Study of shape transitions and GDR width of ^{88}Mo at high temperature and spin

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Introduction

The studies of nuclear properties at finite temperature (T) and angular momentum (I) continue to be both challenging and exciting area of research for last few decades. Giant dipole resonance (GDR) is to be a powerful tool to investgate the nuclear structure at finite T and I. Different formalisms are being used for the nuclear deformation energy calculations. These models can be broadly classified into two categories: (i) the microscopic approaches like relativistic mean-field (RMF) models [1], Hartree-Fock-Bogoliubov with Skyrme [2] or Gogny forces, etc., and (ii) microscopic-macroscopic models [3]. The RMF models are recently extended [4] to rotational excitations and the Skyrme Hartree-Fock-Bogoliubov models are extended to deal independently the rotational and thermal excitations. Hence, so far the models based on microscopic approach, have not evolved to deal simultaneously with deformations, rotational and thermal excitations. Most of these models are capable of explaining several microscopic properties but may not yield precise binding energies. Models based on microscopic-macroscopic approach are regarded well for reproducing the measured binding energies with least error. In our perspective, these models are reliable and it is relatively easier to extend these models for deformed hot and rotating nuclei. In the following text, we outline the essential fundamentals regarding the microscopic-macroscopic approach as utilized in our theoretical framework.

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Theoretical framework

It is well known [3] that the total energy of a nucleus can be written as the sum of the liquid drop model (LDM) energy comprising the macroscopic properties and the fluctuating microscopic part representing the strength of the quantum effects through a deformed shell model. We have employed the formalism based on such a microscopic-macroscopic method to study the shape transitions occurring at high T and I and the variation of GDR width (Γ) in ^{88}Mo. The free energies ($F_{\rm TOT}$) of a nucleus with a fixed deformations at finite T [5, 6] is written as

$$F_{\rm TOT} = E_{\rm RLDM} + \sum_{p,n} \delta F \ .$$

By expanding the rotating liquid drop model energy ($E_{\rm RLDM}$) and the shell correction (δF), we get

$$F_{\rm TOT} = E_{\rm LDM} + \sum_{p,n} \delta F^{\omega} + \frac{1}{2}\omega(I_{\rm TOT} + \sum_{p,n} \delta I) \ .$$

$E_{\rm LDM}$ is the liquid-drop energy corresponding to a triaxially deformed nucleus. δF^{ω} and δI are the shell corrections corresponding to the free energies and spin obtained with exact temperature and spin dependence. ω is the angular velocity tuned to obtain the desired spin given by

$$I_{\rm TOT} = \Im_{rig}\omega + \delta I \ ,$$

and $\Im_{rig}$ is the rigid-body moment of inertia. The single-particle energies and spin projections are obtained by diagonalizing the triaxial Nilsson Hamiltonian in the cylindrical basis.

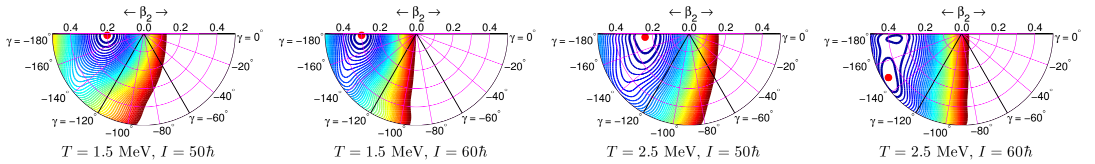

FIG. 1: The free energy surfaces of the nucleus ^{88}Mo at different temperatures (T) and angular momenta (I). The contour line spacing is 0.2 MeV. The equilibrium shape is represented by a filled circle and the first two minima are shown with two thick lines.

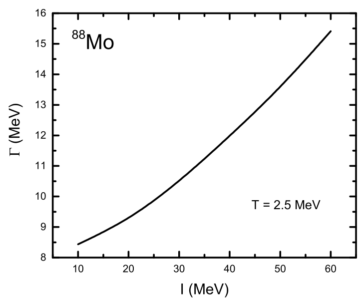

FIG. 2: The GDR width (Γ) of ^{88}Mo obtained with thermal shape fluctuation model is plotted as a function of spin (I) at temperature T = 2.5 MeV.

Results

We have studied the shape transitions occurring in ^{88}Mo nucleus at finite T and I and it's effect on GDR observables [7]. The free energy surfaces (FES) of the nucleus ^{88}Mo are presented in figure 1. At T = 1.5 MeV and $I = 50\hbar$, the FES shows a crisp minimum with the most probable shape at $\beta = 0.2$ and $\gamma = -180°$. As the I increases from 50 to 60$\hbar$, the most probable shape moves to $\beta = 0.3$ and $\gamma = -180°$. But there is no drastic change in the shape of the nucleus at this T. Here the nucleus shows a non-collective oblate shape at both the T and I combinations.

At T = 2.5 MeV and $I = 50\hbar$, the FES shows a gamma-soft ness with the most probable shape at $\beta = 0.25$ and $\gamma \sim -180°$. As the I increases from 50 to 60$\hbar$, the most probable shape changes to $\beta \sim 0.45$ and $\gamma = -150°$. The shape of the nucleus changes from its non-collective oblate to triaxial or near collective prolate shape. This kind of transitions are commonly known as Jacobi shape transitions. At higher T, the role of thermal shape fluctuations are very important in determining the Γ.

In Fig. 2, we present the Γ of ^{88}Mo as a function of I. There is a sharp increase in the Γ at higher I values. This sharp increase in the Γ can be attributed to the large nuclear deformation and the coriolis splitting of the GDR components occures at high I.

Conclusion

We have studied the role of T and I in determining the nuclear shape and the GDR width in ^{88}Mo nucleus. The role of I is more dominant at higher T values. Our study shows that ^{88}Mo could be a good candidate for the study of Jacobi shape transitions at high T and I values.

References

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