Anomalies are viewed in nuclear structure of N = 90 isotones

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The trixiality is noticed in the structure of N = 90 isotones with ϒ- band energy staggering. The S(4) staggering is predicting the structure . The plot of staggering factor S(4) with N highlights the anomaly.

Introduction :

The N = 90 isotones is the best known and most thoroughly studied nuclear region where the isotones are seen to have a maximum deformation. It is interesting to make a correlation between asymmetric parameter(γ), $R_{4/2}$, energy staggering. . Recent experimental data of $R_{4/2}$ have been taken from the website of NNDC, Brookhaven National Laboratory, USA. Davydov et al. [1] proposed rigid triaxial asymmetric rotor model to explain these deviations with the asymmetric parameter ϒ. ϒ varies between 0 and $^{\pi}/_{3}$ and determine the deviation of shape of the nucleus from axial symmetry However BE(2) ratios changes around 140% for ϒ ~ 0^0 to 30^0 when the axial symmetry of nucleus is violated The staggering has long considered as a key signature [2] to study the different structural symmetries in nuclei. A deviation in ϒ- band energy staggering from vibrator to axially symmetric rotor indicates the transitional region. The staggering index $S(4)$ value is 1.68 for triaxial rotor and 0.33 for axially symmetric rotor. For spherical vibrator it is = −1.0. and for

γ -soft rotor or $O(6)$, $S(4)$ = −2.0 and The Bohr and Mottelson model [6] has been widely used to study the deformation of the nucleus. The simplest well known expression for study of rotational spectra is

$$E = \frac{\hbar^2}{2\mathfrak{J}} J(J+1)$$

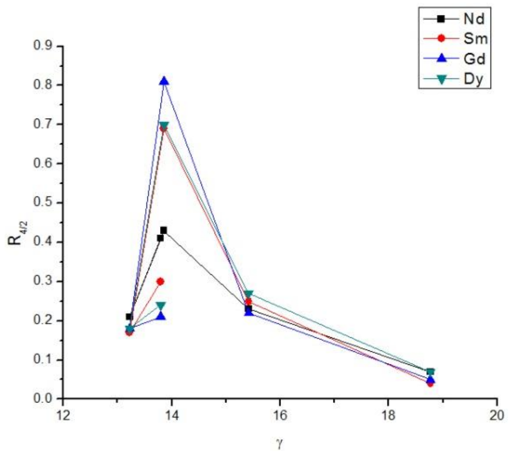
Where $\mathfrak{J}$ and J are the moment of inertia and spin of nuclei respectively. For the well deformed nuclei the moment of inertia [7] increases sharply around N = 90 are illustrated.

Present Approach

We study the first differences of $R_{4/2}$ with Assymetric Parameter ϒ and neutron number and S(4) vs Neutron Number and moment of inertia to understand the triaxiality in nuclei at N = 90. These nuclei lie at an abrupt transition between spherical and rotational nuclear shapes and because of this, have been the subjects of intensive study. The origin of the different deformations is attributed to a subshell closure [3] at Z = 64. The aim of present work is also to study the ground band and ϒ band moments of inertia in N= 90 region.

Figure 1 shows a plot of $R_{4/2}$ [4] (as the first differences of this quantity) against a asymmetric parameter lying between γ~ 13^0 to 16^0 for N = 90 isotones. The importance of asymmetric parameter [5] with static quadrupole deformation has been known for years for the evolution of structure.

$$\gamma = \frac{1}{3}\sin^{-1}\left[\frac{9}{8}\left(1-\left(\frac{R_\gamma - 1}{R_\gamma + 1}\right)^2\right)\right]^{\frac{1}{2}}$$



1. $R_{4/2}$(as the first differences) plotted against a asymmetry parameter γ for N = 90

The kink in the systematic is exactly the limiting value of γ unstable nuclei and close to the value of triaxiallity.

Nd	Sm	Gd	Dy
0.41	0.3	0.21	0.24
0.21	0.17	0.18	0.18
0.43	0.69	0.81	0.7
0.23	0.25	0.22	0.27
0.07	0.04	0.05	0.07

Table 1. shows the values of $R_{4/2}$ as the first differences

In fig.2 the staggering quantity S(4) is plotted as a function of neutron number N.

Odd-even staggering in γ bands can be studied while using the relation

$$S(J) = \frac{\{E(J_\gamma^+)-E[(J-1)_\gamma^+]\}-\{E[(J-1)_\gamma^+]-E[(J-2)_\gamma^+]\}}{E(2_\gamma^+)}$$

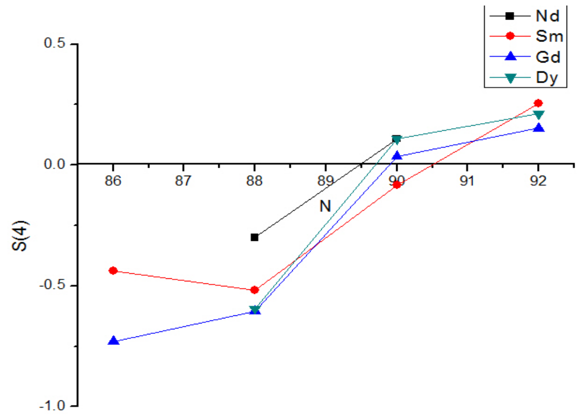


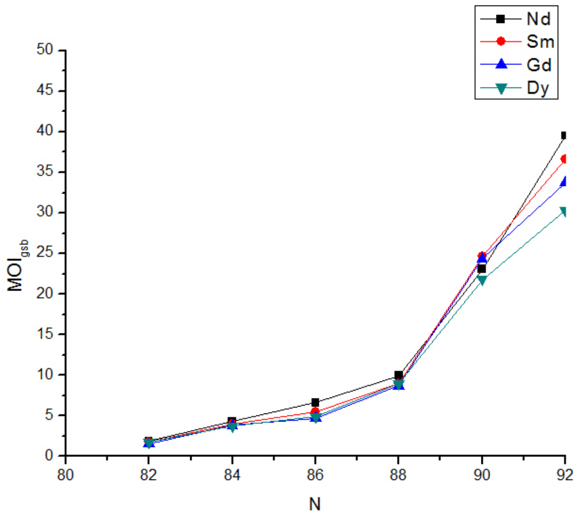
Fig 2. Plot between Staggering Signature S(4) varies as a function of collective structure vs neutron number shows transitional nuclei triaxiallity for N= 90 isotones

The sudden jumps in S(4) values from slightly negative values to positive values around N = 90 indicates the shape transitional nuclei and triaxiality in behavior.

N	Nd	Sm	Gd	Dy
86		-0.437	-0.7296	
88	-0.3	-0.517	-0.605	-0.594
90	0.108	-0.083	0.036	0.107
92		0.2562	0.1526	0.2117

Table 2. Shows S(4) values vs neutron number

In present study fig 3(a) and 3(b) shows the moment of inertia [7] plot $MOI_{gsb} = {}^{3}/_{E(2_g)}$ and $MOI_\gamma = \frac{3}{[E(3_\gamma)-E(2_\gamma)]}$ with N and found sharp change in moment around N = 90.



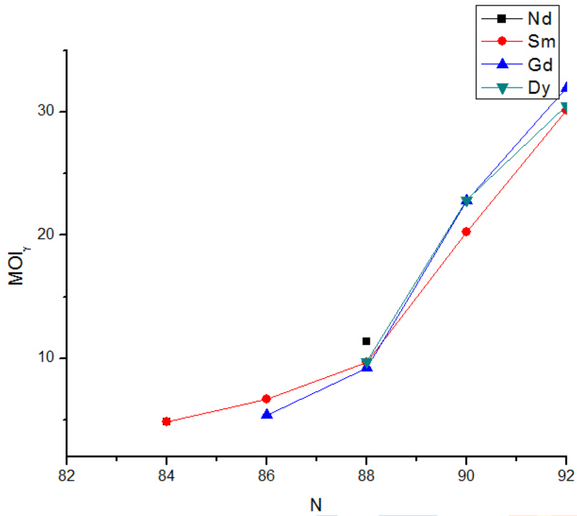


Fig 3(a) & 3(b) shows variation of moment of inertia with N

The knee point is observed around N = 90 which is the transitional region

N	Nd	Sm	Gd	Dy
82	1.9039	1.807	1.5215	1.7881
84	4.3073	4.0148	3.8251	3.7341
86	6.6097	5.5416	4.7018	4.8884
88	9.9437	8.9834	8.7138	8.9659
90	23.056	24.634	24.376	21.766
92	39.526	36.594	33.721	30.321

Table 3(a) shows MOI_{gsb} with N

N	Nd	Sm	Gd	Dy
82				
84	4.8577	4.8246		
86		6.6875	5.3812	
88	11.372	9.655	9.2367	9.7624
90		20.273	22.807	22.842
92		30.121	31.969	30.534

Table 3(b) Shows MOI_{γ} with N

Conclusion

The Present study reflects that the Energy ratio $R_{4/2}$ plotted against asymmetry parameter γ shows sharp kinks at $\gamma = 14^0 \sim 16^0$ a region of N =90 Isotones and staggering parameter S(4) plotted against Neutron Number N shows sudden jumps from positive to negative values give behavior of transitional nuclei and shows triaxiality near N = 90 isotones. The increased value of moment of inertia around N= 90 confirms that isotones shows triaxiality.

References

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