TQPRM calculations for $\{(h_{9/2})_p \otimes (i_{13/2})_n\}$ and $\{(i_{13/2})_p \otimes (i_{13/2})_n\}$ structures in doubly odd ^{176}Ir

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Introduction:

High spin states in $^{176}_{77}$Ir have been investigated by two experiments to deduce the partial level scheme. The reaction ^{149}Sm (^{31}P, 4n) ^{176}Ir was employed in both the experiments [1, 2]. The level scheme determined in the experiments had been labeled numerically from Band 1 – 10. Out of total 10 bands, unusual features have been observed in two bands (Band 4 and 9). Signature reversal [3] is observed in $K_+=4^+$, $\{1/2[660]_p \otimes 7/2[633]_n\}$ band whereas $K_+=4^-$, $\{1/2[541]_p \otimes 7/2[633]_n\}$ band is showing the phenomenon of signature inversion. The phenomena of signature inversion and signature reversal are well reproduced in rare earth region for high- j orbitals [3, 4] by using TQPRM. The results of calculations to reproduce the abnormal feature of signature inversion and signature reversal in ^{176}Ir, above the rare earth region are presented in this paper.

Formulation:

The theoretical formulation of two-quasiparticle plus rotor model (TQPRM) is well known. A detailed description of the model may be found in many papers [5]. In TQPRM approach, the total Hamiltonian is divided into two parts, the intrinsic and the rotational,

$$H = H_{intr} + H_{rot} \qquad \text{..... [1]}$$

The intrinsic part consists of a deformed axially symmetric average field H_{av}, a short range residual interaction H_{pair}, and a short range neutron-proton interaction V_{np}, so that

$$H_{intr} = H_{av} + H_{pair} + V_{np} \qquad \text{….. [2]}$$

The vibrational part has been neglected in this formulation. For an axially-symmetric rotor

$$H_{rot} = \hbar^2/2\Im\,(I^2 - I_3^2) + H_{cor} + H_{ppc} + H_{irrot} \qquad \text{….. [3]}$$

$\Im$ is the moment of inertia with respect to the rotation axis. The set of basis Eigen functions of $H_{av} + H_{pair} + \hbar^2/2\Im\,(I^2 - I_3^2)$ may be written in the form of the symmetrised product of the rotational wave function D^I_{MK} and the intrinsic wave function $|K\alpha_\rho>$ can be written as – $|IMK\alpha_\rho\rangle$ =

$$\left[\frac{2I+1}{16\pi^2(1+\delta_{KO})}\right]^{1/2}\left[D^I_{MK}|K\alpha_\rho\rangle + (-1)^{I+K}D^I_{M-K}R_i|K\alpha_\rho\rangle\right]$$

Where the index α_ρ characterizes the configuration ($\alpha_\rho = \rho_p\rho_n$) of the odd proton and the odd neutron. The TQPRM calculations involve many parameters. The parameters namely Inertia parameter ($\hbar^2/2\Im$), Band Head Energy ($E_{\alpha\pm}$), decoupling parameter and Newby shift (E_N) play an important role in calculations. The Inertia parameter ($\hbar^2/2\Im$) is taken as 10.0keV and 10.5keV for K_+ and $K\_$ bands respectively and adjusted during the fitting process. The matrix elements are also treated as free parameters. Initially a fixed attenuation of 50% of single particle matrix elements only for $i_{13/2}$ neutron is done and further these are adjusted during the calculations. In the present two cases Newby shift is not at all effective to obtain the staggering pattern, only decoupling parameters play very significant role. The calculations require mixing of many 2qp experimentally known and unknown bands; so estimated energies of experimentally unknown bands is obtained by using semi-empirical formulation [6].

Results and Discussion:

The experimental staggering plot of Band 4 and Band 9 in ^{176}Ir shows the feature of signature reversal and signature inversion respectively. The deformation parameters (ϵ_2, ϵ_4) are taken as: (0.233, 0.013) respectively [7]. The Nilsson model parameters, κ and μ used in the calculations are 0.0620 and 0.614 respectively for protons and 0.0636 and 0.393 respectively for neutrons [8].

$K_+=4^+$, $\{1/2[660]_p \otimes 7/2[633]_n\}$:

According to rule, for $K_+=4^+$, $\{1/2[660]_p \otimes 9/2[624]_n\}$ band, $\alpha_f = 1$ i.e. odd spins should be favored throughout the staggering pattern but in the experimental staggering plot even spin states lie lower in energy i.e. signature reversal. The decoupling parameter of neutron is the most dominating factor for the reverse behaviour of observed staggering pattern. The fitted value of matrix element of neutron: $\langle 1/2[660]|1/2[660]\rangle n$ = 0.80000 (-6.65597) to obtain the feature as shown in figure 1(a). With negative value of matrix element, $\langle 1/2[660]|1/2[660]\rangle n$= -6.65597; odd spins are favored and with $\langle 1/2[660]|1/2[660]\rangle n$= 0 then there is no staggering. The origin of signature reversal in $K_+ = 4^+$ lies in the reverse behaviour of K_- =0 and K_+=1 band. The K_-=0, $\{1/2[660]_p \otimes 1/2[660]_n\}$ and K_+=1, $\{1/2[660]_p \otimes 1/2[660]_n\}$ band favors even spin and this behaviour is transmitted through Coriolis coupling and Particle-Particle coupling to $K_+ = 4^+$ band. The decoupling parameter of proton: $\langle 1/2[660]|1/2[660]\rangle p$ and Newby shift are not significant to reproduce the staggering pattern.

K_+=4$^-$, {1/2[541]$_p$⊗ 7/2[633]$_n$}:

For $\{(h_{9/2})_p \otimes (i_{13/2})_n\}$ configuration, α_f = 1 so odd spins should be favored. The odd-even staggering plot of K_+=4$^-$ band shows that even spins are favored up to I_c= 18 and then normal feature is restored. The mechanism responsible for inversion is the reverse behaviour of K_-=0 and K_+=1 band. The K_-=0 band favors even spin and odd spins are favored in K_+=1 band. The reverse feature is transmitted through Coriolis coupling and Particle-Particle coupling to K_+=4$^-$ band. In the present case the Newby shift doesn't affect the pattern; it is the decoupling parameters of both, proton and neutron which is playing the key role. The fitted value of $\langle 1/2[541]|1/2[541]\rangle p$ is -3.08936 (-4.089368) and $\langle 1/2[660]|1/2[660]\rangle n$ is 3.65597 (-6.65597); the Nilsson matrix value is given in the parenthesis. The results are shown in figure 1(b)

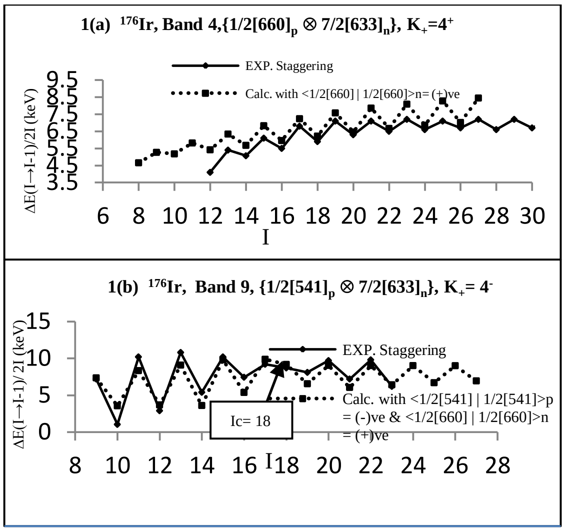

Fig. 1: Results of TQPRM calculations are plotted for ΔE (I→I-1)/2I in (keV) vs. I for bands with configuration $\{(i_{13/2})_p \otimes (i_{13/2})_n\}$and $\{(h_{9/2})_p \otimes (i_{13/2})_n\}$ in ^{176}Ir. Obtained staggering is in good agreement with the experimental staggering pattern. I_c represents the point of signature inversion.

Conclusion:

The feature of signature reversal in $K_+ = 4^+$, $\{1/2[660]_p \otimes 7/2[633]_n\}$ band and signature inversion in K_+= 4$^-$, $\{1/2[541]_p \otimes 7/2[633]_n\}$ band is well reproduced by TQPRM calculations. The decoupling parameters are playing the important role to obtain the required feature. It is very much clear that the phenomenon of signature inversion and signature reversal which was observed in high-j orbitals of rare earths is also present in high-j orbitals above the rare earth region and the same mechanism can reproduce it.

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