Study of K = 0_2 low-lying energy levels in heavy mass nuclei

*Chhail Bihari[1], M. Singh[2], Y. Singh[3], A.K. Varshney[4] and D.K. Gupta[5]

1. Bon Maharaj Engg. College, Vrindavan, Mathura (UP)-281121, India
2. Department of Physics, NIET, Gr. Noida-201306 (U.P.), INDIA.
3. Govt. College, Dharmsala (HP), India
4. R.G.M. Govt. P.G. College, Jogindar Nagar (HP), India.
5. S.S. L.D. G. Engg. College, Aligarh (UP), India.

* E-mail- bchhail@rediffmail.com

The geometric view of the Bohr-Mottelson unified collective model describes β - vibrational band which are the energy levels based on the axially symmetric vibrations of the nuclear core with K=0_2 [1]. In the algebraic Interacting Boson Model (IBM), the K= 0_2 and K=2 bands (i.e. β and γ vibrational bands) belong to the (2N-4, 2) family of states. In IBM, Strong β - γ, E2 transitions comparable to γ - g are predicted. This led to a possibility of interpreting the K = 0_2 band as γ - γ vibrations [2]. Whether this is a general phenomenon happening in all nuclei or limited to few special nuclei only, are still unresolved [3]. Recently J. B. Gupta et al; [4] has shown correlation in β - band with ground state band in medium mass nuclei.

The present work is an extension of the study of deformation related physical quantity $R_{(4/2)}$ in all low-lying energy levels written under g, β and γ bands in Sakai table in heavy mass nuclei. Interestingly the preliminary study of correlation of β - band with ground state band gives a clear message in Th, U and Pu nuclei that these are rigid rotors [5]. In the present work we undertake the detailed calculations of energy levels of β - band employing a Soft Rotor Formula (SRF) believing that these are produced on account of rotation of asymmetric nucleus whose moment of inertia (MOI) and softness parameter (σ) are slightly different than that of MOI and 'σ' of two other rotation which are producing yrast and γ – bands having low energies.

For an excited rotational band the SRF for the level energies is written as

$$E_I = E_K + \frac{I(I+1)}{2\theta_0(1+\sigma I)} \quad (1)$$

For β - band

$E_I = E_{0\beta}$ for I = 0. This gives $E_K = E_{0\beta}$

We have

$$E_{2\beta} - E_{0\beta} = \frac{1}{\theta_0}\left[\frac{3}{1+2\sigma}\right] \quad (2)$$

$$E_{4\beta} - E_{0\beta} = \frac{1}{\theta_0}\left[\frac{10}{1+4\sigma}\right] \quad (3)$$

Dividing Equations (3) by (2) we get

$$\frac{E_{4\beta} - E_{0\beta}}{E_{2\beta} - E_{0\beta}} = \frac{10}{3}\left[\frac{1+2\sigma}{1+4\sigma}\right] \quad (4)$$

This gives the value of softness parameter (σ) and putting 'σ' in Equation (3) or (2) we get θ_0.

Thus, $E_{0\beta}$, $E_{2\beta}$ and $E_{4\beta}$ are input quantities which are if known, we can evaluate 'E_K', 'θ_0' and 'σ', the parameters required to evaluate $E_{6\beta}$, $E_{8\beta}$, $E_{10\beta}$ .... energies of β - band. ^{230}Th, ^{232}Th, ^{232}U and ^{234}U nuclei have been chosen for testing the rotational nature of the β - band in the present work. The reason is that at least first three energy levels of these nuclei are known which are necessary according to SRF to evaluate the input parameter. This is observed that the known values of $E_{6\beta}$, $E_{8\beta}$, $E_{10\beta}$, $E_{12\beta}$, and $E_{14\beta}$ in ^{232}Th, $E_{6\beta}$, $E_{8\beta}$, and $E_{10\beta}$ in ^{232}U and $E_{6\beta}$, $E_{8\beta}$ in ^{234}U are excellently match with the calculated values (Table I). The useful predictions for experimentalists are made for unknown levels in β - band of these nuclei. Further investigations in respect of β - band of these nuclei are also made calculating MOI with useful method $\left(\theta_\beta = \frac{3}{E_{2\beta} - E_{0\beta}}\right)$ and $\left(R_{(4/2)\beta} = \frac{E_{4\beta} - E_{0\beta}}{E_{2\beta} - E_{0\beta}}\right)$ are listed alongwith 'σ_β'.

The near equality of two MOI of K = 0_2 band value (= 3.3) support the validity of assuming rotor structure for β - band in present work.

Table I

Nucleus	Energies/Levels	$E_{0\beta}$	$E_{2\beta}$	$E_{4\beta}$	$E_{6\beta}$	$E_{8\beta}$	$E_{10\beta}$	$E_{12\beta}$	$E_{14\beta}$
^{230}Th	Exp.	634	678	769	-	-	-	-	-
	Present work	634	678	769	901	1066	1259	1477	1571
^{232}Th	Exp.	730	774	873	1023	1221	1467	1753	2073
	SRF	730	774	873	1023	1222	1465	1751	2077
^{232}U	Exp.	691	735	833	985	1187	1435	-	-
	SRF	691	735	833	980	1171	1404	1943	2084
^{234}U	Exp.	810	852	948	1096	1293	-	-	-
	SRF	810	852	948	1096	1294	1540	1931	2167

Table II

Nucleus	$R_{(4/2)}$	θ_β	σ_β	$\theta_{\beta(SRF)}$
^{230}Th	3.13	63.8	0.035	65.2
^{232}Th	3.23	68.49	0.012	66.91
^{232}U	3.25	68.18	0.017	66.0
^{234}U	3.29	71.43	0.0073	70.2

References:

[1]. A. Bohr – Mottelson: Nuclear Structure Vol II (1975).

[2]. F. Iachello and A. Arima: Interacting Boson Model, Cambridge university press (1987).

[3]. P. E. Garrett: J. Phys. G 27, R1 (2001).

[4]. J.B. Gupta et al; Proc. DAE Symp. Nucl. Phys. 57, (2012).

[5]. K.K. Gupta et al; Proc. DAE Symp. Nucl. Phys. (2014) Communicated.