The study of Ru isotopes in the frame work of interacting boson model

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Introduction

The interacting boson model provides the description of various symmetries involve in collective structure [1]. The model led to the U(6) group algebra which yields three dynamical symmetries: SU(5), SU(3) and O(6) which corresponds to anharmonic vibrator, deformed rotor and γ-unstable nuclei, respectively [2]. There are several equivalent ways of writing Hamiltonian [1]. The most general Hamiltonian that has been used to calculate the level energies are

$$
\begin{aligned}
H = \epsilon n_d + a_0 P^\dagger.P + a_1 L.L + a_2 Q.Q \\
+ a_3 T_3.T_3 + a_4 T_4.T_4
\end{aligned}
$$

The energy eigenvalues for three chains are as

$$
\begin{aligned}
E^{(I)}(N, n_d, \nu, n_\Delta, L) &= \epsilon n_d + \alpha \frac{1}{2} n_d(n_d - 1) \\
&+ \beta[n_d(n_d+3) - \nu(\nu+3)] \\
&+ \gamma[L(L+1) - 6n_d] \\
E^{(II)}(N, \lambda, \mu, L) &= \left(\frac{3}{4}\kappa - \kappa'\right) L(L+1) - \\
&\kappa[\lambda^2 + \mu^2 + \lambda\mu + 3(\lambda+\mu)] \\
E^{(III)}(N, \sigma, \tau, \nu_\Delta, L) &= A\frac{1}{4}(N-\sigma)(N+\sigma+4) \\
&+ B\frac{1}{6}\tau(\tau+3) + CL(L+1)
\end{aligned}
$$

A. Soft Rotor Formula (SRF)

Brentano et. al [3] obtained the two parameter formula called the soft rotor formula (SRF)

$$E = \frac{J(J+1)}{\alpha(1+\beta J)} \tag{1}$$

The values of α and β are calculated by fitting 2^+_γ, 4^+_γ energies in even sequence and 3^+_γ, 5^+_γ energies in odd sequence. For all these calculations the experimental data are taken from www.nndc.bnl.gov [4].

B. Back Bending

The discrete derivatives of the resulting energies with respect to the angular momentum [5] are

$$\hbar\omega = \frac{dE(J)}{dJ} \approx \frac{1}{2}[E(J+2) - E(J)]. \tag{2}$$

Alternatively, the angular velocity can also be defined by using the expression for $E(J)$ provided by symmetric rotor Hamiltonian:

$$E(J) = \frac{J(J+1)}{\Im}. \tag{3}$$

The discrete derivative of this expression yields

$$\hbar\omega(J) = \frac{2J+3}{\Im}, \tag{4}$$

from where one can derive a simple expression for the moment of inertia:

$$\Im = \frac{4J+6}{E(J+2) - E(J)}. \tag{5}$$

1. Result and Discussion

Figure 1 shows the comparison of calculated energy of g-, γ-, and β-band with the experimental values and IBM-2 data.

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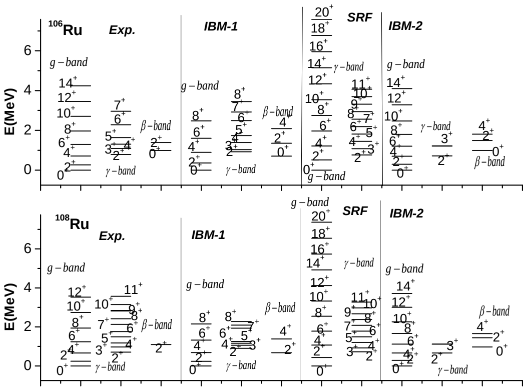

FIG. 1: Results of experimental, IBM-1, soft rotor model (SRF) and IBM-2 [6] of ground, quasi-beta and quasi-gamma band for $^{106-108}$Ru isotopes.

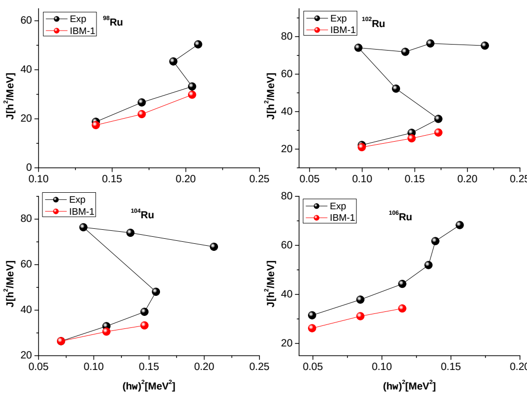

FIG. 2: Back bending in $^{98,102-106}$Ru isotopes.

In $^{106-108}$Ru nuclei the $R_{4/2}$=2.6, 2.7 respectively. Hence structure seems to be varying from γ-soft to the X(5) critical point. The experimental and calculated values show good agreement with each other except γ-band in ^{108}Ru nuclei. In Figure 2, the back bending plot has been shown for even-even $^{98-106}$Ru nuclei. The back bending plot is a graph in which moment of inertia versus $(\hbar\omega)^2$ is plotted. The IBM-1 , IBM-2 results and experimental data are usually compared in terms of these plots. The back bending is associated with the breaking of the first neutron $(h_{11/2})^2$ pair.

Conclusion

The shape transition predicted by this study is consistent with the spectroscopic data for these nuclei. $^{102-108}$Ru are the typical examples of the isotopes that exhibit a smooth phase transition from vibrational nuclei to the γ-soft nuclei. The predictions show that $^{102-108}$Ru isotopes are lined up along the SU(5)-O(6) side of the IBM triangle. The bending for Ru isotopes is observed at angular momentum 12^+.

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