRF	power
2	0.7480	0.7465	0.7337	0.6605	0.57126
4	1.5570	1.5565	1.5729	1.517	1.5751
6	2.4300	2.4300	2.447	2.43	2.505
8	3.3670	3.3670	3.2803	3.367	3.4815
10	4.3700	4.3670	4.1377	4.3164	4.4943
12	5.4380	5.4380	4.9958	5.2731	5.5368
14	6.5700	6.5700	5.8545	6.2344	6.6049
16	67.7680	7.7680	6.7136	7.1988	7.6953
18	9.0350	9.0350	7.5728	8.1653	8.8055
20	10.3720	10.3720	8.4322	9.1335	9.9338

Conclusion

The present work provides a new insight to understand the nuclear structure of the SD-1 band of ^{131}Ce and ^{133}Ce nuclei. In the discussion above, we compared the four formulae: power law, ab, SRF and ejiri. The power law show good accuracy in SD-1 bands.

Acknowledgments

We are grateful to Dr. J. B. Gupta (Ramjas College, Delhi University, Delhi) for constant encouragement. Author also thanks to IET Bhaddal for providing research facility.

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