Nuclear level density parameter's dependence on angular momentum

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Introduction

Nuclear level densities represent a very important ingredient in the statistical Model calculations of nuclear reaction cross sections and help to understand the microscopic features of the excited nuclei. Most of the earlier experimental nuclear level density measurements are confined to low excitation energy and low spin region. A recent experimental investigation [1] of nuclear level densities in high excitation energy and angular momentum domain with some interesting results on inverse level density parameter's dependence on angular momentum in the region around Z=50 has motivated us to study and analyse these experimental results in a microscopic theoretical framework. In the experiment, heavy ion fusion reactions are used to populate the excited and rotating nuclei and measured the α particle evaporation spectra in coincidence with γ ray multiplicity. Residual nuclei are in the range of Z_R = 48-55 with excitation energy range 30 to 40 MeV and angular moemntum in 10 $\hbar$ to 25 $\hbar$. The inverse level density parameter K is found to be in the range of 9.0 -10.5 with some exceptions.

Theoretical Formalism

We use statistical theory [2] of hot rotating nucleus combined with the macroscopic - microscopic approach adequately described in our earlier work [3] where the role of angular momentum and structural effects on the nuclear level density and neutron emission probability is emphasized. Total energy of the excited nuclear system is computed by including Strutinsky shell correction(δE), deformation energy (E_{Def}) and excitaion energy(E^*) to the Liquid Drop Model energy(E_{LDM}). The free energy F of the system is computed by incorporating entropy S and is minimized with respect to deformation parameters β and γ which gives the deformation and shape of the hot rotating nucleus

$$F(Z,N,T,M,\beta,\gamma) = E_{LDM}(Z,N)) +\delta E_{shell}(\beta,\gamma) + E_{def}(\beta,\gamma) +E^*(T,M,\beta,\gamma)) - TS(T,M,\beta,\gamma) \quad (1)$$

The level density parameter is computed as a function of temperature and spin [3]. Since we have included the microscpoic structural effects by incorporating the shell correction, deformation and shape effects of the hot rotating nucleus, our model provides a comrehensive and more reliable picture of the excited nucleus.

Results and Discussion

Fig. 1 shows inverse level density parameter K = A/a(M,T) vs. angular momentum M($\hbar$) for ^{108}Cd, ^{109}In, ^{112}Sn, ^{113}Sb, ^{122}Te, ^{123}I and ^{127}Cs hot rotating nuclear systems. The points with the error bar represent the experimental data of Ref. [1]. We vary T =1.4 MeV to 1.5 MeV to reproduce excitation energy of 30 to 40 MeV. We found a reasonable agreement with the experimental data except in few cases. Inverse level density parameter K should increase with increasing M which is seen in our work for all the nuclear systems. On the contrary, few experimental points show a decline at larger M in the case of ^{113}Sb and ^{127}Cs.

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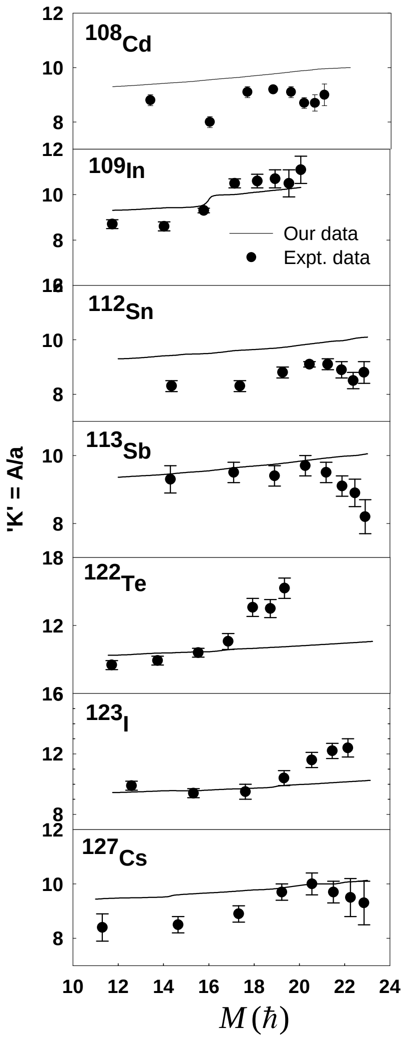

FIG. 1: Inverse level density parameter vs. M(ħ). Solid line represents our work and points with error bar are experimental data.

The sudden decline in K values could be due to a sudden rise in deformation or a shape transition which would lead to increase in level density parameter and decrease in K, but any such deformation or shape changes are not seen in our calculations. The poor agreement of K values in the nuclear system ^{112}Sn is due to the fact that ^{112}Sn is a shell closure and the level density parameter is a minima for a shell closure and K should be a maxima. The experimental points show a minimum for ^{112}Sn which is just the opposite of what is expected and that is why our data points are much above the experimental points. The nuclei below the shell closure are less deformed than those above the shell closure. ^{108}Cd is less deformed than ^{109}In and hence has lower level density parameter 'a' and higher K and hence our values are slightly higher. This indicates that the shell effects influence the level density parameter and must be considered although thier effect is small here due to high excitations.

To conclude, this work is an attempt to study the experimentally derived level density parameter and thier variation with angular momentum using a microscopic approach. Dependence of angular momentum and structural effects on the level density parameter is established. A reasonable agreement with the experimental results is found. Value of K varies from 9 to 10 for most of the cases experimentally as well as theoretically.

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References

[1] Y. K. Gupta, Bency John, D. C. Biswas, B. K. Nayak, A. Saxena, and R. K. Choudhary, Phys. Rev. **C 78**, 054609 (2008).

[2] M.Rajasekaran, T. R. Rajasekaran, and N. Arunachalam, Phys. Rev. **C 37**, 307 (1988).

[3] Mamta Aggarwal, Int. J. of Mod. Phys. **E 17**, 1 (2008).