Shape Evolutions in Hot Rotating Transitional Nuclei

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Introduction

The study of structural transitions of nuclei at high excitation energy and large angular momentum has led us to a new phase in nuclear structure physics. The experimental analysis of giant dipole resonance (GDR) built on excited states have started to yield information about the shape transitions that takes place in such nuclei. This is also well known now that GDR cross section curves are not that clear as we expect in rotating nuclei, because in hot rotating nuclei, thermal fluctuations may make the GDR curves a little complicated to interpret. Due to the 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 the giant dipole resonance built on hot nuclei. The Landau theory [1] offers a natural frame work in which these fluctuations are introduced.

In the earlier calculations, the Landau theory in limited form with expansion of the free energy upto fourth power of β has been used for the study of shape transitions in hot rotating light and medium mass nuclei [2,3]. In those calculations, one is satisfied with taking the moment of inertia of such hot rotating system as a rigid body one which is obviously an approximation. Also, the quality of Landau theory applied to transitional nuclei when the free energy is expanded up to fourth power of β is not as good for lower temperatures and higher spins [4]. Hence in heavy nuclei, at medium temperatures ($T \leq 1.5$ MeV), it is necessary to extend the Landau free energy upto sixth order of β and temperature and spin dependent moment of inertia must be used in the calculations. We have applied this extended form of Landau theory to study the shape evolutions of hot rotating transitional nuclei, especially for the isotope of Neodymium such as ^{142}Nd.

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 inertia with respect to the body fixed z- axis is given by

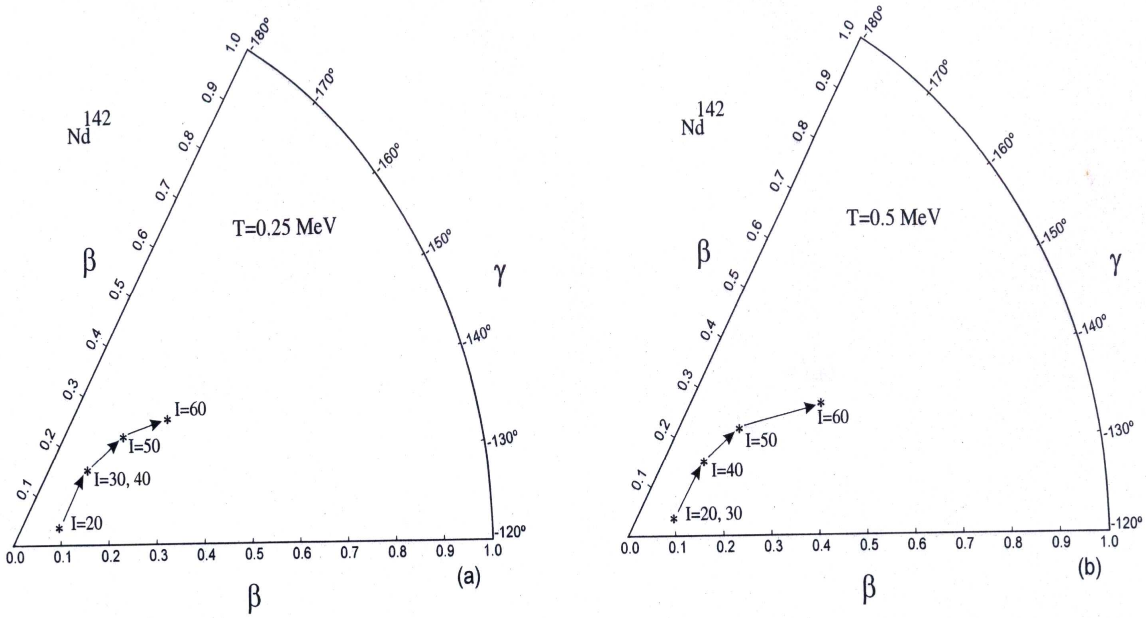
$$J_{zz}(T, \beta,\gamma) = J_0 + J_1 \beta \cos\gamma + J_2^{(1)} \beta^2 + J_2^{(3)} \beta^2 \sin^2\gamma + J_3^{(1)} \beta^3 \cos 3\gamma + J_3^{(2)} \beta^3 \cos\gamma + J_4^{(1)} \beta^4 + J_4^{(2)} \beta^4 \cos 3\gamma \cos\gamma + J_4^{(3)} \beta^4 \sin^2\gamma + \ldots \quad (3)$$

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.

Results and Discussion

In the present work we have made an attempt to study the shape evolutions of hot rotating Neodymium isotopes using the extended Landau model with thermal fluctuations. The Landau constants are evaluated by least square fitting with the free energy surfaces obtained by the finite temperature version of the cranked Nilsson Strutinsky method. The sample results of shape transitions obtained as a function of spin at various temperatures with thermal fluctuations using the extended Landau model for the cases of ^{142}Nd are shown in figures 1(a&b) at temperatures 0.25 & 0.5 respectively. It is noted from fig. 1(a) that at T = 0.25 MeV, the nuclei undergo a shape transition from nearly prolate to nearly oblate as a function of spin and then to more triaxial at higher spins. In the transition, the deformation increases with spin. Almost the same trend, but increased deformations are obtained as a function of spin at temperature 0.5 MeV for the same nuclei. It is also noted from these figures that, the sharp shape transitions are washed out due to thermal fluctuations. This proves the fact that averaging by all possible shapes always turns to triaxial. Almost the same trend is obtained for the other temperatures of ^{142}Nd (not shown).



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