Investigation on kinematic and dynamic moment of inertia for ^{60}Zn

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Introduction

High spin populated nuclear system exhibit phenomena like backbending along with certain changes in moment of inertia [1-2]. As the coriolis force increases at certain angular momentum, nucleon pair breaks and results in shape transition. This alignment of broken pairs along the collective rotational core is connected with sudden increase of angular momentum (I) as a function of rotational frequency probably known as back – bending phenomenon [3]. This phenomenon is also known as band crossing and points to structural changes in the nucleus.

In this present work, rotational energy, kinematic moment of inertia and dynamic moment of inertia and rotational frequency were calculated via statistical theory of hot rotating nuclei and the results are compared with available experimental and other theoretical data.

Formalism

The nucleus can be described in statistical terms by assigning equal probabilities to all nuclear levels of a given internal energy. Statistical descriptions of many-body quantum systems are usually based on unrestricted grand canonical ensemble averages.

The grand canonical partition function for the hot rotating nuclei is given by [4],

$$\ln Q = \sum_i ln[1 + \exp(\alpha_N + \lambda m_i^N - \beta \varepsilon_i^N)] + \sum_i ln[1 + \exp(\alpha_Z + \lambda m_i^Z - \beta \varepsilon_i^Z)] \quad (1)$$

where, the lagrangian multipliers α_Z , α_N and λ conserve the number of protons, neutrons and total angular momentum of the system. The average number of particles, total energy and total angular momentum are projected out of the partition function and are given as,

$$\langle N \rangle = \sum_i \{1 + exp[-(\alpha_N + \lambda m_i^N - \beta \varepsilon_i^N]\}^{-1} \quad (2)$$

$$\langle Z \rangle = \sum_i \{1 + exp[-(\alpha_Z + \lambda m_i^Z - \beta \varepsilon_i^Z]\}^{-1} \quad (3)$$

$$\langle E \rangle = \sum_i \varepsilon_i^N n_i^N + \sum_i \varepsilon_i^Z n_i^Z \quad (4)$$

$$\langle M \rangle = \sum_i m_i^N n_i^N + \sum_i m_i^Z n_i^Z \quad (5)$$

where, n_i^Z and n_i^N are occupational probabilities of the ith shell corresponding to proton and neutron respectively. The entropy (S) is given as,

$$S = \sum_i [n_i^N \ln n_i^N + (1 - n_i^N) \ln(1 - n_i^N)] + \sum_i [n_i^Z \ln n_i^Z + (1 - n_i^Z) \ln(1 - n_i^Z)] \quad (6)$$

The excitation energy $E^*(M,T)$ is obtained using the equation,

$$E^*(M,T) = E(M,T) - E_0 \quad (7)$$

where, E_0 is the ground energy of the system.
The rotational energy E_{rot} is expressed as,

$$E_{rot} = E(M,T) - E(0,T) \quad (8)$$

The rotational frequency ω_{rot} is expressed as,

$$\omega_{rot} = \frac{\partial E_{rot}}{\partial M} \quad (9)$$

Kinematical (j) moment of inertia is calculated from rotational energy as,

$$j = \hbar^2 M \left(\frac{\partial E_{rot}}{\partial M}\right)^{-1} \quad (10)$$

Eignevalues are engendered from triaxially deformed Nilsson Hamiltonian for the deformation parameter (ε) values in steps of 0.1 from 0.0 to 0.6 and the shape parameter (γ) = -180° (corresponding to non-collective oblate) to -120° (corresponding to collective prolate).

Results and Discussion

The theoretical framework of statistical theory of hot rotating nuclei is used to study the structural changes of ^{60}Zn nuclei. The shape changes in the nucleus are related to the collective degrees of freedom (ε and γ). Due to the presence of strong nuclear force, the nucleons i.e., the protons and neutrons tend to pair themselves. For an even – even nuclei, the nucleons are paired such that there are no unpaired nucleons. For a given excitation, the nucleon – pairs are broken inorder to result in excitation of the nucleons to higher orbitals. Thus, all nuclei which are sufficiently deformed have rotational spectra. Fig. 1 shows the rotational energy as a function of angular momentum for the temperature of T = 1.5 and T = 1.75 MeV. The solid circle symbols denote the experimental value [5]. From the plot it is obvious that the experimentally obtained rotational energy value follows the same pattern as that of the obtained theoretical value.

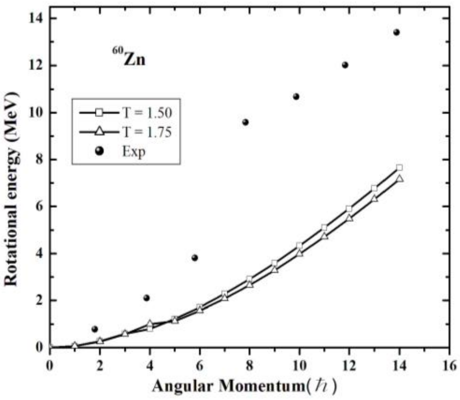

Fig. 1 Rotational energy (E_{rot}) as a function of angular momentum (M) for temperatures T = 1.5 and 1.75 MeV. The solid circles represent the experimental data.

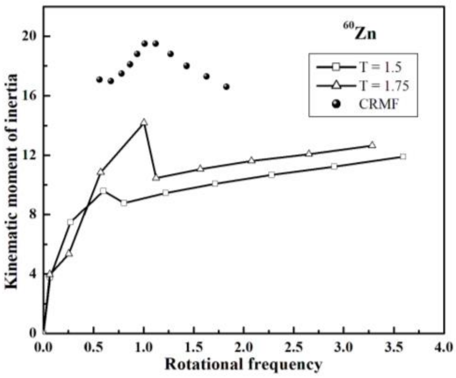

Fig. 2 Kinematic moment of inertia as a function of rotational frequency for temperatures T = 1.5 and 1.75 MeV. The solid circles represent the data calculated from CRMF method [5].

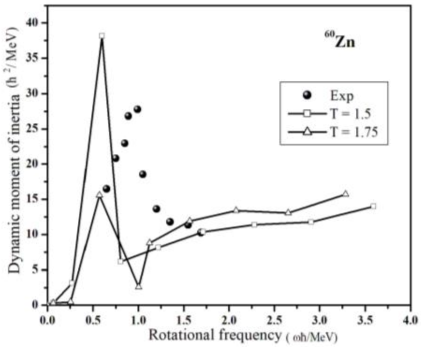

Fig. 3 Dynamical moment of inertia as a function of rotational frequency with same description as in fig. 2.

Figure 2 represents the Kinematic moment of inertia (MOI) versus rotational frequency plot for ^{60}Zn at temperatures T = 1.5, & 1.75 MeV. From the figure, it is observed that a sudden increase in the moment of inertia for a narrow spin range for T = 1.75 MeV indicates the shape transition. But for T = 1.5 MeV the change in MOI is not considerable compared to the other plot. From the theoretical predictions, it is found that the sudden increase in moment of inertia is due to the band crossing.

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