Theory of K-Selection Rule violation in K=25/2$^+$ Isomer decay of ^{183}Re

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Introduction

Many high spin bands are known in ^{183}Re, including K=25/2$^+$ isomer. But the mechanism of K isomer decay to lower K bands is still to be explored. In this paper we study K=25/2$^+$ isomer and the K selection rule [1, 2] violation in deformed nuclei of ^{183}Re by using a microscopic model i.e. Hartree-Fock theory.

We apply the Peierls-Yoccoz procedure [3] 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 J allowed transitions between bands.

TABLE I: J to J-2 BE(2) values in e^{2}fm^4 for K=25/2$^+$ and K=5/2$^+$ band of ^{183}Re.

Transitions	BE(2;J→J-2)	Transitions	BE(2;J→J-2)
$7/2^+_{gr} \to 5/2^+_{gr}$	0.1371×10^5	$27/2^+_{iso} \to 25/2^+_{iso}$	0.6665×10^4
$9/2^+_{gr} \to 7/2^+_{gr}$	0.1164×10^5	$29/2^+_{iso} \to 27/2^+_{iso}$	0.1039×10^5
$11/2^+_{gr} \to 9/2^+_{gr}$	0.8969×10^4	$31/2^+_{iso} \to 29/2^+_{iso}$	0.1236×10^5
$13/2^+_{gr} \to 11/2^+_{gr}$	0.6929×10^4	$33/2^+_{iso} \to 31/2^+_{iso}$	0.1327×10^5
$15/2^+_{gr} \to 13/2^+_{gr}$	0.5457×10^4		

TABLE II: J to J-2 BE(2) values in e^{2}fm^4 and J to J-1 BM(1) values in μ_N^2 for K=25/2$^+$→K=5/2$^+$ band of ^{183}Re.

Transitions	BE(2)	Transitions	BM(1)
$25/2^+_{iso} \to 21/2^+_{gr}$	0.5430×10^{-3}	$25/2^+_{iso} \to 23/2^+_{gr}$	0.1067×10^{-6}
$25/2^+_{iso} \to 23/2^+_{gr}$	0.1091×10^{-2}	$25/2^+_{iso} \to 25/2^+_{gr}$	0.1061×10^{-6}
$27/2^+_{iso} \to 25/2^+_{gr}$	0.1319×10^{-2}	$27/2^+_{iso} \to 25/2^+_{gr}$	0.2151×10^{-5}
$27/2^+_{iso} \to 25/2^+_{gr}$	0.1896×10^{-1}	$27/2^+_{iso} \to 27/2^+_{gr}$	0.2129×10^{-5}

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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. Also for neutrons we have 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. The 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 obtained with a surface delta residual interaction. To get states of good J, angular momentum projection is done by the help of projection operator [4, 5]

$$|\psi^J_K\rangle = \frac{2J+1}{8\pi^2}\int d\Omega D^{J*}_{MK}(\Omega)R(\Omega)|\phi_K\rangle \quad (1)$$

where, R(Ω) is the rotation operator and Ω represents 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. The reduced matrix elements of tensor operator T^L with multipolarity L is expressed as

$$\langle\psi^{J_1}_{K_1}||T^L||\psi^{J_2}_{K_2}\rangle = \frac{(J_2+1/2)(2J_1+1)^{1/2}}{(N^{J_1}_{K_1K_1}N^{J_2}_{K_2K_2})^{1/2}} \times \sum_{\mu(\nu)} C^{J_2\ L\ J_1}_{\mu\ \nu\ K_1}\int_0^\beta d\beta sin(\beta) d^{J_2}_{\mu K_2}(\beta) \times\langle\phi_{K_1}|T^L_\nu e^{-i\beta J_y}|\phi_{K_2}\rangle (2)$$

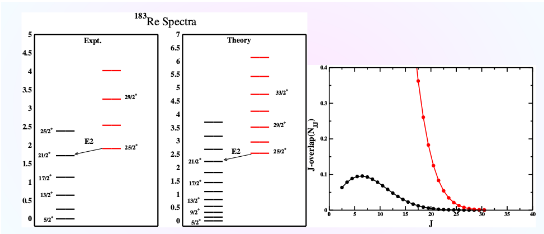

FIG. 1: (a) Energy spectra of K=$5/2^+$ and K=$25/2^+$ of ^{182}W (b) Plot of J overlaps for K=$5/2^+$ and K=$25/2^+$ intrinsic states. (Black line denotes K=$5/2^+$ and red line denotes K=$25/2^+$)

where,

$$N^J_{K_1K_2} = \int_0^\pi d\beta sin(\beta) d^J_{K_1K_2}(\beta) \times\langle\phi_{K_1}|e^{-i\beta J_y}|\phi_{K_2}\rangle \quad (3)$$

is the overlap integral. It is to be noted that the Clebsh Gordan coefficient in Eqn. 2 for the reduced matrix element has only J selection rule and there is total absence of K-selection rule for inhibition of J allowed electromagnetic transitions.

Results and Conclusion

Angular momentum projection from K=$5/2^+$ and K=$25/2^+$ intrinsic states is done and the results of the spectra is shown in Fig.1(a) along with the overlap integral (Eqn. 3) in Fig.1(b), suggesting that the wave packets are well spread. We get the energy overlap (Eqn. 2) of the K=$25/2^+$ states $\langle 25/2^+_{isomer}|H|25/2^+gr\rangle = 1.06\ MeV$ whereas the experimental energy difference between the two states is $\Delta(25/2^+_{isomer} - 25/2^+gr) = 0.477\ MeV$. We find that the interaction energy is very small i.e. 0.186×10^{-5} MeV. There is negligible K mixing occuring in this case. Table I shows the BE(2) values K=$5/2^+$ and K=$25/2^+$ band. Also, the BE(2) and BM(1) for K=$25/2^+$→K=$5/2^+$ are enlisted in Table II which reveal that the transitions are finite and of the order 10^{-3} of the values of transitions within a band. It is noteworthy that there is no K selection rule in our theoretical model prohibiting E2 and M1 transition but only J selection rule. Thus, we conclude that the K selection rule violating E2 and M1 transitions from the $25/2^+$ to $5/2^+$ band are finite but retareded which is in agreement with experiments [1, 6] and there is no K mixing in our microscopic calculation.

References

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