

## Investigation of nuclear level density in the temperature range of 1 to 3 MeV for a mass region of $A \sim 110$

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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];

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

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<sup>-1</sup>. 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  $\alpha$  particle evaporation spectra from two iso-

topes, <sup>100</sup>Sn and <sup>116</sup>Sn populated through reactions <sup>16</sup>O+<sup>94,100</sup>Mo in an excitation energies range of  $E \sim 36$ -117 MeV.

### Experimental Details and Data Analysis

Two experiments were carried out using <sup>16</sup>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 <sup>94</sup>Mo and <sup>100</sup>Mo with thickness 1.8 mg/cm<sup>2</sup> and 1.0 mg/cm<sup>2</sup>, 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  $\sim 0.30$  msr were placed at  $\pm 20^\circ$  for normalization with Rutherford scattering events. The CsI(Tl) detectors were energy calibrated using <sup>228,229</sup>Th  $\alpha$  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  $\mu$ s) and another with long shaping time (3.0  $\mu$ s). The correlation between long and short integration time results in different slope for different particles [6].

The measured  $\alpha$  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  $\alpha$  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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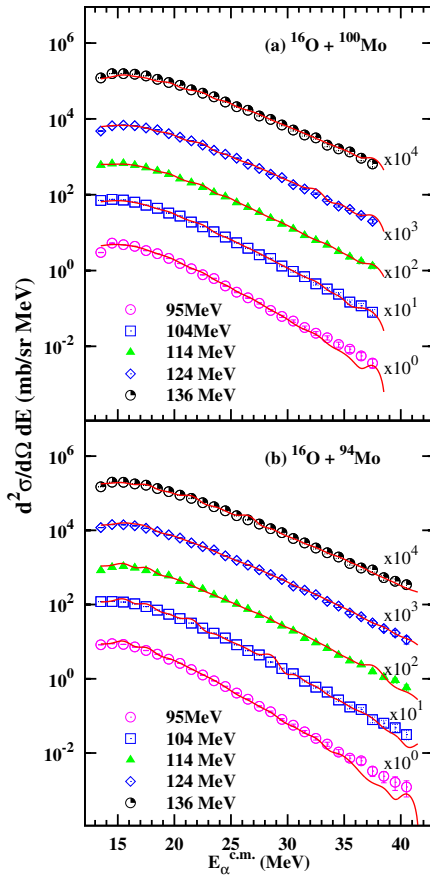


FIG. 1: Experimental  $\alpha$  particle energy spectra of different excitation energies along with PACE2 calculations for  $^{16}\text{O}+^{94,100}\text{Mo}$  systems.

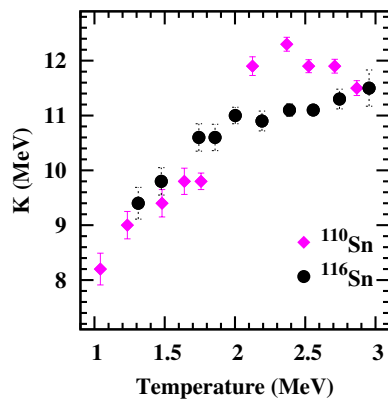


FIG. 2: Inverse level density parameter ( $K$ ) as a function of temperature.

parameter  $K = A/a$  was kept as free parameter to obtain a best fit using  $\chi^2$  minimization

technique. Data were fitted in the  $\alpha$  particle energy range of 18.5-39 MeV.

## Results and Discussions

Typical experimental  $\alpha$  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,  $^{116}\text{Sn}$  shows saturating behavior, but,  $^{110}\text{Sn}$  still shows increasing trend. Eventually, at  $T=2.5$  MeV,  $^{110}\text{Sn}$  also saturates and merge with  $K$  values of  $^{116}\text{Sn}$ .

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  $^{110}\text{Sn}$  is showing large  $K$  values than the neutron-rich  $^{116}\text{Sn}$  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.

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