Retarded Decay of the $K = 25/2^+$ isomer to the $K = 5/2^+$ band in ^{183}Re with higher order multipoles

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Introduction

Including five isomeric bands, more then 20 bands have been known in ^{183}Re [1, 2]. Among the isomeric bands, three are high K in nature which decay to low K bands and two are low K in nature. The mechanism for decaying of high K isomer band to lower K bands is still to be explored. Here we have used deformed Hartree-Fock and J projection formalism [3, 4] to study the low multipole decay amplitudes from high K band to low K band in ^{183}Re along with violation of K selection rule in deformed nuclei [5]. Particularly we have systematically studied the transition from $K = 25/2^+$ isomer band to $K = 5/2^+$ ground band. We have applied the Peierls-Yoccoz procedure [6] which gives J selection rule for reduced matrix elements for electromagnetic transitions among states of various bands, but there is no K selection rule forbidding between allowed transitions.

Hartree-Fock theory and Angular Momentum Projection Formalism

We start with the model space which consists of 1g 7/2, 2d 5/2, 2d 3/2, 3s 1/2, 1h 11/2, 1h 9/2, 2f 7/2, 1i 13/2, and 2g 9/2 with single- particle energies -6.92, -5.30, -3.58, -3.298, -4.376, 1.0, 2.0, 3.0 and 5.5 MeV respectively for protons oblital and 1h 9/2, 2f 7/2, 2f 5/2, 3p 3/2, 3p 1/2, 1i 13/2, 1i 11/2, 2g 9/2, and 1j 15/2 with single particle energies -10.943, -11.629, -8.407, -8.739, -7.776, -9.494, -4.049, -3.485 and -0.95 MeV respective for neutrons orbital above the inert ^{132}Sn shell closer. The nucleon-nucleon force strength of the residual interaction (surface delta) is taken as 0.15 MeV.

The microscopic model of Hartree-Fock comprises of self consistent deformed Hartree-Fock mean field calculation with a surface-δ residual interaction. To get states of good J, angular momentum projection is done with the help of projection operator

$$P_K^{JM} = \frac{2J+1}{8\pi^2} \int d\Omega \; D_{MK}^{J\,*}(\Omega)\; R(\Omega) \quad (1)$$

here $R(\Omega)$ is the rotation operator and Ω stands for the Euler angles (α, β, γ). The energies and electromagnetic transition operators are calculated by finding out their matrix elements which consists of integration over Euler angles. Reduced matrix elements of tensor operator T^L of rank L are given by,

$$\langle \Psi_{K_1}^{J_1} || T^L || \Psi_{K_2}^{J_2} \rangle = \frac{1}{2} \frac{(2J_2+1)(2J_1+1)^{1/2}}{(N_{K_1K_1}^{J_1} N_{K_2K_2}^{J_2})^{1/2}} \times \sum_{\mu\nu} C_{\mu\nu K_1}^{J_2 L J_1} \int_0^\pi d\beta \sin(\beta) d_{\mu K_2}^{J_2}(\beta) \times \langle \phi_{K_1} | T_\nu^L e^{-i\beta J_y} | \phi_{K_2} \rangle \quad (2)$$

where T^L is an electromagnetic operator (E2, M1 etc) and $N_{K_1K_2}^J$ is the amplitude overlap for angular momentum J (K_1, K_2 are axial quantum numbers.).

For calculation of various electromagnetic transition elements, we have used e_p=1.5e and e_n=0.5e as effective charges for proton and neutron respectively.

Results and Discussion

The Angular Momentum projected spectra for ground band ($K = 5/2^+$) and isomeric

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band $K = 25/2^+$ are plot in Fig. 1 along with Experimental spectra. The first band is of 1 Quasi Particle (QP) with odd proton in Ω=5/2$^+$ orbit, where second band is 3QP in nature with odd proton in Ω=5/2$^+$ orbit and 2 odd neutrons in Ω=9/2$^+$ and 11/2$^+$ orbits. The theoretical band head energy (BHE) of $K = 25/2^+$ is .212 MeV more then the experimental energy. Only α=+1/2 branch is observed experimentally from both the bands where our model give prediction both $\alpha = \pm 1/2$ branches with good J overlap. For batter picture we have separated both the branches and plot in Fig. 1.

Except BHE and spectra we also calculate the transition matrix elements for various in-band as well as inter band transition, which are given in the Table I and II.

TABLE I: J → J-2 BE(2) values in e^2fm^4 for K=25/2$^+$ and K=5/2$^+$ band.

K=25/2$^+$		K=5/2$^+$	
Transition	BE(2)	Transition	BE(2)
29/2 → 25/2	176.62	9/2 → 5/2	1378.36
31/2 → 27/2	390.03	11/2 → 7/2	2127.36
33/2 → 29/2	562.55	13/2 → 9/2	2431.04
35/2 → 31/2	646.47	15/2 → 11/2	2462.41
37/2 → 33/2	610.37	17/2 → 13/2	2318.46

TABLE II: BE(4) values for J → J-2 and J → J-4 in e^2fm^8 for K=25/2$^+$.

J → J-2		J-2 and J → J-4	
Transition	BE(4)	Transition	BE(4)
29/2 → 25/2	0.79x10^6	31/2 → 25/2	0.12x10^5
31/2 → 27/2	1.34x10^6	33/2 → 27/2	0.40x10^5
33/2 → 29/2	1.54x10^6	35/2 → 29/2	0.84x10^5
35/2 → 31/2	1.51x10^6	37/2 → 31/2	1.41x10^5
37/2 → 33/2	1.34x10^6	39/2 → 33/2	2.06x10^5

Conclusion

We study the the decay matrix elements from 25/2$^+$ isomer to 5/2$^+$ ground bands through E2, M1 and E4 multipole. The E2 and M1 amplitude are very much suppressed. The E4 decay amplitudes, although small compared to the in-band value, are significant.

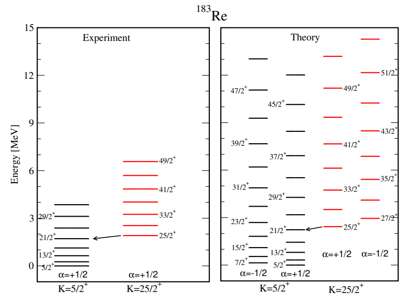

FIG. 1: Comparison of Theoretical and Experimental spectra of Ground band and $K = 25/2^+$ isomer band. Experimentally only α=+1/2 branches are observed, where theory give both $\alpha = \pm 1/2$ branches with good amplitude.

Thus we conclude that, E4 transitions from K-isomer should be carefully studied for High K isomer decay. So far such studies are very rare or non-existent. Higher order multipoles are important for K isomer decay.

References

[1] C.M.Baglin, Nucl.Data Sheets 134, 149 (2016).

[2] F. G. Kondev, G. D. Dracoulis and T. Kibedi, At. Data and Nucl. Data Tables 103, 50 (2015).

[3] G. Ripka, The Hartree-Fock Theory of Deformed light Nuclei, Advances in Nuclear pysics, Vol 1, Baranger and E. Vogt (Plenum 1966), pp. 183-259; R. E. Peierls and J. Yoccoz, Proceedings of the Physical Society A70, 381 (1957).

[4] C. R. Praharaj, Band structure of nuclei in Deformed Hartree-Fock and Angular Momentum Projection theory, in Proceedings of INT Workshop on Nuclear Many-Body Problems for 21 st Century, University of Washington (2007).

[5] A. Bohr and B. R. Mottelson, Nuclear Structure, Volume II (World Scientific 1975).

[6] R. E. Peierls and J. Yoccoz, Proceedings of the Physical Society A70, 381 (1957).