Energy systematics in ground and gamma bands of $^{98\text{-}112}$Ru

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Long back Weeks & Tamura Van Isacker and Puddu tried to explain the systematic features of energy levels, B(E2) values and other properties of Ru & Pd nuclei on the basis of Boson Expansion Technique (BET) and Interacting Boson Model (IBM) respectively [1]. The BET and IBM are microscopic models and have the additional advantage over other models (e.g. pairing plus quadrupole model, rotation vibration model and asymmetric rotor model) that both treat neutrons and protons independently. The opposite trends of experimental $B(E2;2_2^+ \rightarrow 0_1^+)$ values with mass number in the two chains of isotopic could not be explained by these microscopic models (These models give similar trends for both the chains). The experimental $B(E2;3_1^+ \rightarrow \frac{2_1^+}{4_1^+})$ branching ratio for Ru & Pd nuclei are found small as expected for 3 phonon character of the 3^+ state. The calculated values were 2 to 10 times larger than experiments. Besides, the calculated energy levels in both the chains of nuclei deviate to the higher as well as the lower sides of the experimental energy. These deviations cannot be accounted for by including rotation vibration interaction shifts the calculated levels in one direction only. Surprisingly asymmetric rotor model (ARM) had given a good agreement between experimental and theoretical values [2]. There is revival of interest in ARM as systematic trends have been obtained in basic deformation parameters β and γ with product of valance nucleon N_pN_n in medium as well heavy mass region but not in A~100 mass region [3]. The value of parameter γ for Mo & Pd Chains of nuclei varies smoothly with mass number, decreasing for Mo nuclei and increasing for Pd nuclei. The Ru chain of nuclei is intermediate between these two chains having opposite trends for parameter γ and has an irregular behavior for γ. In the present work, we consider the ARM with rotation vibration interaction as applied by Liao ji-zhi [4]. According to which

$$E_{In}(b) = a\varepsilon_{In}(1-\varepsilon_{In})\text{..........................}(1)$$

Where, $a = \hbar^2 / J_0$ and is evaluated using Grodzins semi-empirical relation and according to which

$$a = \frac{\hbar^2}{J_0} = \frac{408}{\beta^2 A^{7/3}} MeV \text{ ....}(2)$$

ε_{In} are model energies in units of $\hbar^2 / J_0$. 'b' is rotation vibration coupling parameter which instead of keeping static is now considered dynamic keeping in mind the simple viewpoint that shape of the nucleus changes as it passes into an excited state. A change of the nuclear shape in excitation leads to a connection of rotation motion with surface vibrations. And the rotation vibration interaction comes to play its role in rectifying the level energies. The values of 'b' are evaluated on fitting experimental energies in the above relation. There is a clear trend of decreasing "b" with the increase of spin for each nucleus in yrast as well as γ – band. But if general trend is studied in both the bands, we have for 2_2^+ (γ – band head) 'b' = 299, ε_I =16.7 and for 4_1^+ (g- band) 'b' 301, ε_I =17.0 for ^{104}Ru. This makes us think that it is not spin but ε_I (model energy) which is related with 'b' irrespective of nature of band whether g or γ.

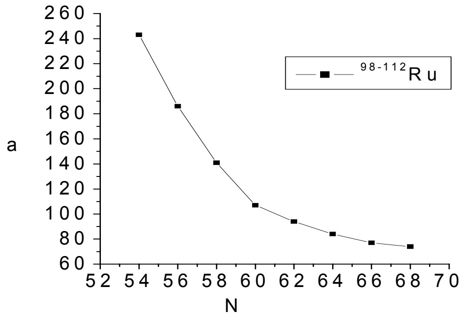

Fig.1

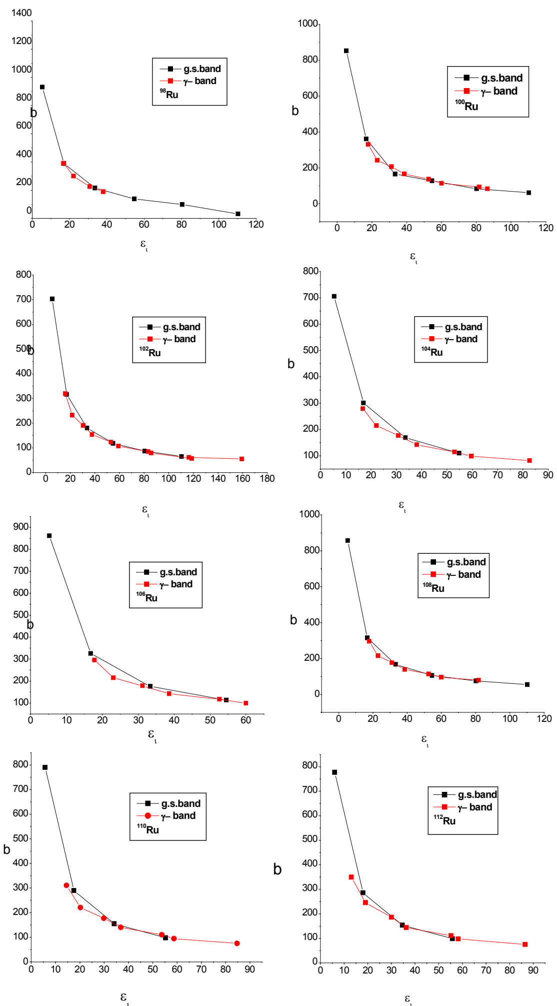

Fig. 2

Such things do appear in other nuclei also. In ^{102}Ru, for spins 2_2^+, 4_1^+, 6_2^+, 8_1^+, 8_2^+, 10_1^+ the values of ε_I and 'b' are (16, 319), (17, 316), (53, 123), (55, 118), (83, 85) and (80.5, 87). The 'a' versus N plot is another striking relation in the present study (Fig.1). The moment of inertia parameter extracted from experimental β varies smoothly with N. In particular the deformation β decreases with N and the parameter 'a' increases with decrease of N in the investigated mass range. The trend is very much expected since the deformation should have a maximum at mid shell (N= 66). Experimental β shows the expected trend for ^{110}Ru, (N=66) β = 0.303 (max.) while ^{112}Ru (N=68) β = 0.302. But the values of 'a' for these nuclei are 77 & 74, the reason being the mass number (A) in the expression of 'a' in eq. 2 (table 1).

N are related with β and also with 'a'. ε_I are related with 'b'. Thus, knowing γ alone one could evaluate ε_I and N gives the value of 'a' (Fig 2). ε_I gives the value of 'b' (Fig 3). One could make 'a', 'b', ε_I in terms of single variable. At the least, our results point to the interest in further study. We have predicted many unknown energies knowing only γ & β.

Table I: Values of parameters γ, β, N and a

Nuclei	γ	β	N	a
^{98}Ru	22	0.195	54	243
^{100}Ru	21	0.217	56	186
^{102}Ru	22.5	0.244	58	141
^{104}Ru	22	0.274	60	107
^{106}Ru	21	0.286	62	94
^{108}Ru	21	0.296	64	84
^{110}Ru	23.5	0.303	66	77
^{112}Ru	26	0.302	68	74

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