Level density and thermodynamics in hot rotating ^{96}Tc nucleus†

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One of the basic aims in diverse fields of science (physics, chemistry, and biology) is understanding the small system, which manifests many striking properties due to its tiny dimension. The study of thermodynamic properties of such small system like atomic nucleus, in spite of being an arduous task, is highly imperative as those properties describe how such systems respond to the changes in their environment. In addition, the knowledge of nuclear thermodynamics also enables us to understand the presence of pairing phase transition in the nucleus, whose effect was included in the nuclear theory after the Bardeen-Cooper-Schrieffer (BCS) theory. Thus, the study of nuclear thermodynamics has gained much enthusiasm in the recent past.

Measuring the nuclear level density (NLD) is the starting point to obtain the thermodynamic quantities (TQ) of atomic nuclei. Earlier, the NLD was measured below the particle threshold energy at very low angular momentum J and extrapolated to the higher energy by using the functional form of the Fermi-Gas model to estimate the TQs. But, the knowledge of the NLD functional form is not yet satisfactory due to the lack of experimental data at high E^* and J. Therefore, it would be better if one could measure the NLD below and above the particle threshold, and compare the measured data with a consistent theoretical calculation to investigate TQs of atomic nuclei. In the present work,[1)] the angular momentum gated NLDs in the excitation energies range of $E^* \sim$ 5–15 MeV are extracted by using the evaporated neutron energy spectra in the ^{4}He+^{93}Nb reaction and compared with the results of different microscopic calculations.

The experimental NLD along with the results of different theoretical calculations for J = 12 and 16 $\hbar$ are shown in Fig. 1. It is observed that EP+IPM (exact pairing plus independent particle model) explains rather well the experimental data and thus it was used to extract the thermodynamic properties of ^{96}Tc nucleus. The TQ of ^{96}Tc have been estimated using EP+IPM NLDs for J = 12 and 16 $\hbar$ as shown in Fig. 2. It is quite interesting to note that the free energy, entropy, and average energy show the correct trend as that observed in the nearby ^{96}Mo nucleus.[2)] However, the bump in the heat capacity (signature of pairing phase transition) of ^{96}Tc is not as pronounced as that seen in ^{96}Mo,[2)] in spite of being the same mass. This difference might come from the pairing property of odd-odd ^{96}Tc nucleus, which is weaker than that in even-even ^{96}Mo. It is also observed that the angular momentum does not have much effect on the nature of the TQs. However, at low T, there is a noticeable change in the heat capcity due to the angular momentum. Therefore, it would be very interesting to study the angular momentum effect on the pairing phase transition in even-even systems in future.

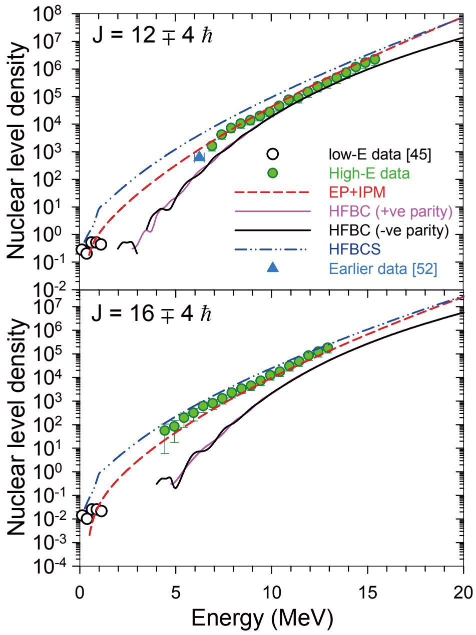

Fig. 1. Angular momentum gated NLD (symbols) along with the results of different theoretical calculations.

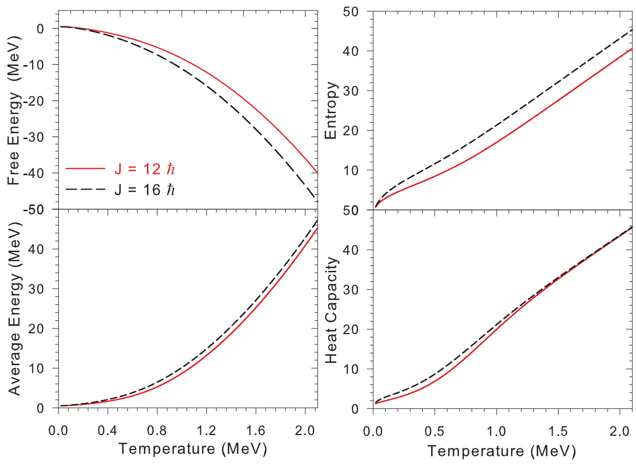

Fig. 2. Angular momentum gated TQs as functions of temperature obtained using EP+IPM level densities.

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