Investigation of nuclear level density in the temperature range of 1 to 3 MeV for a mass region of A∼110

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Introduction

Nuclear level density (NLD), is a fundamental property of atomic nucleus and it's crucial to understand the several physical phenomenon in nuclear physics and astrophysics. It is a key ingredient in the prediction of nuclear reaction cross sections using statistical models. Therefore, it is also a very much important input in designing new nuclear technologies. Primarily, it is described in phenomenological framework, where its excitation energy dependence is given by Fermi-gas (FG) approximation [1];

$$\rho(E) = \frac{\pi}{12}\frac{\exp(2\sqrt{aE})}{a^{1/4}E^{5/4}} \qquad (1)$$

where E is the excitation energy of the nucleus and $a = (\pi^2/6)g$, where g is the single particle density at the Fermi surface. In the FG approximation, the NLD parameter 'a' is constant at around A/15 MeV^{-1}. The parameter $K = A/a$ is referred as inverse level density parameter. Experimentally, the value of K is observed at around 8 MeV for energies around the neutron separation. The deviation from K=15 to 8 MeV has been described in terms of the finite nuclear size and increase of effective nucleon mass [2]. The transition of K towards the FG value with increasing nuclear temperature has been observed experimentally in some of the scattered works [3].

It is of utmost importance to understand thoroughly the transition of K in different mass regions. Also, it has been conjectured that NLD parameter 'a' depends not only on A but N and Z separately [4]. Isospin dependence of NLD also come through the symmetry energy which is not clearly understood [5]. With these motivations we measured the α particle evaporation spectra from two isotopes, ^{100}Sn and ^{116}Sn populated through reactions ^{16}O+^{94,100}Mo in an excitation energies range of $E \sim$ 36-117 MeV.

Experimental Details and Data Analysis

Two experiments were carried out using ^{16}O beam from BARC-TIFR Pelletron Linac facility, Mumbai, India, one for beam energy range of 55 to 80 MeV [6] and another for 95.6 to 136.6 MeV. Targets consisted of two self supporting foil of enriched ^{94}Mo and ^{100}Mo with thickness 1.8 mg/cm^2 and 1.0 mg/cm^2, respectively. The emitted alpha particles were detected using CsI(Tl) detectors mounted in the backward hemisphere of Charged Particle Detector Array at laboratory angles of 115°, 124°, 134°, 140°, 145°, 150°, 155°. Two silicon surface barrier detector having solid angles of ∼0.30 msr were placed at ±20^o for normalization with Rutherford scattering events. The CsI(Tl) detectors were energy calibrated using ^{228,229}Th α source. Extrapolation of the light yield produced in CsI(Tl) detectors beyond 8 MeV was performed using in-beam data from earlier measurements [7]. Particle identification in CsI(Tl) detectors was achieved using Ballistic deficit method [8]. It requires two different shaping amplifiers, one with short shaping time (0.5 μs) and another with long shaping time (3.0 μs). The correlation between long and short integration time results in different slope for different particles [6].

The measured α particle energy spectra at different laboratory angles were converted to centre-of-mass frame using the standard Jacobian. The c.m. spectra of different laboratory angles overlapped very well, indicating dominant compound nuclear evaporation. Averaged c.m. spectra were compared with the α spectra calculated using statistical model code PACE2. The diffuseness parameter was chosen to be 0.5 $\hbar$. The inverse level density pa-

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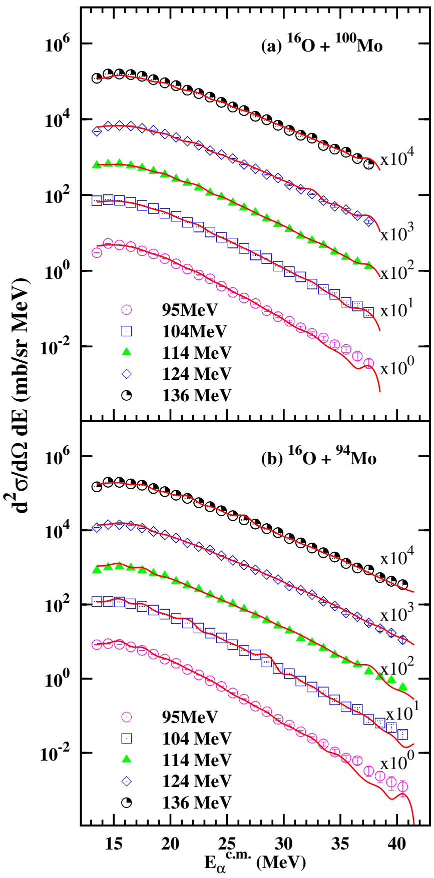

FIG. 1: Experimental α particle energy spectra of different excitation energies along with PACE2 calculations for ^{16}O+^{94,100}Mo systems.

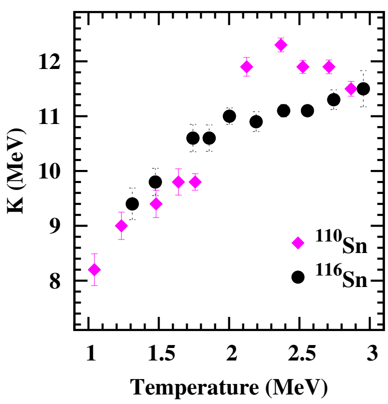

FIG. 2: Inverse level density parameter (K) as a function of temperature.

rameter $K = A/a$ was kept as free parameter to obtain a best fit using χ^2 minimization technique. Data were fitted in the α particle energy range of 18.5-39 MeV.

Results and Discussions

Typical experimental α energy spectra along with best fit PACE2 calculations are shown in Fig. 1 for both compound nuclear systems. It is observed that the best fitted inverse level density parameter K increases with increasing beam energy. An average nuclear temperature (T) was estimated corresponding to each beam energy using the best fit K-value, in relation $E = aT^2$. The variation of K as a function of temperature is shown in Fig. 2. It is seen from Fig. 2 that initially K increases linearly with increasing T for both isotopes. At T=2 MeV, ^{116}Sn shows saturating behavior, but, ^{110}Sn still shows increasing trend. Eventually, at T=2.5 MeV, ^{110}Sn also saturates and merge with K values of ^{116}Sn.

Transition of K values from 8 to 12 MeV in going temperatures from 1 to 3 MeV supports earlier observations [3]. It is very intriguing to observe that neutron deficient ^{110}Sn is showing large K values than the neutron-rich ^{116}Sn at temperatures value between 2 to 2.5 MeV. Detailed analysis and a theoretical understanding is being carried out which will be presented during symposium.

Acknowledgments

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References

[1] H. A. Bethe, Phys. Rev. **50**, 332 (1936).
[2] S. Shlomo, J. B. Natowitz *et al.*, Phys. Lett. B **252**, 187 (1990).
[3] B. J. Fineman *et al.*, Phys. Rev. C **50**, 1991 (1994).
[4] S. I. Al-Quraishi, S. M. Grimes *et al.*, Phys. Rev. C **63**, 065803 (2001).
[5] A. Brondi, A. Di Nitto *et al.*, EPJ Web of Conferences **2**, 04002 (2010).
[6] G. K. Prajapati *et al.*, Proceedings of the DAE Symp. on Nucl. Phys. **62** (2017).
[7] Y. K. Gupta *et al.*, Phys. Rev. C **86**, 01461502 (2012).
[8] J. Gal *et al.*, Nucl. Instrum. methods A **399**, (1997) 407.