Hyperdeformation Through Jacobian Instability In Excited Krypton Isotopes

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Introduction

The existing possibility of discovering extremely deformed nuclear shapes with $\approx 3{:}1$ axis ratios has attracted the attention of both theoreticians and experimentalists for a number of years. The first reported experimental data interpreted as evidence for a hyper deformed nuclear shape was the observation by Galindo-Uribarri et al. [1], of a peak at $\Delta E \approx 30keV$. Over the past few decades, a number of theoretical papers have made predictions of which nuclei are good candidates for observing hyperdeformations. Dudek, Werner and Riedinger [2] first predicted that deep hyperdeformed minima $(\beta_2 \approx 1.0)$ would occur at high spin in heavy nuclei. The rotating liquid drop model (RLDM) has already predicted that nuclei should experience a shape transition at very high spins from noncollective oblate to collective prolate (or nearly prolate) with the superdeformed major to minor axes ratio of 2:1 or more. The shape evolution of rotating nuclei ultimately produces the above shape transition called the Jacobi shape transition which is analogous to the Jacobi shape instability occurring in gravitating rotating stars. While the Jacobi shape transition lead to super deformation with the above configurations, that can also lead to another more deformed case with $\beta>0.8$ called as hyperdeformation. Nuclei in the mass region A=70–90 have attracted considerable theoretical and experimental interest in recent years because of a wide variety of nuclear phenomena that occur in this region [3]. In this work, we aim at predicting such hyperdeformed shapes through Jacobi shape transitions in even-even krypton isotopes, ^{74}Kr & ^{76}Kr as a function of spin.

Theoretical Formalism

The cranked Nilsson Strutunsky method is used in the calculations. The total energy E_{TOT} at fixed deformation is calculated using the expression

$$E_{TOT} = E_{LDM} + \sum_{p,n} \delta E + \frac{1}{2}\omega(I_{class} + \sum_{p,n} \delta I)$$

(1)

Here the liquid drop energy E_{LDM} is given by the sum of Coulomb and surface energies corresponding to a triaxially deformed shape defined by the deformation parameters β and γ. The spin $I_{classical}$ is obtained from the rigid-body moment of inertia with surface diffuseness correction. The shell correction (δE) is the difference between the deformation energies evaluated with a descrete single particle spectrum and by smoothening that spectrum $(\delta E = E - \tilde{E})$. Similarly the shell correction corresponding to the spin is given by $(\delta I = I - \tilde{I})$. It is to be stated that pairing is not taken into account in these calculations since Jacobi transition occurs at very high spins where pairing is unimportant.

The calculations are carried out by varying ω values in steps of $0.025\omega_0$ from $\omega = 0.0$ to $\omega = 0.3\omega_0$, ω_0 being the oscillator frequency for tuning to fixed spins. Since we are interested in predicting the Jacobi shape transitions, γ is varied from -180^0 to -120^0 in steps of -10^0, $\gamma=-180^0$ corresponding to noncollective oblate and $\gamma=-120^0$ corresponding to collective prolate. Since the Jacobi transition involves hyperdeformation, β values are varied from 0.0 to 1.2 in steps of 0.1.

Results and Discussion

The constant spin potential energy surfaces are extracted for the even-even krypton isotopes, ^{74}Kr & ^{76}Kr, to study the shape evolution and also to look for the possible Jacobi shape transitions leading to hyper deformations in them. Figures 1&2 show the equilibrium shape evolution of ^{74}Kr and ^{76}Kr isotopes respectively at different spins performed with the tuned spin cranked Nilsson Strutinsky method [4]. We see from Fig.1 that ^{74}Kr is triaxial in its ground state and the shape changes to oblate as spin increases to 4 ħ. As angular momentum increases, the oblate deformation also increases and acquires β=0.4 at I=40 ħ. The Jacobi shape transition takes place from noncollective oblate to hyperdeformed prolate with β=0.9 at an angular momentum I=48 ħ in ^{74}Kr. As angular momentum increases, the ^{76}Kr nucleus (Fig.2) which is originally spherical at I=0, acquires some oblate deformation, corresponding to an elongation upto β=0.4 for I=46 ħ. Beyond 46 ħ, the Jacobi shape transition takes place: the nucleus becomes prolate with β=0.7 at an angular momentum of 48 ħ. It is to be noted from the above discussion that the Jacobian instability is clearly occurring in the considered krypton isotopes at high spin and is found to be a second order phase transition in one case and it is a third order transition in the other case. It can be concluded that, the Jacobian instability is predicted in even-even krypton isotopes which occurs within the spin range 44-48 ħ which leads to hyperdeformed shapes such as β=0.9 for ^{74}Kr and β=0.7 for ^{76}Kr.

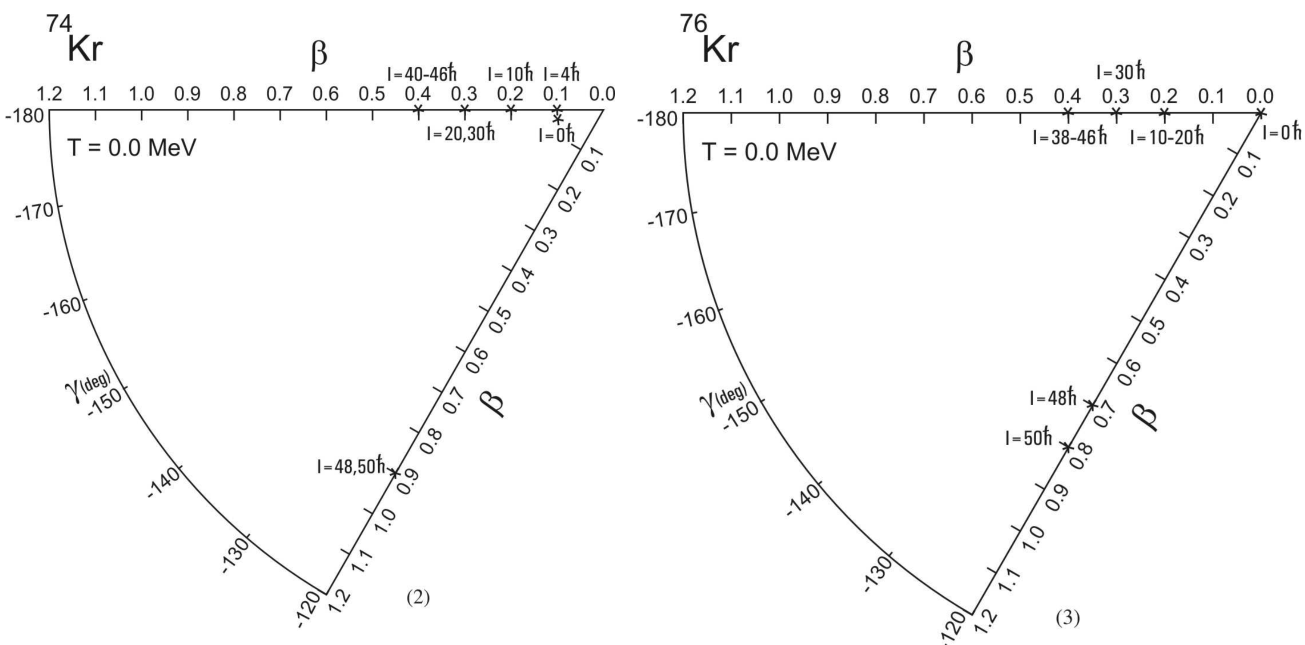

FIG. 1-2. Potential energy maps showingequilibrium shape evolutions for ^{74}Kr and ^{76}Kr

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