On nuclear shapes of ^{170}Er

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Introduction

In recent past extremely rich experimental data has come in light in low – lying nuclear spectroscopy. The basic property of nucleus is its geometric shape and it is quantified in terms of geometric deformation parameters β and γ. The possibility of static triaxial shape is a long-standing problem in nuclear structure physics. The γ – unstable and γ – rigid models predict the similar values of energy levels in ground state band but a significant difference is found in the γ – band. The γ – unstable model group the γ – band energy levels as $2+, (3+, 4+), (5+, 6+), \ldots$ while γ – rigid model group these energy levels as $(2_2^+, 3_1^+), (4_2^+, 5_1^+), 5_1^+ \ldots$ respectively. The relative displacement of odd spin levels with respect to even spin levels that is odd – even staggering (OES) be taken as a signature of nucleus being γ – soft, γ – rigid or axial.

The staggering indices S (I) for experimental as well as theoretical energy levels of γ – band is expressed as –

$$S(I) = \frac{(E_I + E_{I-2}) - (2E_{I-1})}{E2_1^+}$$

For axially symmetric rotor, S(I) does not show any variation in phase and remain small in magnitude. The pattern of S(I) versus spin (I) in experiment if found similar in phase with that of γ – rigid model [1] then nucleus is said to be rigid in nature while if the experimental energy staggering pattern is similar to that of γ – soft model [2]in phase, the nucleus is said to be γ – soft.

We undertake the study of ^{170}Er nucleus in the present work. The γ – band energies for this nucleus have appeared in literature showing many high spin states.

Table – 1
Experimental staggering indices S (I) alongwith ARM for $\gamma = 11.5^0$ and $\gamma = 13^0$ calculated from $E2_2^+/E2_1^+$ [1] and $B(E2; 2_1^+ \to 0_1^+)$ [3] values for ^{170}Er nucleus

S (I)	Exp. Value	ARM [1] γ=11.5^0	ARM [3] γ=13^0
S (4)	0.510	0.041	0.036
S (5)	-0.090	0.017	0.026
S (6)	0.700	0.039	0.0001
S (7)	-0.130	0.008	-0.006
S (8)	0.780	0.009	0.150
S (9)	-0.320	-0.030	-0.850
S (10)	0.860	0.120	0.225
S (11)	-0.470	-0.100	-0.230
S (12)	1.860	0.217	0.550
S (13)	-1.360	-0.224	-0.334
S (14)	1.280	0.360	0.670
S (15)	-1.080	-0.400	-0.75
S (16)	1.800	0.570	1.005
S (17)	-1.700	-0.630	-1.130
S (18)	2.270	0.820	1.400
S(19)	-1.84	-0.910	-1.570

According to ref. 1 violation of axial symmetry of even nuclei the energy states for I = 2 (2_1^+, 2_2^+) one for I = 3 (3_1^+) three for I = 4 (4_1^+, 4_2^+, 4_3^+), two for I = 5 (5_1^+, 5_2^+) etc are generated. Their energies are evaluated using asymmetric rotor relations. The staggering indices S (I) feeding experimental and asymmetric rotor model (ARM) values are evaluated and are listed in table 1. The values of asymmetric parameter γ are calculated using experimental energy ratio $E2_2^+/E2_1^+$ [1] and $B(E2; 2_1^+ \to 0_1^+)$ [3]. The values of S(5) and S(7) in experiment and theory are nearly zero, therefore we can consider all values of S (I) {table – 1} in same phase for experiment and theory both up to the spin I = 19. Thus, the nucleus is rigid in nature in beginning and remains as such at higher spin also. This is also reflected from relative magnitude the parameter *ΔE1* and *ΔE2* [4]. The value of asymmetric parameter (γ) is slightly improved in ref. 3. and these ARM values at higher spin give S (I) values nearer to that of experiment including similarity in phase of S(7) in experiment and ARM. The plot between staggering indices and spin is shown in fig. 1.

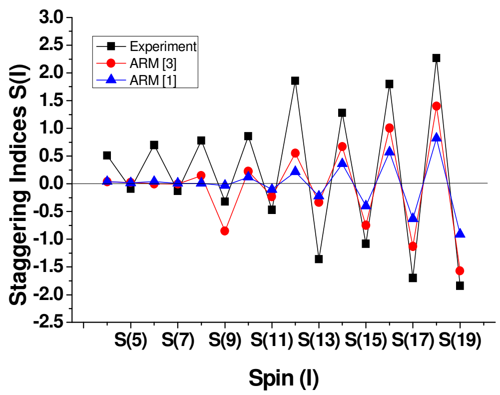

Fig. 1
Plot between Staggering Indices S(I) and spin (I) in γ – band for ^{170}Er nucleus

The parameters *ΔE1* and *ΔE2* are defined as –

$\Delta E1 = E3_1^+ - (E2_1^+ + E2_2^+) \approx 0$

(for γ – rigid – rotor shape) and

$\Delta E2 = E3_1^+ - (2E2_1^+ + E4_1^+) \approx 0$

(for γ – soft shape).

We get these values for ^{170}Er feeding experimental energies as –

$\Delta E1 = 2$ eV and $\Delta E2 = 592$ eV.

Thus, our calculations in the framework of rigid triaxial rotor model inferred that ^{170}Er may be rigid at low spins and remains as such at higher spins also. In support of our results on ^{170}Er nucleus, it will not be out of place to mention that McCutchen [5] refers to special solutions of the Bohr – Mottelson Hamiltonian that gave predictions for a triaxial structure in respect of some nuclei including ^{170}Er. In addition, Liao – Ji – Zhi have predicted triaxial nature of fourteen nuclei including ^{170}Er.

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References:

1. A. S. Davydov and G. F. Filippov, Nucl. Phys. A 8, 237 (1958).
2. J. Wilets and M. Jean; Phys. Rev. 102, 788 (1956).
3. K. K. Gupta et al; Phys Rev C 26, 685 (1982).
4. Mani Varshney, M. Singh, Yuvraj Singh, Chhail Bihari, A. K. Varshney, K. K. Gupta and D. K. Gupta; Phys. Scr. 83, 015201 (2011).
5. E. A. McCutchen, D. Bonatsos, N.V. Zamfir and R. F. Casten; Phys. Rev. C 76, 024306 (2007).
6. Liao Ji – zhi; Phys. Rev. C 51, 141 (1995).