Role of Fluctuations in the Structural Transitions of Hot Rotating Transitional Nucleus

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Introduction

It is now well established fact that giant dipole resonance from excited nuclei is a very useful probe to study the dynamics of hot rotating nucleus [1]. Hot and rotating nuclei are expected to exhibit a rich variety of different shapes. At excitation energies close to the Yrast line the shapes are determined by the shell structure. At higher temperature the finite occupation probability of orbitals above and below Fermi surface at which the shell effects should be weakened can be estimated to approximately $T = 1.5 - 2MeV$ from the expected degrees of shell energies as a function of temperature. Once shell effects are gone nuclei are expected to follow the shapes predicted for a charged liquid drop [2]. At very high angular momentum, nuclei should develop large prolate deformations prior to fission. Growing experimental information is presently becoming available on the shapes and properties of highly excited nuclei, formed in heavy ion reactions. To perform such a study of hot rotating nuclei mean-field theories such as the finite temperature cranked Strutinsky calculations were being used.

Role of Fluctuations

The main theoretical methods used to describe hot nuclei are taken from statistical mechanics. The Landau theory [3] offers a natural frame work in which these 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 ≤ 1.5MeV), it is necessary to extend the Landau free energy up to sixth order of β [4-5]. 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 formulation

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

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

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 ^{150}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 triaxial shape 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.

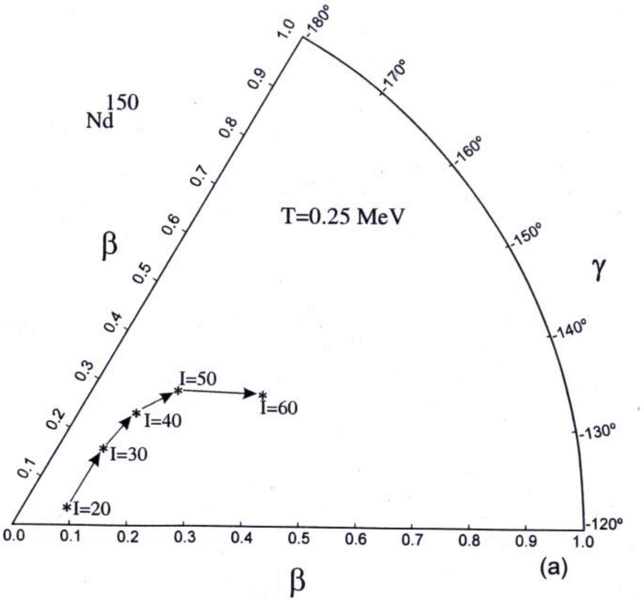

Fig. (i)

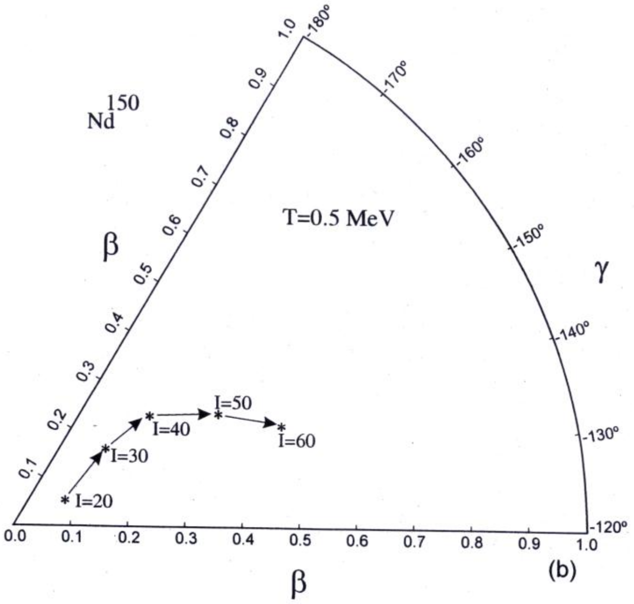

Fig. (ii)

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