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 $\gamma$-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

$$H = \epsilon n_d + a_0 P^1.P + a_1 L.L + a_2 Q.Q + a_3 T_3.T_3 + a_4 T_4.T_4$$

The energy eigenvalues for three chains are as

$$E^{(I)}(N, n_d, \nu, n_\Delta, L) = \epsilon n_d + \alpha \frac{1}{2} n_d(n_d - 1) + \beta \nu(n_d + 3 - \nu) + \gamma L(L + 1) - 6n_d$$

$$E^{(II)}(N, \lambda, \mu, L) = \left(\frac{3}{4} \kappa - \kappa'\right) L(L + 1) - \kappa[\lambda^2 + \mu^2 + \lambda\mu + 3(\lambda + \mu)]$$

$$E^{(III)}(N, \sigma, \tau, n_\Delta, L) = A \frac{1}{4}(N - \sigma)(N + \sigma + 4) + B \frac{1}{6} \tau(\tau + 3) + CL(L + 1)$$

A. Soft Rotor Formula (SRF)

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

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

The values of $\alpha$ and $\beta$ are calculated by fitting $2^+_2$, $4^+_4$ energies in even sequence and $3^+_3$, $5^+_5$ 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

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

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

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

The discrete derivative of this expression yields

$$h\omega(J) = \frac{2J + 3}{3},$$

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

$$\mathfrak{I} = \frac{4J + 6}{E(J + 2) - E(J)}.$$}

1. Result and Discussion

Figure 1 shows the comparison of calculated energy of g-, $\gamma$-, and $\beta$-band with the experimental values and IBM-2 data.
In $^{106-108}$Ru nuclei the $R_{4/2}=2.6, 2.7$ respectively. Hence structure seems to be varying from $\gamma$-soft to the X(5) critical point. The experimental and calculated values show good agreement with each other except $\gamma$-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 $(h\omega)^2$ 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 $\gamma$-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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References