Fluctuations on Nuclear Level Density Parameter

D.R. Jayahar Devadhason[1] and V. Selvam[2]

[1]Department of Physics, Marthandam College of Engineering and Technology, Kanyakumari - 629 177, INDIA.
[2]Department of Physics, Rani Anna Govt. College for Women, Tirunelveli-627 008, INDIA.

The knowledge of nuclear level densities is a crucial input in various fields and applications such as the creation of consistent theoretical description of excited nucleus properties and the nuclear reaction cross-section calculations for many branches of nuclear physics, nuclear astrophysics, nuclear medicine, and applied areas such as medical physics, etc. The analytical expressions used for the nuclear level density calculations are based on the Fermi gas model. The most widely used description of the nuclear level density is the Bethe formula, based on the thermodynamic relation between entropy and the average energy of a system considered in the framework of non-interacting particles of the Fermi gas. However, the subsequent contributions based on this do not take into account the collective effects, which may play a basic role in describing the nuclear level density of some deformed nuclides.

The evaluation of the level density parameter 'a' is important since it plays a major role in the determination of the nuclear level density, which is a basic ingredient in any statistical analysis of nuclear reactions. It has been a subject of many investigations at low and high excitation energies, both for experimentalists and theoreticians. At finite temperatures both small and large amplitude shape fluctuations can influence the level density parameter [1].

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 ^{110}Sn and ^{116}Sn as a function of temperature and angular momentum using Landau theory including thermal fluctuations [2]. The thermodynamical functions were evaluated using cranked Nilsson – Strutinsky prescription, that is,

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

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

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

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

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

Using the standard entropy relation S=2aT, and the averaged quantity given in equation (4), one determines the level density parameter including shape fluctuations as,

$$\langle a\rangle = \frac{\langle S(I,T)\rangle}{2T} \quad (5)$$

The level density parameter calculated at equilibrium configuration (β_0, γ_0) without thermal fluctuations is

$$a = \frac{S(\beta_0,\gamma_0)}{2T} \quad (6)$$

I/T	0.5 MeV	1.0 MeV	1.5 MeV	2.0 MeV	2.5 MeV	3.0 MeV
10	8.515	8.782	8.886	8.921	9.306	9.428
20	8.624	8.706	8.805	8.904	9.221	9.437
30	8.832	8.835	8.994	8.997	9.392	9.568
40	8.836	8.859	8.997	9.032	9.637	9.739
50	8.872	8.885	9.091	9.340	9.637	9.739

Table 1: NLD parameter for the case of **^{110}Sn** as a function of temp. and angular momentum

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 ^{110}Sn and ^{116}Sn nuclei are shown in the tables 1 and 2. It is seen from the tables that there is a marked variation in the level density as function of temperature and spin and the change in level density as a function of temperature is more pronounced than that obtained as a function of angular momentum. The results obtained are also in conformity with the temperature dependence of the level density parameter observed experimentally [5].

I/T	0.5 MeV	1.0 MeV	1.5 MeV	2.0 MeV	2.5 MeV	3.0 MeV
10	8.726	8.994	9.098	9.133	9.518	9.620
20	8.836	8.918	9.017	9.116	9.433	9.249
30	9.044	9.047	9.168	9.209	9.604	9.780
40	9.048	9.071	9.199	9.244	9.849	9.951
50	9.084	9.097	9.203	9.552	9.868	9.923

Table 2: NLD parameter for the case of **^{116}Sn** as a function of temp. and angular momentum

References:

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