Systematics of Nuclear Level Density Parameter around A~ 50-80

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Introduction

Study of the Nuclear level density (NLD) parameter 'a' is of special importance as it represents an important ingredient of the statistical model, which is required for the nuclear calculations in heavy-ion induced reactions, astrophysics applications and fission or fusion reactor designs. Recently many advances have been made in the theory to refine the knowledge of this parameter, so it is necessary to carry out experimental investigations of nuclear level density at various excitation energies and angular momentum domains. Experimental information on 'a' comes from two major sources: thermal neutron capture resonance at low excitation energy and angular momentum [1]; and particle evaporation spectra in heavy-ion fusion reactions at high excitation energy and angular momentum, analyzed in the framework of the statistical model [2]. Recently Y. K. Gupta *et al.* [3] have demonstrated an experimental technique for the determination of K in the mass region A~180.

In this work, we have analyzed the alpha particle evaporation spectra for different asymmetric target-projectile combinations corresponding to mass range A~50–80 and excitation energy range of 65-85 MeV. The statistical model code PACE2 [4] was used to determine the values of inverse level density parameter (K=A/a) by comparing the experimental spectra with the code predictions.

Experimental Techniques

The reaction ^{16}O + ^{48}Ti (E_{lab}=76MeV) studied in the present work populates the compound nucleus (CN) ^{64}Zn at excitation energy, E*~67MeV. The Experiment was performed with 15UD pelletron at IUAC, New Delhi, India. A ^{48}Ti foil of 1.0 mg/cm^2 thickness was used as target. The experiment was done using general purpose scattering chamber (GPSC). Light charged particle spectra were recorded using ΔE-E telescopes (ΔE=40 μm, E=5mm and 6mm) [5]. The spectra were taken at 30°, 36°,42°,48° and 54°.

Results and Discussion

After the energy calibration, data from the telescopes were used to obtain the two dimensional plot between total energy deposited ($E_{Tot.}$) along X-axis and ΔE along Y-axis, was used for charged particles identification. A BANANA gate was put to get the α-particle spectrum. All other systems (A~50-80) reported in this work were taken from the previously published works [5-11]. The experimental techniques in the data extraction from these systems were similar to the techniques described here.

The theoretical spectra were generated by using standard statistical model code PACE2 after simulating for a minimum of 9999 events. The level density used in PACE2 calculations is given by:

$$\rho(E_X, J) = \frac{(2J+1)}{12}\sqrt{a}\left(\frac{\hbar^2}{2\Im}\right)^{3/2}\frac{\exp(2\sqrt{aU})}{U_{ex}^2}$$

where $U_{ex} = E_X - \Delta P(Z) - \Delta P(N)$ and $U = U_{ex} - E_{rot}$, where $E_{rot} = (\hbar^2/2\Im)J(J+1)$ is the rotational energy. ΔP(Z) and ΔP(N) are the ground state pairing energy differences obtained from Gilbert and Cameron's compilation for odd – even mass differences. The moment of inertia $\Im$ was calculated using Sierk rotating liquid drop model [12]. The transmission coefficient as a function of energy and orbital angular momentum of the emitted particle is conventionally generated by the optical model potentials (OMPs). In these calculations for α-particle emission, the OMP parameters of Igo and Huizenga [13] were used. The initial angular momentum distribution for the compound nucleus was obtained from the Bass systematic [14] for the fusion cross-section together with an angular momentum diffuseness of ~ $0.3\hbar$.

In the present work, we have focused on deriving K for different systems by comparing the experimental spectra with the corresponding PACE2 predictions obtained using the different values of K. The normalization required for this purpose was done by matching the area under the predicted spectra with that of the experimental spectra for the same energy interval. We have used the least-squares method for analyzing the data to extract the most probable values and corresponding variance in the parameters being determined. The α-particle energy spectrum is a non-linear function and, in this case, least squares solutions are determined by minimizing the statistical variance given by:

$$S(K) = \sum_{i=1}^{N} [\,Y_i - f(K, E_i)]^2 / \sigma_i^2$$

where Y_i is the double differential cross section in ith energy bin, $f(K, E_i)$ is the result of PACE2 calculation for the same energy bin for K after normalization of the spectrum, σ_i is the statistical error in Y_i. We have evaluated S(K) as a function of K using the above equation and, in most cases, a parabolic dependence of S(K) on the parameter 'K' was observed. Best–fit parameter 'K' was determined from the minimum of the parabola. The solid circles and solid lines shown in Fig.1(a) are experimental and PACE2 spectra (for K=11) respectively, after the normalization for the system $^{16}O + ^{48}Ti$ and Fig.1(b) shows the nearly parabolic variation of S(K) with the parameter K.

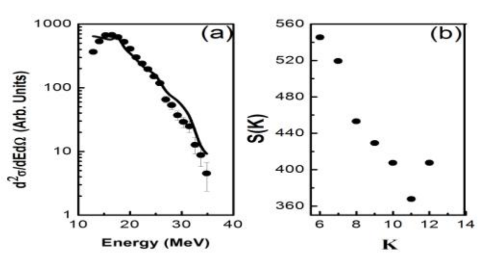

Fig. 1 (a) Comparison of experimental α-spectrum at 54° for the system $^{16}O+^{48}Ti$ with theoretical spectra as described in the text. (b) Variation of S(K) with K for the same system.

Table 1: The reactions studied in the present work and relevant experimental parameters.

System	ER	E* (MeV)	Ref. No.	K (MeV)
$^{16}O+^{48}Ti$	^{60}Ni	67	5	11
$^{27}Al+^{32}S$	^{55}Co	67	6	8
$^{12}C+^{45}Sc$	^{53}Mn	84	7	9
$^{16}O+^{54}Fe$	^{52}Fe	85	8	14
$^{16}O+^{64}Zn$	^{66}Ge	75	9	7
$^{16}O+^{45}Sc$	^{57}Co	84	10	8
$^{16}O+^{40}Ca$	^{76}Kr	76	11	10

The determination of K for more such asymmetric systems in the mass region A~50-80 and various excitation energies is in progress.

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