Shape Evolutions in Hot Rotating ^{78}Kr Nucleus

V. Selvam [1] and D.R. Jayahar Devadhason [2]

[1]Department of Physics, R.D. Govt. Arts College, Sivagangai-630 561, INDIA.
[2]Department of Physics, Marthandam College of Engineering and Technology, Kanyakumari-629 177, INDIA.

Introduction

The advent of powerful accelerators in recent-times has made it possible to study the behavior of nuclei under extreme conditions of temperature and angular momentum. The properties of hot rotating nuclei are usually studied by observing the particle and γ- decay patterns of the compound nucleus. The major interest of this field is the study of the evolution of nuclear shape with temperature and spin, and in particular the possible shape transitions in them. Hot and rotating nuclei are expected to exhibit a rich variety of different shapes. To study the shapes of hot rotating nuclei, mean field theories such as the microscopic Hartree-Fock Bogoliubov cranking theory [1] and Landau theory [2] have to be used. Appart from these, the more appropriate Mottelson – Nilsson [3] and Nilsson – Strutinsky [4] approaches can also be used for studying hot rotating nuclei. The purpose of this work is to study the shape evolutions in ^{78}Kr nucleus as a function of spin and temperature. In the first phase of this work, the cranked Nilsson Strutinsky method for fixed spins [4] is used to obtain the shape and deformation for the considered nuclei. Then Landau theory of shape transitions is used to study the shape variations due to thermal fluctuations.

Theoretical Framework

For a nucleus with a given temperature and angular momentum, the equilibrium state is the state which minimizes the free energy and is computed using Strutinsky pescription as,

$$F(T,I;\beta,\gamma) = E(T,I;\beta,\gamma) - TS - E_s + E_{RLDM} \quad (1)$$

where E_s is the Strutinsky smoothed energy for extracting shell correction and E_{RLDM} is the rotating liquid drop energy given by

$$E_{RLDM} = E_{LDM} - \frac{1}{2} J_{rig}\,\omega^2 + \hbar\,\omega I_s \quad (2)$$

For finite temperature, one should also consider thermal fluctuations which create shapes different from the most probable shape obtained by minimizing the free energy. According to Landau theory, the free energy as a function of spin and temperature is.,

$$F(T, I; \beta,\gamma) = F(T,I=0;\beta,\gamma) + I^2/[2J_{zz}(\beta,\gamma,T)] \quad (3)$$

where

$$F(T,I=0,\beta,\gamma) = F_o(T) + A(T)\,\beta^2 - B(T)\,\beta^3 \cos 3\gamma + C(T)\,\beta^4 \quad (4)$$

and

$$J_{zz} = J_o(T) - 2R(T)\,\beta\cos\gamma + 2J_1(T)\,\beta^2 + 2D(T)\,\beta^2 \sin^2\gamma \quad (5)$$

For a given spin and temperature, the ensemble average of β and γ are,

$$\overline{\beta} = \frac{\int \beta\, P(\beta,\gamma)\, \beta^4 \left|\sin 3\gamma\right| d\beta d\gamma}{\int P(\beta,\gamma)\, \beta^4 \left|\sin 3\gamma\right| d\beta d\gamma} \quad \text{and}$$

$$\overline{\gamma} = \frac{\int \gamma\, P(\beta,\gamma)\, \beta^4 \left|\sin 3\gamma\right| d\beta d\gamma}{\int P(\beta,\gamma)\, \beta^4 \left|\sin 3\gamma\right| d\beta d\gamma} \quad (6)$$

Results and Discussion

The constant spin potential energy surfaces were first generated for ^{78}Kr nucleus using cranked Nilsson Strutinsky method to study the shape evolution and also to look for the possible Jacobi shape transitions in them. We performed calculations taking $\gamma = -120^0$ to -180^0 and $\beta = 0.0$ to 1.2 and spin I = 0 to 60$\hbar$. The resulting free energy surfaces for finite temperature are least square fitted with those of Landau theory to extract the respective Landau constants. Then the averaged values of β and γ are evaluated by using equation (6) to obtain the shape variations with thermal fluctuations.

Figures 1 and 2 show the sample results of shape transitions obtained as a function of spin at temperatures T = 0.0 MeV and T = 1.5 MeV respectively for the case of ^{78}Kr. It is observed that ^{78}Kr nucleus which is spherical at lower values of angular momentum, changes its shape to oblate at I=20 ħ. As spin increases, the deformation also increases and which attains β=0.4 at I=44 ħ. The Jacobi shape transition occurs at a critical spin of 50 ħ in this case with β changing from 0.4 (oblate) to 0.8 (prolate). At high temperature T = 1.5 MeV, with thermal fluctuations the shape becomes triaxial and the deformation increases as a function of spin. The sharp Jacobi type shape transition is also modified due to thermal fluctuations.

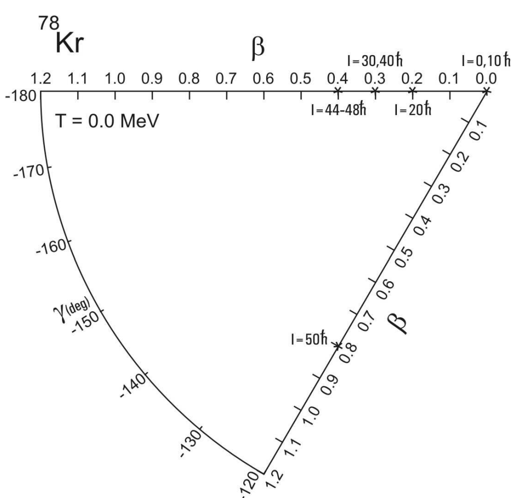

FIG.1: Shape evolutions in ^{78}Kr obtained as a function of spin at temperature T = 0.0 MeV.

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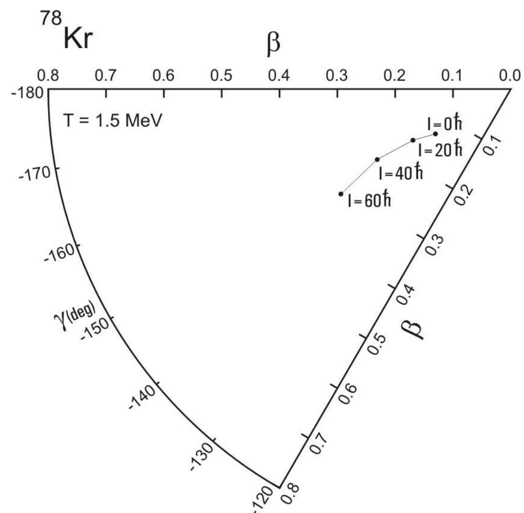

FIG.2: Shape evolutions in ^{78}Kr obtained as a function of spin at temperature T = 1.5 MeV.

References

[1]K.Sugawara Tenabe et al. Nucl. Phys. **A357**, 45(1981)I=44 ħ.
[2]Y.Alhassid et al. Nucl. Phys. **A469**, 205(1987)
[3]G.Shanmugam and M.Thiagasundaram Phys. Rev. **C39**, 1623(1989)
[4]G. Shanmugam and V. Selvam Phys. Rev **C62**, 014302(2000).