Investigation of Isospin effect on the Nuclear level density parameter in $A \sim 130$ mass region

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Introduction

The nuclear level density is an important quantity required to understand the various aspects in nuclear physics and astrophysics. It also has implications in designing new nuclear reactor technologies. Therefore, a precise understanding of the NLD as function of excitation energy [1], angular momentum [2], isospin [3, 4] and other constants of motion is of significant importance. It is best described within a phenomenological framework using the Fermi-gas model (FGM) [5]. In this approach a key quantity is the NLD parameter, a, which is simply related to the density of single-particle levels at the Fermi energy. This parameter is given by the simple expression $a = A/K$, where A is the nuclear mass number and K is an inverse-level-density parameter. Within this framework of FGM, the NLD parameter depends only on the mass number, A. The isospin effects in NLD is somewhat neglected largely in FGM because these effects are expected to be small for nuclei near the valley of stability. However, it has been conjectured that the level density parameter decreases with increasing isospin [6]. Above conjectures have been supported by recent experimental observations.

Experimental information about the NLD parameter, a, at excitation energies above the neutron separation can be obtained from the slope of evaporated particle spectra from heavy ion fusion reactions. Recently, it is shown that the inverse-level density parameter, K, is appreciably higher for a neutron rich excited nucleus in comparison to the similarly excited nucleus but neutron deficient. Above investigations [3] were carried through fusion evaporation in ^{16}O + ^{94,100}Mo reactions. Above results indicated that the difference is more at the lower excitation energies. A theoretical work by S. Shlomo *et.al.* [7] suggest that NLD parameter vary quite differently in different mass regions. Therefore, it is very important to perform experimental investigations in different mass regions in a wide energy region. With this motivation, we performed fusion evaporation measurements in ^{16}O + ^{116,124}Sn reactions at compound nuclear excitation energies in the range of 38 to 60 MeV.

Experimental Details and Data Analysis

The experiment was performed using ^{16}O beam from BARC-TIFR Pelletron facility at Mumbai. ^{16}O beam with energies, 61, 65, 70 and 75 MeV was bombarded on self sporting foils, ^{116}Sn and ^{124}Sn each of the thickness 1.6 mg/cm^2. Isotopic enrichment of all the foils was more than 95%. Charge particles were detected using CsI(Tl) detectors and $\Delta E - E$ silicon surface barrier (SSB) telescopes, mounted in the backward hemisphere of Charge Particle Detector Array (CPDA) at laboratory angles of 130°, 135°, 140°, 145°, and 155°. Two SSB detectors with each having solid angle of $\sim$ 0.30 msr were placed at $\pm 20^o$ for Rutherford normalization purpose. The detectors were placed in such a way that the angle for a pair of Silicon telescopes and CsI(Tl) detectors remains the same with respect to the beam direction. Above arrangement was made for three pairs for the comparison purpose. The CsI(Tl) detectors were energy calibrated using known energies of α particles from standard ^{229}Th radioactive source. Extrapolation of the light yield produced in CsI(Tl) detec-

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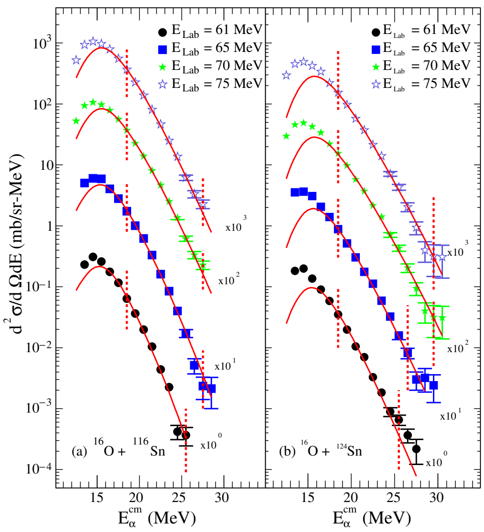

FIG. 1: Averaged α-particle energy spectra at different energies in c.m. frame (a) for ^{16}O + ^{116}Sn reactions (b) for ^{16}O + ^{124}Sn reactions. The lines represents best fit statistical model calculation (using CASCADE code). The individual spectra have been scaled appropriately for better visualization.

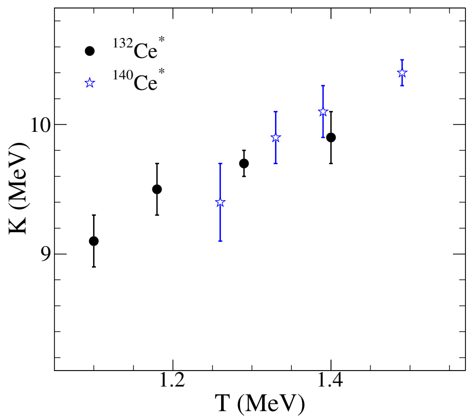

FIG. 2: Inverse level-density parameter as function of temperature for ^{132}Ce* and ^{140}Ce* nuclei.

tors beyond 8 MeV was performed using in-beam data from earlier measurements [2]. SSB detectors were energy calibrated using ^{229}Th radioactive source and in-beam using elastic scattering events from ^{16}O + ^{197}Au reaction at different beam energies. Particle identification in CsI(Tl) detector and surface barrier telescope was achieved using pulse shape discrimination and partial energy loss method, respectively. α-particle energy spectra were extracted from CsI(Tl) detectors and $\Delta E - E$ telescopes, placed at different laboratory angles. It is observed that α-particle energy spectra from the pair of CsI(Tl) and SSB telescope, having same angle with respect to beam direction overlap quite well which further confirm the accuracy of energy calibration of both detectors. The α-particle energy spectra were converted to centre-of-mass (c.m.) frame using the standard Jacobian. The c.m. spectra of detectors at different laboratory angles overlapped very well, indicating dominant compound nuclear evaporation. The centre-of-mass energy spectra of different laboratory angle detectors were averaged at each beam energy. Typical α-particle energy spectra are shown in Fig.1.

Results and Discussions

Averaged c.m. α-particle spectrum at each beam energy was compared with statistical model calculations carried out using CASCADE code. The inverse level density parameter, K, was kept as a free parameter. The χ^2 minimization was performed in the α-particle kinetic energy region above 18.5 MeV as marked by two vertical line in Fig.1.

Experimental α-particle energy spectra along with best fitted statistical model calculations are shown in Fig.1 for both the compound nuclear systems at different beam energies. An averaged temperature was determined at each beam energy using the recipe discussed in Ref. [3]. The best fit inverse-level density parameter is plotted as a function of nuclear temperature as shown in Fig.2. It is observed that in contrast to earlier work [3], the level-density parameter is same within the experimental uncertainties for two widely different isotopes of Ce in the present work. It might be noted here that the present data have been analyzed using the analytical statistical model code, CASCADE, whereas the earlier data presented in Ref. [3] which showed a significant isospin dependence were analyzed using a Monte Carlo statistical model code, PACE2.

Detailed data analysis using both statistical model codes, analytical (CASCADE) and Monte Carlo (PACE2), will be presented.

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