Study of $^{148\text{-}152}$Sm nuclei employing γ – derived from B (E2) values and level energies

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The study of Samarium nuclei has been a challenging theoretical problem, since they lie in the range from near spherical to well deformed shapes. ^{148}Sm was believed to be basically spherical while ^{154}Sm is thought to be well deformed nucleus and $^{150\text{-}152}$Sm are transitional nuclei. The reduced electric quadrupole transition probability (in the unit of e^2b^2) from first 2^+ state changes very rapidly, from 0.141 to 0.274 to 0.670 between ^{150}Sm and ^{152}Sm and from 0.670 to 0.922 between ^{152}Sm and ^{154}Sm. This indicates a rapid change in the average γ value as shown by the expression for the quadrupole moment of the first 2^+ state of triaxial nucleus [1].

$$Q_2 = \frac{3ZR^2\beta}{(5\pi)^{1/2}}\left(\frac{6\cos 3\gamma}{7(9-8\sin^2 3\gamma)^{1/2}}\right) \qquad (1)$$

The usual Davydov – Filippov method [1] of deducing the asymmetric parameter γ from the energy of the 2_2^+ state has already been commented as being unreliable by Beker et al. [2]. Discussing the internal consistency in asymmetric rotor model [1], Esser el al. [3] had shown that γ derived from $B(E2;2_2^+ \to 2_1^+/0_1^+)$ ratio in heavy mass region has nearly equal value with that of γ derived from traditional method of DF [1]. It has been noted that these γ – values are useful in describing the B(E2) ratios determined in experiment but, as for individual values of reduced quadrupole electric transitions and energy level of anomalous rotational band (γ – band) are concerned, these γ - values failed badly. A better quantitative agreement in energies and quadrupole electric transition both at same time had been considered actively. Some researchers [4 – 5] agreed to evolve new method of determining γ in which γ enhances by few degree at $\gamma \sim 15^0$ [4] while diminishes γ by few degree at $\gamma \sim 25^0$ [5].

There exist two basic relations in DF model-

$$E2_1^+ + E2_2^+ = E3_1^+ \qquad (2)$$

and

$$B(E2;2_1^+ \to 0_1^+) + (E2;2_2^+ \to 0_1^+) = \frac{e^2Q_0^2}{16\pi} \qquad (3)$$

We notice that relation (2) is nearly obeyed in samarium isotopes (Table – I).

We evaluate the γ using relation (3) and the following relations

$$E2_1^+ = \frac{16\hbar^2}{2I_0}\left[\frac{a-(81-72\sin^2 3\gamma)^{1/2}}{4\sin^2 3\gamma}\right] \qquad (4)$$

$$\frac{6\hbar^2}{2I_0} = \frac{1224}{A^{7/3}\beta^2} \qquad (5)$$

According to general empirical rule of Grodzians [6] and $Q_0 = 32R^2\beta/\sqrt{5\pi}$ ....(6) γ-deformation may be characterized by a single and simple parameter β [7]. The deformation parameter (γ) obtained by different approaches are listed in table II.

This is clear from the table II that Esser could reduce γ in ^{150}Sm but did not enhance γ in $^{152\text{-}154}$Sm from traditional γ evaluated from DF – method. Varshni and Bose [4] failed in $^{148\text{-}150}$Sm to determine γ. Meyer-ter-vehn reduce γ in $^{148\text{-}150}$Sm, but did not enhance γ $^{152\text{-}154}$Sm and hence downed just like Esser et al. Interestingly present approach did reduce γ in ^{148}Sm from 22.5 (DF) to 18.5 in ^{150}Sm from

20.5 (DF) to 19.0 (which is minimum) and at the same time enhanced γ from 13 (DF) to 16 in ^{152}Sm and from 9.5 (DF) to 13.5 in ^{154}Sm. Thus, a simple (present) approach succeeds in achieving the required necessary value of non-axiality parameter that yields energy as well quadrupole transitions with much better quantitative agreement with the experiment.

Table – I

Validity of the relation $E2_1^+ + E2_2^+ = E3_1^+$ in $^{148\text{-}154}$Sm nuclei.

A	$E2_1^+(KeV)$	$E2_2^+(KeV)$	$E2_1^+ + E2_2^+(KeV)$	$E3_1^+(KeV)$
148	550.10	1453.60	2003.70	1902.90
150	339.90	1193.81	1527.70	1504.50
152	121.77	1083.79	1205.60	1233.60
154	82.05	1522.45	1604.50	1540.00

Table – II

The values of asymmetric parameter γ calculated by the method of Esser et al [3], Davydov – Filippov [1], Meyer – ter – vehn [5], Bose and Varshni [4] and present approach along with the recommended values.

A	$\gamma_{present}$		γ	γ	γ	γ	γ
	Max.	Min.	Esser [3]	DF [1]	Meyer [5]	V. B. [4]	Recommended
148	18.5	18.5	22.5	22.5	19.6	-	18.5
150	21.5	19.0	18.0	20.5	17.5	-	19.0
152	16.0	13.5	13.0	13.0	12.5	22.0	16.0
154	13.5	5.0	5.0	9.5	9.5	15.5	13.5

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