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Features of High j- orbitals in Rare Earth Region

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Abstract- A systematic of the signature inversion & Signature reversal phenomena in odd- odd nuclei in rare earth region are presented. It is mainly observed in high j-orbitals. These are the systematic of ($h_{11/2p}$ x $i_{13/2n}$) orbitals. We have analyzed in total 41 cases (Experimental data have been collected from http://www.nndc.bnl.gov/chart/)in rare earths region (Z=61 to Z=75). For these configuration bands, the even spin members should lie lower in energy. However revert behaviors is observed up to certain spin called signature inversion. The point of Inversion is mentioned in the systematic shown in table. The point is shifted towards lower spin as we move towards higher isotopes. These features like signature dependence, signature inversion and signature reversal are well explained by two-quasiparticle rotor model (TQPRM). Goel et al have developed TQPRM for even-even and odd-odd nuclei. The model well explained the signature dependence and signature inversion in 152Eu, 156Tb and 160Ho of odd-odd nuclei. The signature reversal observed in 170Yb of even-even nuclei was also well explained by TQPRM model. The odd-even staggering in rotational band is due to the residual interaction. The Newby shift for the K=0 band and decoupling parameter for K=1/2 band are basically responsible for such behavior. The K=0 and K=1 bands are staggered band. This staggering is transmitted to higher K values by Coriolis coupling or by PPC (particle-particle coupling). Availability of large experimental data of odd-odd nuclei helps to do the further work in this region. We are in process not only to explain this feature but also shifting in the point of inversion as mass number increases. In future we will present systematic by TQPRM calculations.

Index Terms- Signature Inversion, Signature Reversal, Signature Dependence and odd-even staggering, Inversion point, Two-quasiparticle rotor model (TQPRM), Particle-Particle coupling, Coriolis coupling

I. Introduction

Many unusual features have been observed in the high-j rotation spectra of deformed odd-odd & even-even nuclei like signature dependence, signature inversion and signature reversal. The phenomena of Signature inversion & Signature reversal are well explained by the two quasiparticles plus axially symmetric rotor model (TQPRM) calculations in 152Eu, 156Tb, 160Ho of odd-odd nuclei and 170Yb of even-even nuclei by Goel et al. We have analyzed the experimental data for rare earth region from 61Pm to 75Re. Here we have considered only high j-orbitals bands. Total 41 cases of ($h_{11/2}$ x $i_{13/2}$) have been observed.

The K_+= (Ω_p+Ω_n) bands of odd-odd nuclei generally exhibit very smooth behavior in contrast to the K_-= |Ω_p-Ω_n| bands which exhibit odd-even staggering. However, the K_+ bands composed of the high-j configuration display a very strong odd-even staggering in their rotational energy spacing, implying signature dependence. While K_- bands show almost smooth behavior for high-j orbitals where it is known. At high rotational frequencies, signature and parity are the only two good quantum numbers available to label a state.

The Hamiltonian for an odd-odd nucleus has a signature dependence, which leads to alowering of the levels of the rotational band having signature α_f=1/2(-1)$^{j}_{p}$$^{-(1/2)}$+1/2(-1)$^{j}_{n}$$^{-(1/2)}$; these constitute the favored signature sequence. For ($h_{11/2}$ x $i_{13/2}$) configuration bands, α_f =0, the even members should lie lower in energy. It has, however, been observed that the odd-spin members lie lower in energy up to a certain spin I_c; the normal signature dependence is restored afterwards. This anomalous effect is known as signature inversion by Jain et al (1988).

II. SYSTEMATIC OF THE SIGNATURE INVERSION PHENOMENON

Now sufficient data is available therefore it is possible to review the systematic of high-j orbital for odd-odd nuclei. We have compiled the data and presented some very important and special features under different categories:

i. In most of the cases it has been observed odd spin members lie lower in energy up to a certain spin Ic; the normal signature dependence is restored afterwards. This is known as Signature Inversion. The point of inversion is given in the systematic table for the respective isotope.
ii. In some bands it is observed that odd spin members lie lower in energy no spin restored up to a high spins. It is an abnormal feature called Signature Reversal. The cases where signature reversal is observed are given by SR in the systematic table.
iii. The even spin members lie lower in energy. This is the required normal feature which is also observed in some of the bands by Renrong et al (1997). It is given by N in the systematic table.

III. RESULTS

The summary of compiled data for rare earth region is given in the Table 1. Some of the figures showing such behavior is also given as Figure 1. We have plotted Eγ energies verses spin. These features are well explained by TQPRM model. The signature inversion 152Eu, 156Tb and 160Ho are well explained by this model. The signature reversal in 170Yb of even-even nuclei is also well explained by this model developed by Goel et al (1992) . We will make our model more informative and will incorporate gamma deformation to explain all important features of odd-odd and even-even nuclei. Our target is to explain these important and anomalous features by our model and also to explain shifting in the point of inversion as we move lower isotope to higher one. The main reason behind such features are the strongly staggered K=0 and K=1 bands of the chain. This staggering is transmitted to higher K bands through Coriolis coupling or the PPC (particle-particle coupling) In future we will present the complete systematics by our model. We have already published three-four papers related to these features in odd-odd and even-even nuclei. Presently large amount of the experimental data is available which attract theoreticians to go for further work in this area. We are in process of TQPRM calculations to explain and present the systematic of odd-odd and also for even-even nuclei.

The methodology we are going to use the Two-quasiparticle rotor model (TQPRM) which is already published in Goel et al (1994).

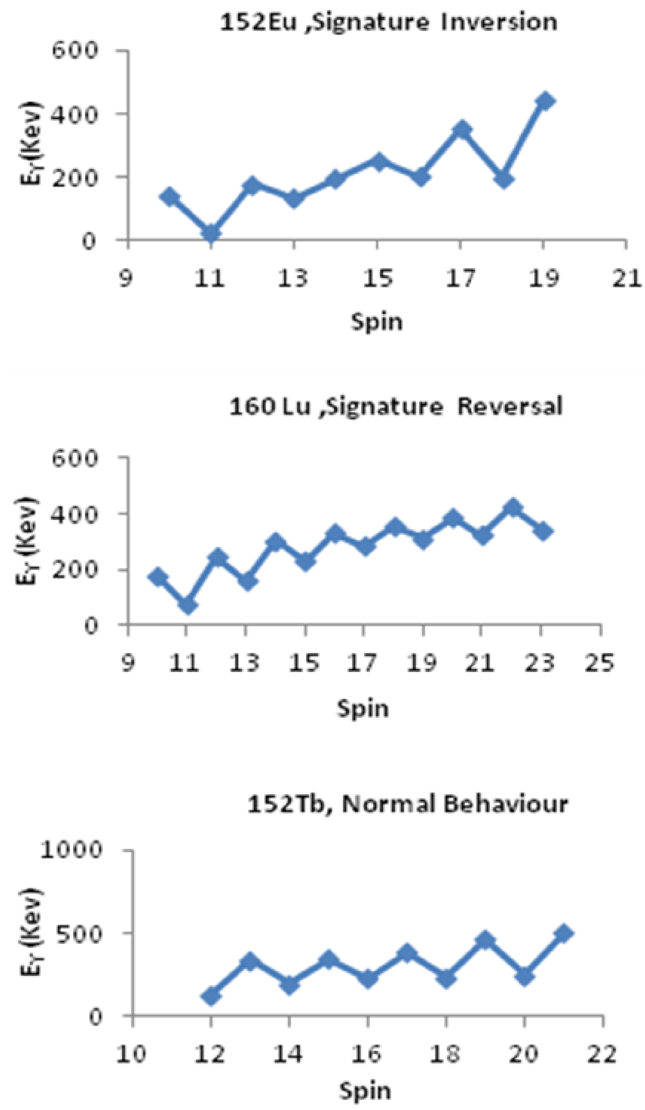

Figure 1 : E_Υ(kev) verses spin for odd-odd nuclei

Figure Caption**:** We have plotted experimental E_γ (kev) energies verses spin to show features like signature inversion, signature dependence and signature reversal in odd-odd nuclei.

Table: Systematic Study of Odd-Odd Nuclei.

Table Caption**: The experimental data are taken from nndc site**. In the table K_+ bands of high j-orbitals are reported. Each box list the following information: ***Top row: K*** (observed), I_c (Inversion), ***Middle row:*** K and configuration from systematic**,** ***Bottom row:*** lowest observed spin & its energy in kev. xxx denotes energy unknown. Configurations are abbreviated as: ***protons***: A=5/2[532], B=7/2[523], C=9/2[514] ***Neutrons: U***=1/2[660], V=3/2[651], W=5/2[642], X=7/2[633], Y=9/2[624], Z=11/2[615]. Complete study of all the nuclei with its different isotopes is done by plotting graphs between spin and Gamma Energies. The analysis is shown in the table.

*NS signifies Smooth Behaviour, no odd-even staggering.
**NC signifies energy is not confirmed, it is in the form of W+, X+, Y+, Z+

75Re								?, N 8,CX 8,NC**	8, SR 8,CX 8,NC**		9,N 9,CY 9,443	10,NS* 10,CZ 10,917
73Ta			?, SR 5,CU 11,NC**	?, 21 6,CV 9,NC**	?,18 6,CV 10,NC**	?, 21 5,CU 10,NC**		8, NS* 8, CX 8,NC**	8, NS* 8,CX 8,NC**	9, N 9,CY 9,NC**	?, NS* 9,CY 9,77	
71Lu		?, SR 4,BU 9,NC**	?, 20 5,BV, 10,NC**	?,18 7,CW 7,NC**	7, 17 7,CW 8,287	7,? 7,CW 9,NC**	?, N 7,CX 8,NC**					
69Tm		?, >27 4,BU 9, xxx	?, 18 6,BW 9, NC**	6, 16 6,BW 6,NC**	6, 15 6,BW 6,NC**	6, 13 6,BW 6,NC**	? , N 7,BW 7,NC**					
67Ho	?, N 4,BU 11,NC**	?, 19 4,BU 9, xxx	5, 17 5,BV 8,208	6, 15 6,BW 6,118	**6,** N 6,BW 6,106	6, NS* 6,BW 6,140						
65Tb	?, N 3,AU 9,1212	?, 17 3,AU 9, NC**	4, 12 4, AV 6,379									
63Eu		5, 14 4,AU Or AV 5,181										
N	87	89	91	93	95	97	99	101	103	105	107	109

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