Backbending in high Spin States of ^{80}Kr

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Introduction

The study of high-spin states in Kr isotopes near A = 80 region has attracted a considerable interest in recent years. A variety of shapes, shape coexistence as well as backbending phenomenon have been studied in the many of Kr isotopes [1] - [5]. Recently in 2010, Shape mixing dynamics in the low-lying states of proton-rich ^{72,74,76}Kr isotopes has been studied by Koichi Satoa and Nobuo Hinoharab using collective Hamiltonian, which is derived microscopically by means of the CHFB (constrained Hartree-Fock-Bogoliubov) + Local QRPA (quasiparticle random phase approximation) method [2]. Using cranked shell model and shell correction method with the Woods-Saxon average field and pairing term, Gross et al. [3] already concluded that the first backbending in the ^{78}Kr yrast line is due to the alignment of a pair of $g_{9/2}$ protons, while the second irregularity is interpreted in terms of the $g_{9/2}$ neutron alignment with the change in $\gamma = 15$ to $\gamma = -30$. In the case of ^{80}Kr, the high spin structure has been studied by Doring et al. [1] rather extensively and has provided considerable insight into the structure of f-p-g shell nuclei and the competition between single-particle and collective degrees of freedom. Backbending phenomenon is reported in ^{80}Kr at $\omega = 0.5$ MeV.

Encouraged by the above studies on Kr isotopes near A = 80 region, we would like to investigate backbending phenomenon in ^{80}Kr at high spins using our cranked Hartree-Fock-Bogoliubov (CHFB) theory employing a pairing + quadrupole + hexadecapole model interaction [4–6].

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Theoretical Formulation and Model

We employ a quadrupole-plus-hexadecapole-plus-pairing model interaction hamiltonian,

$$H = H_0 - \frac{1}{2}\sum_{\lambda=2,4}\chi_\lambda \sum_\mu \hat{Q}_{\lambda\mu}(-1)^\mu \hat{Q}_{\lambda-\mu} - \frac{1}{4}\sum_{\tau=p,n} G_\tau \hat{P}^\dagger_\tau \hat{P}_\tau \ , \quad (1)$$

where, H_0 stands for the one-body spherical part, χ_λ term represents the quadrupole and hexadecapole parts with λ = 2, 4 and the G_τ term represents the proton and neutron monopole pairing interaction. Explicitly we have

$$\hat{Q}_{\lambda\mu} = (\frac{r^2}{b^2})Y_{\lambda\mu}(\theta,\phi) \, , \quad (2)$$

$$\hat{P}^\dagger_\tau = \sum_{\alpha_\tau,\bar{\alpha_\tau}} c^\dagger_{\alpha_\tau} c^\dagger_{\bar{\alpha_\tau}} \ . \quad (3)$$

In the above $c^\dagger$ are the creation operators with $\alpha \equiv (n_\alpha l_\alpha j_\alpha m_\alpha)$ as the spherical basis states quantum numbers with $\bar{\alpha}$ denoting the conjugate time-reversed orbital. The standard mean field CHFB equations [7] are solved self-consistently for the quadrupole, hexadecapole and pairing gap parameters. The deformation parameters, and pairing gaps are defined in terms of the following expectation values:

$$D_{2\mu} = \chi_2 < \hat{Q}_{2\mu} >, \ D_{4\mu} = \chi_4 < \hat{Q}_{4\mu} > \quad (4)$$

$$\hbar\omega\beta\cos\gamma = D_{20} \ , \hbar\omega\beta\sin\gamma = \sqrt{2}D_{22} \ , \hbar\omega\beta_{40} = D_{40} \ ,$$

$$\Delta_\tau = \frac{1}{2}G_\tau < \hat{P}_\tau > \ . \quad (5)$$

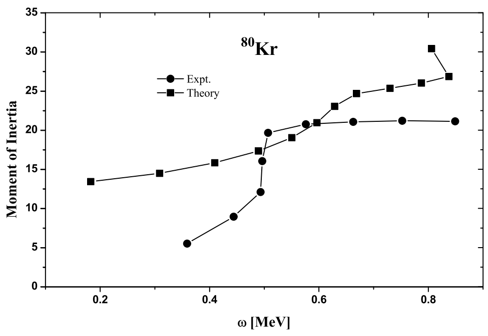

FIG. 1: variation of moment of inertia as a function of rotational frequency in ^{80}Kr.

The oscillator frequency $\hbar\omega = 41.0A^{-1/3}$ (MeV), and β, γ and β_{40} are the usual deformation parameters, while Δ_p and Δ_n are the pairing gap parameters for protons and neutrons, respectively.

Results and Discussions

In order to demonstrate the change in structure as a function of angular momentum, we display a plot of moment of inertia I as a function of rotational frequency ω in the Fig. 1. It is clear from the Fig. 1 that experimental results exhibit upbends at J = 8, at frequency $\omega = 0.5$ MeV like a sharp discontinuity at a point. In the theoretical curve this small sudden jump is smoothed out, but it does exhibit the gross features similar to the measurements.

It is here worth to point out that a conclusion has been drawn already in Ref [8, 9] that in ^{80}Kr at spins J = 8 and J = 10, the positive-parity ground-state band is crossed by an aligned two-quasiparticle $g_{9/2}$ proton band. Doring et al. [1] showed that the ground-state positive-parity band is crossed by a two-quasiproton (2qp) band at a rotational frequency $\omega = 0.5$ MeV and becomes yrast above the 8+ state. Verma et al. [10] also concluded recently that observed backbendings in ^{80}Kr around spins J = 8 is reproduced around spins J = 6, with the result indicating the crossing of both oblate and prolate $g_{9/2}$ 2-qp bands.

Our results (shown in Fig. 1), however do not show very sharp backbendings but the results are very much close to experimental results specially in the region of interest at J = 8, 10, 12 and 14 correspond to moment of inertia I = 15 - 20. A very sharp backbending can be seen though at a very high spin.

Acknowledgments

Authors would like to thank Prof. H. L. Yadav and Prof. A. Ansari for their unconditional support and guidance.

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