Nuclear Level Density Parameter In Hot Rotating Nuclei

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Hot rotating nuclei are usually produced in heavy ion fusion reactions through transfer of the energy and angular momentum of the relative motion into internal degrees of freedom. The single - particle motion of nucleons is renormalized in an important way through the coupling to the nuclear surface [1]. At finite temperatures both small and large amplitude shape fluctuations can influence the level density parameter.

The temperature dependent level density parameter plays an important role in the study of shape transitions in hot rotating nuclei. It can be investigated by mean field theories such as Hartree - Fock method and the Landau theory of phase transitions, but these theories ignore the statistical thermal fluctuations. For a nucleus with finite number of particles, such fluctuations on level density parameter can be large. The aim of this work is to obtain the level density parameter for ^{61}Cu and ^{63}Cu as a function of temperature and angular momentum using Landau method including thermal fluctuations[2]. The thermodynamical functions were evaluated using cranked Nilsson – Strutinsky prescription, that is,

$$F(T,I;\beta,\gamma) = E(T,I;\beta,\gamma) - TS - E_s + E_{RLDM} \quad (1)$$

According to Landau theory of phase transitions the probability the system has to display a given shape characterized by the parameters (β,γ) is given by

$$P(\beta,\gamma) = Z^{-1} \exp[-F(\beta,\gamma)/T] \quad (2)$$

where $Z = \int d\tau \exp[-F(\beta,\gamma)/T]$ is the partition function.

The Bohr rotation – vibration volume element is used in the calculations and is

$$d\tau = \beta^4 |\sin 3\gamma| \, d\beta d\gamma \quad (3)$$

The ensemble average of the entropy that depends on β,γ is calculated by the relation

$$\langle S(I,T)\rangle = Z^{-1} \int d\tau \, P(\beta,\gamma) \, S(\beta,\gamma) \quad (4)$$

From standard relation S=2aT, and using averaged quantity equation (4), one determines the level density parameter including shape fluctuations, that is,

$$\langle a\rangle = \langle S\rangle/2T \quad (5)$$

Now the value $a = S(\beta_0, \gamma_0)/2T \quad (6)$

gives the level density parameter calculated at equilibrium configuration (β_0, γ_0) without thermal fluctuations.

In the calculations performed here, the Landau theory is used in complete form and the constants are evaluated by least square fitting with the ω=0 free energy surfaces obtained by using the cranked Nilsson – Strutinsky method [3,4].

The results obtained for the level density parameter as a function of temperature and angular momentum for the case of ^{61}Cu and ^{63}Cu nuclei are shown in the tables 1 and 2. It is seen from the tables that the change in level density obtained as a function of temperature is more than that obtained as a function of angular momentum. The results obtained are also in conformity with the marked temperature dependence of the level density parameter observed experimentally [5].

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Table 1: Level density parameter as a function of temperature and angular momentum for the case of ^{61}Cu

I/T	0.5MeV	1.0 MeV	1.5 MeV	2.0 MeV	2.5 MeV
1/2 ħ	7.964	8.122	8.178	8.210	8.186
21/2 ħ	7.836	8.154	8.163	8.187	8.188
41/2 ħ	7.862	8.933	8.087	8.155	8.192
61/2 ħ	7.875	8.936	8.106	8.165	8.211

Table 2: Level density parameter as a function of temperature and angular momentum for the case of ^{63}Cu

I/T	0.5MeV	1.0 MeV	1.5 MeV	2.0 MeV	2.5 MeV
1/2 ħ	8.663	9.021	9.166	9.205	9.180
21/2 ħ	8.535	9.053	9.186	9.186	9.182
41/2 ħ	8.562	8.833	9.142	9.142	9.185
61/2 ħ	8.575	8.835	9.153	9.153	9.191

References:

[1] C. Mahaur et al., Phys. Rep. **120**, 1(1985)

[2] Y. Alhassid et al., Nucl. Phys. **A469**, 205(1987)

[3] G. Shanmugam and V. Selvam, Phys. Rev. **C62**, 014302(2000)

[4] V. Selvam and D.R. Jayahar Devadhason, Proc. of the DAE Symp. on Nucl. Phys. (INDIA) **55**, (2010).

[5] G. Nebbia et al., Phys. Lett. **B176**, 20(1986).