Temperature dependence of the excitation energy in ^{163}Dy

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Introduction

Nuclear Level density is one of the earliest concepts in nuclear physics introduced by Bethe soon after the composition of nuclei was firmly established [1]. It is a basic nuclear property and an ingredient of the theory of nuclear reactions So that all the thermodynamic quantities and cross sections of nuclear reactions can be identified by it. In this regard, various groups in the world have Spend through their empirical studies [2-3] or our recent theoretical works [4-6].

In this work, using the new experimental data of ^{163}Dy [2], the nuclear level density parameters are determined by the Bethe formula and constant temperature model. Finally, the entropy and temperature dependence of the excitation energy are determined.

Nuclear Level density

Nuclear level density is a characteristic of nucleus, that is defined as the number of levels per unit of energy at a given excitation energy, $\rho(E)$.

The average level density is defined as follows:

$$\rho(E) = \frac{dN}{dE} \qquad (1)$$

The nuclear temperature is defined as follows:

$$\frac{1}{T} = \frac{d}{dE} ln\rho(E) \qquad (2)$$

Constant temperature model (CTM) for the nuclear levels density is shown:

$$\rho(E) = \frac{1}{T}\exp\left(\frac{E-E_0}{T}\right) \qquad (3)$$

Nuclear temperature (T) and back shift energy (E_0) can be determined by fitting the macroscopic formulas to the experimental data on the nuclear level density. The Bethe formula of nuclear level density for Back shifted Fermi Gas (BSFG) model is:

$$\rho(E) = \frac{e^{2\sqrt{a(E-E_1)}}}{12\sqrt{2}\sigma a^{1/2}(E-E_1)^{5/4}} \qquad (4)$$

In this case, the level density parameter (a) and back shifted energy (E_1) are obtained by fitting. The spin distribution J is obtained by spin cut-off parameter σ^2 as follows:

$$f(J) = \exp\left(\frac{-J^2}{2\sigma^2}\right) - \exp\left(\frac{-(J+1)^2}{2\sigma^2}\right)$$

$$\approx \frac{2J+1}{2\sigma^2} exp\left[-\frac{(J+1/2)^2}{2\sigma^2}\right] \qquad (5)$$

and Spin dependence of the level density is determined as follows:

$$\rho(E,J) = \rho(E)f(J) \qquad (6)$$

The spin cut-off parameter σ^2 dependent on the effective moment of inertia (I_{eff}) and nuclear temperature (T):

$$\sigma^2 = \frac{I_{eff}\,T}{\hbar^2} \qquad (7)$$

The nuclear moment of inertia for a rigid body is $I_{rigid} = \frac{2}{5}MR^2$ where M=A is the nuclear mass and $R = 1.25A^{1/3}fm$ is the nuclear radius, then

$$\sigma^2 = 0.0150A^{5/3}T \qquad (8)$$

Gilbert and Cameron spin cut-off parameter for Bethe formula with a reduced moment of inertia was calculated as follows:

$$\sigma^2 = 0.0888A^{2/3}\sqrt{a(E-E_1)} \qquad (9)$$

The temperature dependence and the level density

The level density parameters of CT model and BSFG model were first calculated by fitting the nuclear level density to the experimental data measured by the Oslo group [2].

The results for the level density parameters of ^{163}Dy are presented in Table 1.

Table 1: The level density Parameters of ^{163}Dy

Nuclei	E_1[MeV]	a[MeV^{-1}]	E_0[MeV]	T[MeV]
^{163}Dy	-0.492	16.6656	-1.3339	0.5498

The calculated nuclear level density as a function of excitation energy in Constant temperature and Back-shifted Fermi gas models for ^{163}Dy are shown in Fig. 1. Their corresponding experimental values [2] are also plotted for comparison. In general, both CT and BSFG models present satisfactory results using the parameters given in Table 1. Finally, the temperature dependence of excitation energy is determined for ^{163}Dy nuclei and is shown in Fig. 2. As can be seen from Fig. 2, oscillations around the constant temperature value T=0.54 M

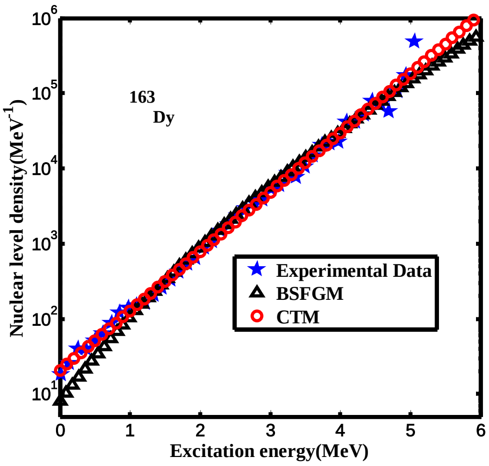

Fig. 1 The calculated and experimental level density as a function of excitation energy in ^{163}Dy nucleus.

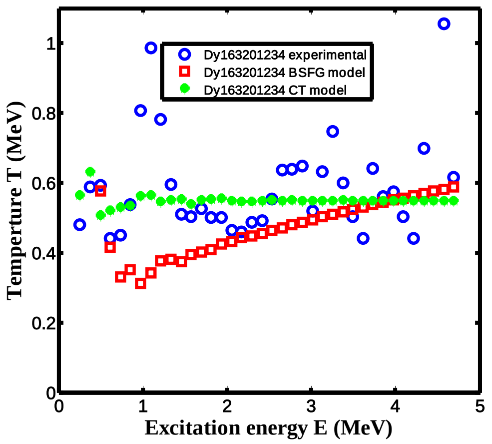

Fig. 2 nuclear temperature as a function of excitation.

Conclusion

The nuclear level density parameters in BSFGM and CTM are determined using the recent experimental level density data of ^{163}Dy measured by the Oslo group. Then temperature dependence of the excitation energy has been extracted in two models and in the microcanonical ensemble. Our results reveal that the CTM can reproduce microcanonical results better than the BSFGM in low energy.

References

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