Anomolous alpha particle evaporation spectra in ^{16}O + ^{116,118,124}Sn reactions

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Introduction

Undesratanding of nulcera level density is very important from the stand points of nuclear physics and astrophysics. It is a key ingredient in the prediction of nuclear reaction cross sections using statistical models. Therefore, it is also very much important input parameter in designing new nuclear technologies. At higher temperatues, information about the nuclear level densities are obtained by analyzing the particle evaporation spectra within the framework of a statistical models. It is often necessary to have an accurate estimate of the NLD of highly excited nuclei as a function of the excitation energy [1, 2], angular momentum [3], isospin [4] and other constants of the motion. It is quite appropriate to described the NLD in phenomenological framework, where its excitation energy dependence is given by Fermi-gas (FG) approximation [5].

$$\rho(E_{ex}) \simeq \frac{\pi}{12} \frac{\exp(2\sqrt{aE_{ex}})}{a^{1/4} E_{ex}^{5/4}} \tag{1}$$

where E_{ex} is the excitation energy of the nucleus and a is nuclear level density (NLD) parameter related to single particle density at the Fermi energy $g(\varepsilon)$ through the relation $a = (\pi^2/6)g(\varepsilon)$. It is more convenient to use inverse level density parameter, $K = A/a$, where A is mass of the nucleus.

Recently, investigations for temperature and isospin dependence of inverse level density parameter K in mass regions A$\sim$110 were carried out [6]. α-particle evaporation spectra in ^{16}O+^{94,100}Mo reactions were measured. Inverse level density parameter, K, was determined for ^{106}Cd and ^{112}Cd isotopes by simulating high energy tail of the -particle evaporation spectra with statistical model code PACE2. An overall increasing behavior of the K value is observed with increasing temperature in the range of 1 to 3 MeV. It is observed that in the temperature region below 2-MeV, the parameter K is higher for the neutron rich ^{112}Cd than ^{106}Cd by around 1 MeV. Semiclassical calculations were performed which included deformation dependent level density parameter. These calculations also reproduce the K values as a function of temperature determined from the statistical model analysis of α-particle evaporation spectra.

In order to improve the understanding of isospin dependence of the NLD parameter, above work has been further extended in the mass region of A$\sim$132. Alpha particle energy spectra have been measured in ^{16}O + ^{116,118,124}Sn reactions with beam energies in the range of 95 to 136 MeV.

Experimental Details and Data Analysis

The experiment was carried out using ^{16}O beam from BARC-TIFR Pelletron Linac facility at Mumbai. ^{16}O beam with energies, 95.5, 104.9, 114.6, 124.6 and 136 MeV was bombarded on self sporting foils, ^{116}Sn,^{118}Sn and ^{124}Sn with thickness 430 μg/cm^2, 320 μg/cm^2, and 1.9 mg/cm^2, respectively. Isotopic enerichment of all the foils was more than 95%. α-particles were detected using ten CsI(Tl) detectors, mounted in the backward hemisphere of Charge Particle Detector Array (CPDA) [7] at laboratory angles of 115°, 124°, 134°, 140°, 145°, 150° and 155°. Two silicon surface barrier detectors with each having solid angle of $\sim$ 0.30 msr were placed at $\pm 20^o$ for Rutherford normalization purpose. 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) detectors beyond 8 MeV was performed using in-beam data from earlier measurements [3]. Particle identification

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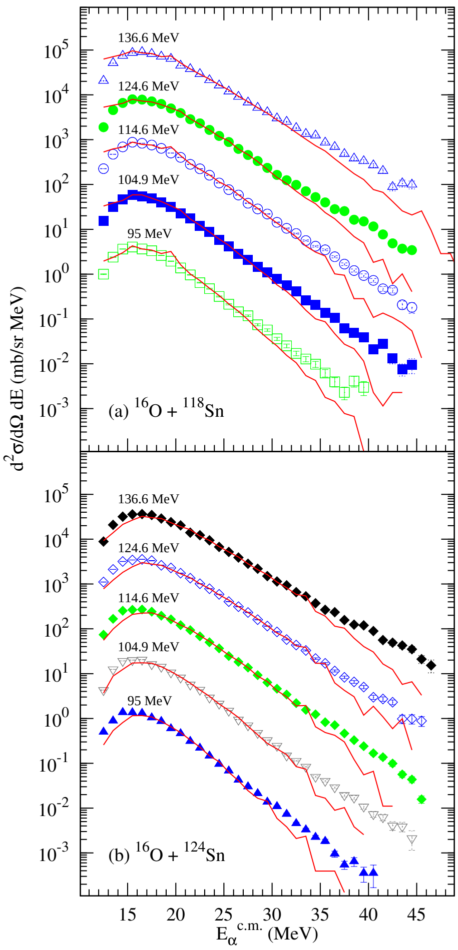

FIG. 1: Experimental α particle energy spectra of different excitation energies along with PACE2 calculations for ^{16}O+^{118,124}Sn systems. The individual spectra have been scaled appropriately for better visualization. Beam energies are mentioned along with each curve.

in CsI(Tl) detectors were achieved using Ballistic deficit technique [8]. It requires two different shaping amplifiers, one with short shaping time (0.2 μs) and another with long shaping time (3.0 μs). The correlation between long and short integration time resulted in different slope for different particles. Data were acquired in event by event mode using VME-based data acquisition system.

The measured α-particle energy spectra at different laboratory angles were converted to centre-of-mass frame using the standard Jacobian transformation. 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-paricle spectra calculated using statistical model code PACE2. The inverse level density parameter, K, was kept as a free parameter to obtain a best fit using χ^2 minimization technique.

Results and Discussions

Typical experimental α-particle energy spectra along with best fit PACE2 calculations are shown in Fig. (1) for ^{16}O+^{118,124}Sn systems. PACE2 predictions are unable to explain the high energy tail above 30 MeV of the evaporation spectra. α-particle spectra show an enhancement in comparison to the PACE2 predictions in the tail region for all the three reactions. Detail data analysis and theoretical calculations using PACE2 and CASCADE codes will be presented.

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