Shape evolution in $^{162}_{72}$Hf with spin

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Introduction

The nuclear shapes and deformations have drawn much the attention of nuclear physicists. To a certain extent, the highly complicated nature itself enhances the enthusiasm of those who work in this area. No single theory can describe the nuclear structure and properties completely, since the knowledge about the forces which shape the nucleus is very limited. The repulsive Coulomb force between protons, the short ranged attractive nuclear force between nucleons, the shell effects and pairing correlation have their own roles in deciding the shape and deformation of nuclei. The atomic nuclei exhibit spherical, quadrupole and higher order multipole deformed shapes, eventhough the quadrupole deformed shapes are mostly discussed. Due to the interplay between single particle and collective degrees of freedom, the coexistence of different shapes at the same spin and similar energies is also not rare [1],[2],[3],[4]. With the developments in the advanced gamma ray specroscopy, the high spin study of nuclei became one of the most interesting topics in nuclear physics.

Theretical formalism

The nuclear shape and deformation are characterized by two collective parameters, the deformation parameter β or ε and the triaxiality γ. Stable deformed nuclei with $\beta_2 < 0.3$ are commonly found in the rare earth region [5], [6]. These nuclei form a rich source for the study of phenomena such as shape changes, shape coexistence etc. The yrast states of ^{162}Hf in the range of spin 0-60 and thereby the shape evolution with respect to spin are discussed in this paper, exploring cranked Nilsson Strutinsky shell correction method [7] and Potential energy Surface (PES) diagrams. The rotational spectrum of a nucleus is represented by [8]:

$$E_I = \frac{\hbar^2}{2\jmath} I(I+1) \quad (1)$$

where $\jmath$ is the moment of inertia and I is the total spin.

We have performed the total energy calculations for ^{162}Hf in the spin range 0-60 in steps of 10 units. The range of triaxiality parameter used is 0-60^o and a frequency range of 0-1.5 MeV is employed. The quadrupole deformation parameter ε_2 is varied from 0 to 0.8.

Discussion of the results

The PES diagrams of ^{162}Hf for a spin range of 0-60 are drawn and three typical cases are illustrated in Fig. 1, which clearly show the shape evolution. The quadrupole deformations and shapes corresponding to the equilibrium states at different spins are identified and tabulated in Table 1.

At spin 0, there is the coexistence of a prolate minimum with $\varepsilon_2 = 0.182$ and a triaxial minimum with $\varepsilon_2 = 0.191$. At spin 10 also, the same competition between prolate and triaxial minima is seen. But at spin 20-30, only prolate minima and at spin 40-50 only triaxial minima are predicted. The nucleus is shifted towards an oblate yrast with $\varepsilon_2 = 0.203$, as the spin approaches 60. Since the nuclear rotation modifies the microscopic structure of deformed nuclei, the equilibrium shape of nuclei will change with spin [2]. Hence the shape transition in nuclei with respect to spin is not surprising.

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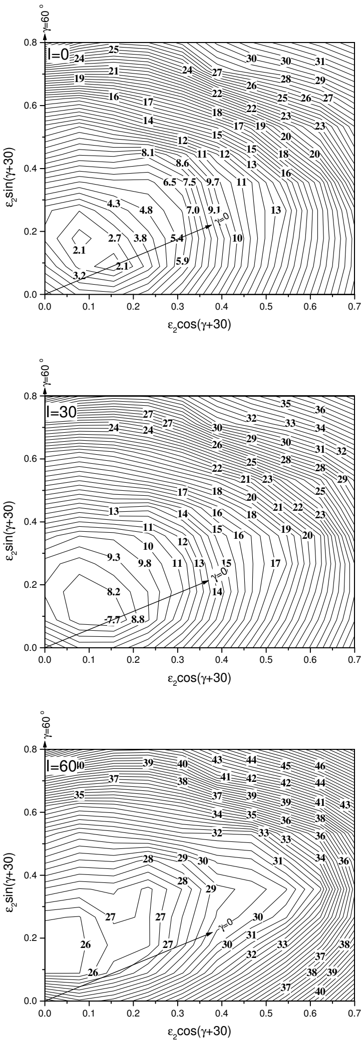

FIG. 1: PES diagrams of ${}^{162}_{72}$Hf nucleus for spins 0, 30 and 60.

In summary, ^{162}Hf is a suitable candidate for the high spin study. The nuclear equilibrium shapes and deformations are highly spin dependent. A reduction in quadrupole deformation ε_2 is observed with spin. Though ^{162}Hf is having stable prolate and triaxial yrasts in the ground state, it migrates towards stable oblate shape through a triaxial plane, as the spin rises to high values.

TABLE I: The computed equilibrium qudrupole deformations and shapes of ${}^{162}_{72}$Hf nucleus at different spins.

Spin	Equilibrium ε_2	Equilibrium shape
0	0.182	prolate
	0.191	Triaxial
10	0.178	prolate
	0.190	Triaxial
20	0.173	prolate
30	0.162	prolate
40	0.128	Triaxial
50	0.114	Triaxial
60	-0.203	Oblate

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