Shape transitions in neutron rich $^{110-112}$Ru nuclei and empirical relations

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1. Introduction:

For neutron rich A ≥ 100 nuclei, the nuclear shape changes rapidly as valence nucleons fill the $g_{9/2}$ proton and $h_{11/2}$ neutron orbitals which is manifest by such phenomenon as the sudden onset of quadrupole deformation in Sr-Zr isotopes, the development of triaxial degrees of freedom in Mo- Ru isotopes, and the predicted transition of a triaxial shape from prolate to oblate in Ru- Pd isotopes. The ramifications on the nuclear structure because of various shapes make these neutron rich nuclei an ideal testing ground for various theoretical models. The shape transition was predicted by Kumar and Baranger from solving Bohr's Hamiltonian using the pairing plus quadrupole model [1]. However, the experimental technique is difficult to apply for nuclei away from the valley of β stability such as neutron rich Ru – Pd isotopes. Recently Wu et al., [2] suggested an alternative approach that recognizes processes that may yield a distinct signature to differentiate between two shapes in their work one such opportunity address a possible evidence of a triaxial shape transition from prolate to oblate in neutron rich Ru isotopes by studying the band crossing phenomenon which is sensitive to the interplay between the single particle and shape degrees of freedom.

In the study of even even neutron rich Ru isotopes, the electromagnetic properties of the γ – vibrational bands are well described by a rigid triaxial rotor for lower spin state and by the rotation vibration collective model for the higher spin states. Thus interpretation in further suggested by the observation of nearly identical moment of inertia, the rotational frequency below the first band crossing, between the ground state and the γ – structural bands for both ^{110}Ru and ^{112}Ru which conclude a weak pairing, a more likely suitable explanation of observations.

2. Discussion and conclusion:

In the present work we undertake the soft rotor energy formula suggested by Brentano et al.,[3] for yrast band ,may be employed to calculate the perturbed energies of the anomalous rotational band (γ – band) generated by rotation of the rigid asymmetric atomic nucleus and the two parameter formula (TPF) of Gupta et al., [4] in which E_J is replaced by ε_I and J by 'b'

$$E_J = aJ^b \tag{1}$$

Where 'a' and 'b' are constants and E_J is energy calculated and J is spin (only of yrast band)

$$\varepsilon_I = cb^d \tag{2}$$

ε_I is asymmetric rotor model (ARM) energy with spin and 'b' is rotation vibration coupling strength, 'c' and 'd' are constants (for yrast as well as γ – band since both are rotational band in ARM. The soft rotor formula (SRF) use six parameters 'α' and 'J' are different for yrast, even and odd γ - bands energies [5] where two parameter formula (TPF) of Y Singh et al., [6] use only two parameter, 'c' and 'd' for yrast and γ – band. If TPF give closer values to experiment then it hints towards rigid shape of nucleus in least parameters are involved. Thus only known γ, we can see ε from Liao table, we can conclude 'b' from this equation be

$$E = a\varepsilon(1 - b\varepsilon)$$

It gives the required of that level energy.

This is obtained on looking at table 1 that both the empirical relations give the values of energy levels especially in γ – band which deviate from the experiment to both sides. The average of the two, if taken, we see the approximate value of experiment. Thus the present work suggests an easy method to predict the unknown energy.

Table 1

The comparison of calculated energies is SRF and TPF in $^{110-112}$Ru nuclei.

Levels	Exp	SRF	TPF	Exp	SRF	TPF
g-band						
2_1^+	241	241	-	237	237	-
4_1^+	664	664	-	645	645	-
6_1^+	1239	1241	-	1190	1201	-
8_1^+	1944	1857	-	1839	1787	-
10_1^+	2759	2517	2803	2563	2412	2592
12_1^+	3647	3207	3712	3226	3064	3379
γ -band						
2_2^+	622	602	551	524	526	486
3_1^+	859	852	754	747	749	690
4_2^+	1084	1068	1091	981	985	1048
5_1^+	1375	1364	1332	1235	1238	1244
6_2^+	1684	1528	1892	1570	1438	1807
7_1^+	2020	1872	2052	1841	1726	1925
8_2^+	2397	1988	2931	2263	1890	2746
9_1^+	2775	2378	2928	2535	2213	2712
10_2^+	3255	2444	4023	3033	2340	3734
11_1^+	3625	2885	3962	3291	2701	3522
12_2^+	4153	2902	5412	3870	2791	4788

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