Level density parameter−its dependence on angular momenum induced structural transitions

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Introduction

The nuclear level density(NLD) parameter related to the density of the single particle levels near the Fermi surface, is influenced by the shell structrure, deformation and shape of the nucleus which can be profoundly altered by rotation and the nuclear temperature. Recently there have been various experimental efforts to determine NLD and study its dependence on collective excitations and deformation which is crucial to understand from a theoretical perspective which is the objective of the present study. We investigate variation of level density with angular momentum due to structural transitions for ^{119}Sb [1] and ^{185}Re∗ for which recent measurements on neutron evaporation spectra and level density variation with angular momentum have been reported. Neutron spectra for ^{119}Sb found a decreasing trend in inverse level density parameter (k=A/a) for increasing angular momentum J, whereas in ^{185}Re∗ [2], 'K' is found to remain almost constant for increasing J. Experimental study in Ref. [3] suggested increasing 'K' with the increasing angular momentum for lower J values but predicted a decreasing trend at higher J values for ^{113}Sb and ^{127}CS for which our theoretically derived 'K' values showed increasing trend for increasing J [4]. These experimental results do not offer a conclusive trend in the variation of level density with spin although the specualtions about the effect of collectivity and deformation on NLD have been reported. We investigate the influence of spin induced structural transitions on the level density parameter and provide significant inputs on the variation of 'K' with angular momentum reported in recent experimental works [1, 2].

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Brief description of work

We use Macroscopic-Microscopic approach [6] using a triaxially deformed Nilsson potential along with the shell correction and Statistical theory of [5, 6] hot rotating nuclei. We compute entropy and minimize the free energy $F =$ E $-TS$ for Nilsson deformation parameters β and γ which give deformation and shape of the excited nuclei. The internal excitation energy (U_{th}) of the residual nuclei is computed using $U_{th} = E^* - E_{rot} - S_n - E_n$, where E^* is the total excitation energy available to the system due to reaction process which is shared between rotational energy (E_{rot}), neutron separation energy (S_n) and average neutron kinetic energy of the outgoing neutron (E_n). Calculations are performed for ^{119}Sb(at $E^* = 31$ Mev) and ^{185}Re∗ (at 30 MeV and 40 MeV) as given in Refs. [1, 2]. The level density parameter is extracted for angular momentum (we use spin projection M) $= 12\hbar - 23\hbar$ using the expression a = $S^2/4U$.

Results and Discussion

Fig. 1((a) -(c)) shows Inverse level density parameter 'K' for ^{119}Sb and ^{185}Re as a function of angular momentum (M). The structural transitions in the corresponding nuclear systems are shown in Fig.1.((d) -(f)) where the deformation and shape changes with angular momentum M($\hbar$) are very evident which are also reflected in the corresponding 'K' values (Fig.1 ((a)-(c)). Our calculated 'K' values and the trend of variation of 'K' with M is in reasonable agreement with the experimental ones. Our calculated values show an increasing 'K' with increasing M($\hbar$) over a large range of angular momentum but de-

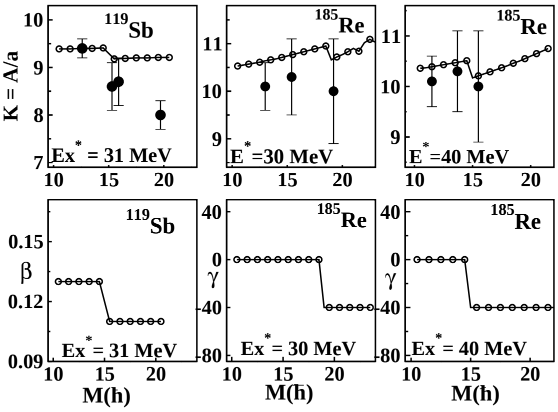

FIG. 1: Inverse level density parameter K vs. M($\hbar$) for (a)^{119}Sb (b)^{185}Re for 30 MeV (c) ^{185}Re for 40 MeV (d) deformation β vs. M($\hbar$) for ^{119}Sb, shape parameter γ vs. M for ^{185}Re (d) 30 MeV (e) 40 MeV.

crease at those spin values when there is a deformation or shape change which is evident in Fig. 1 (a-c). This small drop in our 'K' value agrees with the drop in experimental 'K' value [1, 2]. The Refs. [1, 2] have very few data points and on the basis of this data they have predicted a decreasing trend with spin for ^{119}Sb and almost constant 'K' for ^{185}Re. Our study suggest that the decrease in 'K' value of experimental points is due to structural changes (deformation change seen in Fig. 1(d) for ^{119}Sb and shape transition from Prolate non-collective to triaxial in ^{185}Re$*$ in Fig.1 (e),(f)). A very small effect of backbending is also observed at shape transition but is not significant. Well deformed systems show strong backbending effects. In the absence of any structural changes, 'K' increases smoothly with increasing M and sometimes appears to be constant with very small changes as indicated in Ref. [2].

Conclusion

Experimentally derived Inverse level density parameter 'K' and its variation with angular momentum in ^{119}Sb and ^{185}Re is studied in a microscopic approach. 'K' values are influenced by the changes in shape and deformation. Our calculated 'K' values show reasonable agreement with the experimental data. 'K' increases with angular momentum but decreases due to shape or deformation changes at certain M values which are in agreement with the decreasing trend of experimental 'K' values, but the available experimental data has very few data points to give a conclusive trend in the variation of K with M. More data points especially for higher angular momentum over a wider range would give a better insight.

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