Shape Transitions In Hot Rotating ^{154}Nd Nucleus

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Introduction

Heating can have a profound effect on nuclear shapes, causing a variety of shape transitions. The possibility of heating the nucleus to a finite temperature opens a new direction in the study of nuclear structure. The major interest in this field is the study of evolution of nuclear shape under extreme conditions of spin and temperature. In recent times, a unified framework based on the Landau theory of phase transitions has been applied to explain the universal features of the nuclear shape transitions [1]. Due to finite number of degrees of freedom, it is necessary to include thermal shape fluctuations in order to obtain good fits to experimental observables, such as GDR built on hot nuclei. The Landau theory offers a natural framework in which these thermal fluctuations are introduced.

The quality of Landau theory applied to transitional nuclei when the free energy is expanded up to fourth power of β is not good for lower temperatures and higher spins. Hence in heavy nuclei at medium temperatures ($T \leq 1.5$MeV), it is necessary to extend the Landau free energy up to sixth order of β [2-4]. We have applied this extended form of Landau theory to study the shape evolutions of hot rotating transitional nuclei, especially for the various isotopes of Neodymium. In order to obtain the constants involved in the non–rotating component of the free energy expansion, the potential energy surface obtained by the Strutinsky procedure is used. The temperature and spin dependent moment of inertia is used, which is important in transitional nuclei and the Landau constants are extracted by fitting procedure.

Theoretical Framework

According to the extended Landau model [5] the free energy at any spin I can be expanded to the sixth order in β as follows:

$$F(T, \beta, \gamma) = F_0 + F_2 \beta^2 + F_3 \beta^3 \cos 3\gamma + F_4 \beta^4 + F_5 \beta^5 \cos 3\gamma + F_6^{(1)} \beta^6 + F_6^{(2)} \beta^6 \cos^2 3\gamma + \ldots \quad (1)$$

Here F_0, F_2,… are temperature dependent Landau parameters. These expansion coefficients are determined by least square fit to the Strutinsky calculation results in the Neodymium isotopes. Then the angular momentum is brought in within the cranking approach. The free energy for fixed spin is given by

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

where, the temperature dependent moment of nertia with respect to the body fixed z- axis is given by

$$J_{zz}(T, \beta,\gamma) = J_0 + J_1 \beta \cos\gamma + J_2^{(1)} \beta^2 + J_2^{(3)} \beta^2 \sin^2\gamma + J_3^{(1)} \beta^3 \cos 3\gamma + J_3^{(2)} \beta^3 \cos\gamma + J_4^{(1)} \beta^4 + J_4^{(2)} \beta^4 \cos 3\gamma \cos\gamma + J_4^{(3)} \beta^4 \sin^2\gamma + \ldots \quad (3)$$

The parameters J_0,J_1…… are also determined by a fitting procedure. For a given spin and temperature, the ensemble average of β and γ gives the averaged β and γ.

In the calculations performed here the spin is varied from I = 0 ħ to 60 ħ, temperature is varied from 0.25 to 1.5 MeV in steps of 0.25 MeV and γ is varied from -120^0 to -180^0 in steps of -10^0. In order to look for near oblate and near prolate shapes, γ in steps of -2 degrees are carried out in the region -120^0 to -130^0 and -170^0 to -180^0.

Results and Discussion

The results obtained for example in the case of ^{154}Nd for the two temperatures T=0.25 MeV and 0.5 MeV are shown in figures (i) and (ii).

It is seen from the figures that at low temperature T=0.25MeV a normal shape transition from nearly prolate to nearly oblate and then to triaxial as a function of spin is obtained as shown in fig. (i). But at temperature T=0.5 MeV, there is a shape transition from normal deformed nearly oblate to superdeformed nearly prolate shape via triaxial at spin I = 60 ħ as shown in fig. (ii). It is important to note that the expansion of Landau free energy in Landau theory of shape transitions is sufficient for obtaining superdeformed configuration in transitional nuclei at normal temperatures.

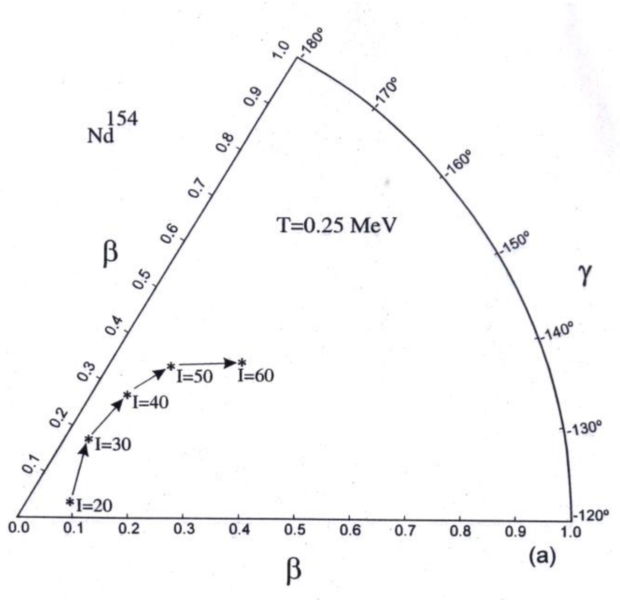

Fig. (i)

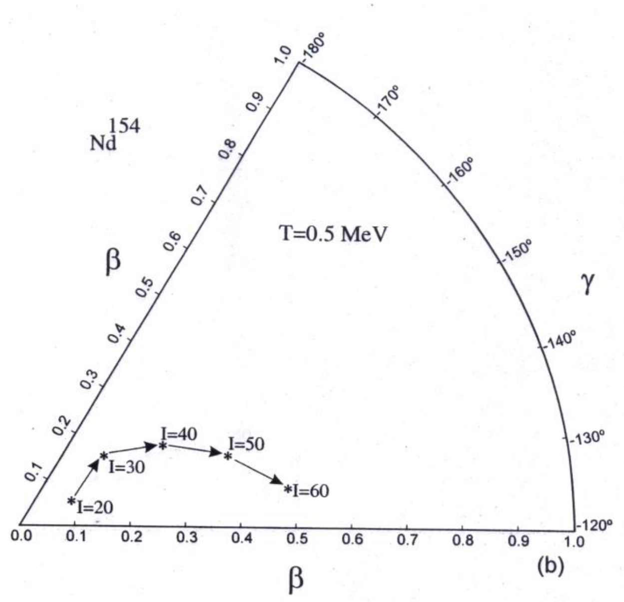

Fig. (ii)

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