High spin states of ^{84}Zr – Yrast and non-yrast high temperature states

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Introduction

High spin states of the cold and hot rotating nucleus ^{84}Zr are studied and the phenomena of shape coexistence and the shape phase transitions are searched by employing the Cranked Hartree-Fock-Bogoliubov (CHFB) theory using a pairing + quadrupole + hexadecapole model interaction for the yrast states and the statistical theory (ST) of hot rotating nuclei for high temperature high spin states. Nuclear structure of the high-spin states in the mass region A = 80 possesses many interesting features like shape coexistence, structural softness, strong dependence on spin and particle numbers, magnetic rotation and the quasiparticle alignment (QPA) in the $0g_{9/2}$ state [1]. The nuclei around N ≈ Z = 40 are the waiting point nuclei for rp-process [2] and the study in this proton rich region around A=80 has been motivated by some extensive measurements [1]. The structure of ^{84}Zr has been studied using in-beam γ-ray spectroscopy [3] and multiple superdeformed bands in ^{83,84}Zr have been studied [4] and three discrete transitions are observed between the yrast superdeformed band and states of normal deformation in ^{84}Zr [5].The intrinsic shape of a nucleus is greatly altered when the temperature degree of freedom is included which induces a shape transition usually towards sphericity at a critical temperature for nonrotating nuclei whereas for the rotating systems the shape changes to oblate noncollective (n-c) with some exceptions to prolate n-c as seen in some of our earlier works [6]. Study of the shape transitions due to rotation and temperature in highly deformed Zr region is the objective of present work.

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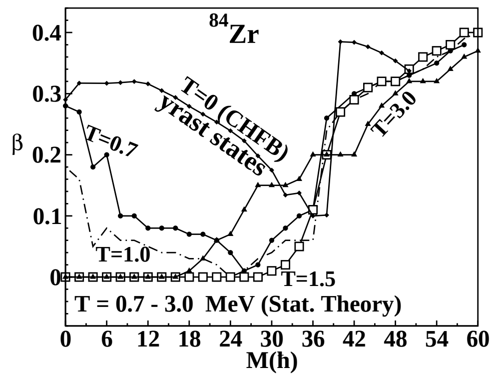

FIG. 1: Equilibrium deformation β vs angular momentum M($\hbar$) at T=0 (CHFB) and T = 0.7 to 3 MeV (Statistical theory).

Brief description of work

We use a quadrupole-plus-hexadecapole-plus-pairing model interaction hamiltonian [7, 8] for evaluating yrast states of ^{84}Zr. The temperature degree of freedom has been incorporated to a rotating nucleus by using the Statistical theory of [6] hot rotating nuclei. We compute excitation energy and entropy at temperatures (T) =0.7 to 3.0 MeV and angular momentum (M)=0 to 60$\hbar$. We minimize the free energy $F = E - TS$ for Nilsson deformation parameters β and γ which give deformation and shape of the excited nuclei.

Results and Discussion

Spin dependence of deformation for the yrast states (T=0 MeV) studied using CHFB theory are shown in Fig. 1, where the deformation parameter $\beta = 0.3$ at low angular momentum values. High spin states at high

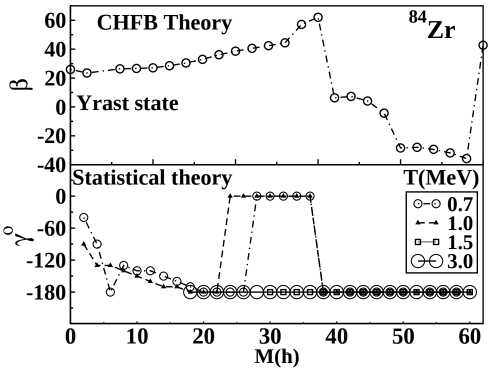

FIG. 2: shape parameter γ vs angular momentum M(h$\hbar$) for yrast states at T=0 (CHFB) and non-yrast states at T = 0.7 to 3 MeV (Statistical theory) γ convention used in both theories are different.

temperature investigated using the Staistical theory are also plotted in Fig. 1 where β decreases with increasing T but attains much higher values at high spin states at T around 3 MeV. The shapes of the nucleus at T=0 (using CHFB) and T=0.7 to 3 MeV (ST) are shown in Fig. 2. It may be noted that the triaxiality predominates in yrast (in agreement with [**?**]) and nearly yrast (low temperature) regions at low spins with transition to elongated shapes at mid spin values 30-38 $\hbar$ and to highly deformed oblate shapes at higher spins. A strong backbending effect is seen in between 30-40 $\hbar$. Both the theories predict a strong shape change at spin $> 36\ \hbar$. ^{84}Zr is well deformed at zero and low T and low spin values with a sharp shape transition to highly deformed shapes at high spin states in agreement with prediction of superdeformed states at high spin [**?**]. But the most important observation is to note that at high spin states, the highly deformed nucleus ^{84}Zr remains highly deformed even with the increasing temperature upto T = 3 MeV. This makes it a very promising candidate for GDR studies.

Conclusion

The yrast and non-yrast states of ^{84}Zr are studied using CHFB theory and statistical theory respectively. At low and mid spin values, triaxiallity dominates with shape change to prolate to oblate at high spin states. CHFB predicts band crossing in mid spin region. High spin states of ^{84}Zr for spin value $> 36\ \hbar$ are highly deformed even at high T$\approx$ 3 MeV that makes it a very promising candidates for GDR studies.

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