Study of K-Isomers in Hafnium Nuclei

B.B. Sahu[1],* Z. Naik[2], S. K. Ghorui[3], and C.R. Praharaj[4]
[1]*Kalinga Institute of Industrial Technology (KIIT) University, Bhubaneswar-751 024, INDIA*
[2]*School of Physics, Sambalpur University, Jyotivihar, Sambalpur-768 019, INDIA*
[3]*Dept. of Physics, IIT Ropar, Rupnagar 140001, INDIA and*
[4]*Institute of Physics, Sachivalaya Marg, Bhubaneswar-751 005, INDIA*

Introduction

The Hf nuclei are known for K isomers occuring at low excitation energies. A number of strongly deformed bands have been observed in ^{170}Hf [1], ^{171,172}Hf [2, 3]. To understand the properties of the ground and K isomeric bands of Hafnium and other nuclei one needs a theoretical model which takes into account the residual interaction among the nucleons in a large enough valence space and gives the proper deformed single-particle states and the multi-nucleon configurations for these nuclei. To this end, we have adopted in this work the Deformed Hartree-Fock (DHF) model to get the deformed single-particle states and the deformed multi-nucleon configurations. Ground and K-isomeric intrinsic states are constructed, and for each intrinsic state (configuration), states of good angular momenta are obtained by Angular Momentum Projection.

Theoretical Framework

A deformed shape such as one described by slater determinant of deformed orbits $\mid \Phi_K >$ is localized in angle and, by the uncertainty principle, is not a state of good angular momentum (J). Thus $\mid \Phi_K >$ does not have a unique J quantum number and is a superposition of various J states [4–7],

$$\mid \Phi_K >= \sum_I C_{IK} \mid \Psi_{IK} > . \quad (1)$$

*Electronic address: bbsnou@gmail.com

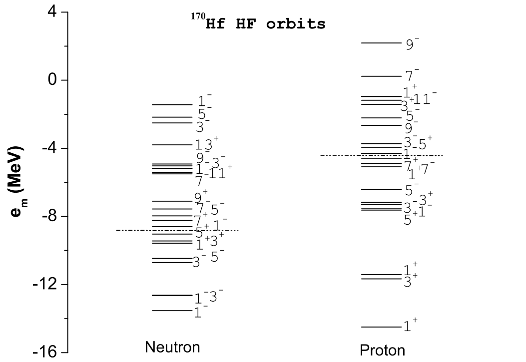

FIG. 1: Deformed HF orbits of ^{170}Hf.

One needs to project out states of good angular momenta from the intrinsic state Φ_K with the Angular Momentum Projection operator,

$$P_K^{IM} = \frac{2I+1}{8\pi^2} \int d\Omega D_{MK}^{I}{}^*(\Omega) R(\Omega). \quad (2)$$

Results and Discussion

The deformed HF orbits are calculated with a spherical core of ^{132}Sn, the model space spans the 2s$_{1/2}$, 1d$_{3/2}$, 1d$_{5/2}$, 0g$_{7/2}$, 0h$_{9/2}$ and 0h$_{11/2}$ orbits for protons and the 2p$_{1/2}$, 2p$_{3/2}$, 1f$_{5/2}$, 1$_{f7/2}$, 0h$_{9/2}$ and 0i$_{13/2}$ orbits for neutrons respectively. We use surface delta interaction [9] as the residual interaction among the active nucleons to obtain deformed single particle orbits. The calculated results are presented in Fig. 1.

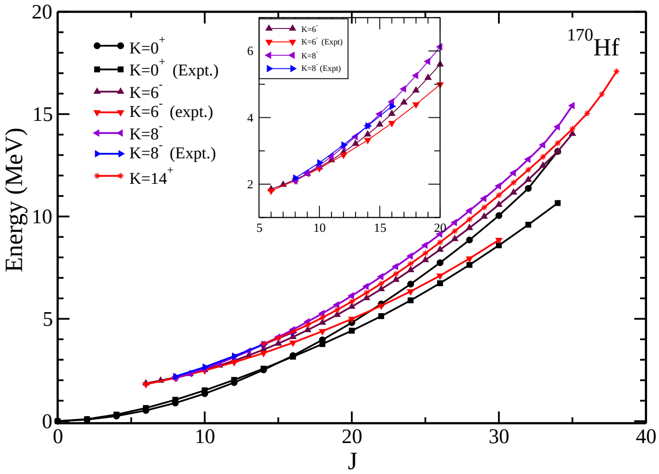

FIG. 2: Energy spectra of ^{170}Hf. Experimental values are taken from Ref. [8]

Conclusions

We use the deformed HF and angular momentum projection technique to obtain energy spectra of ground and excited large K-bands of ^{170}Hf. The spectra for the various bands are obtained by angular momentum projection are presented in Fig. 2. The experimental ground band is fairly well explained in our calculation. The K=8$^-$ band coming from proton excitation across the fermi surface ($7/2^+9/2^-$ occupation) is also shown. This band is satisfactorily explained in our calculation compared to experiment. The variation of energy with J of this band matches quite well with the corresponding variation of energy with J of the experimental $K = 8^-$band. We have also studied the K-isomers of neighboring Hf nuclei, their energy spectra and electromagnetic properties [10].

Acknowledgments

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