Nuclear level density parameter in the Z∼52 and Z∼82 shell regions

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Introduction

Studies of evaporated particle spectra from heavy ion reactions, especially the high energy part of alpha particles, give direct information about the nuclear level density (NLD) parameter a and its dependence on excitation energy and angular momentum. Experimental information on excitation energy and angular momentum dependence of NLD parameter, however, are severely limited. Also, the study of level density is important for heavy nuclei at higher angular momentum because this is directly related to the issue of stability of heavy nuclei during their synthesis.

In our previous works, alpha particle spectra up to energy 30 MeV were measured in a number of heavy ion reactions[1, 2]. In the present work, the detector systems were optimized to measure the alpha particle spectra well beyond this limit and also made improved statistical model comparisons employing variety of NLD prescriptions using the Empire3.1[3] and PACE4 codes[4]. The reactions ^{11}B + ^{115}In and ^{11}B + ^{197}Au were used in the present work to populate the desired residual nuclei of Z=52 and Z=82. Preliminary results from the present work are reported here.

Experimental details

The experiment was carried out using ^{11}B beam of energy 53 MeV and the Charged Particle Detector Array (CPDA) at BARC-TIFR Pelletron LINAC facility. Self supporting targets ^{115}In, ^{197}Au and ^{181}Ta of thickness 800 μg/cm^2, 720 μg/cm^2 and 10 mg/cm^2 were placed on a ladder at the center of the CPDA chamber. The charge particles emitted in the reactions were detected by using eight $\Delta E - E$ detector telescopes (silicon pad (300 μm) - CsI(Tl) (10 mm)) of solid angle 13 msr mounted in the reaction plane in the laboratory angular range of 85° to 169°. A surface barrier detector of solid angle 0.02 msr was mounted at θ_{lab}=30° to measure the Rutherford scattering events for normalization purpose. The silicon pad detectors energy calibrations were carried out using alpha particles from ^{228,229}Th source and in-beam measurement using Rutherford back scattering (RBS) from ^{181}Ta at a low beam energy (39 MeV ^{11}B). Simulations of RBS spectra were made using SIMNRA code[5]. CsI (Tl) detectors were energy calibrated using alpha particle spectra from ^{228,229}Th source after removing silicon pad detectors at the end of the run.

Data analysis and Results

Experimentally measured alpha particle energy spectra were converted from laboratory to centre of mass system by using the standard Jacobian. The measured alpha particle spectra were compared with statistical model code of Empire 3.1 and PACE4. In Empire code there are several options for level density calculations and we used the Generalized Superfluid Model (GSM) and the default Enhanced GSM (EGSM) options. The form of level density used in the GSM options calculation for an excitation energy is given by:

$$\rho(E_x, J, \pi) = \frac{e^S}{2\sqrt{det^2}} \frac{2J+1}{\sqrt{8\pi\sigma^2_{eff}}} e^{(-\frac{(\frac{J+1}{2})^2}{2\sigma^2_{eff}})}; \quad (1)$$

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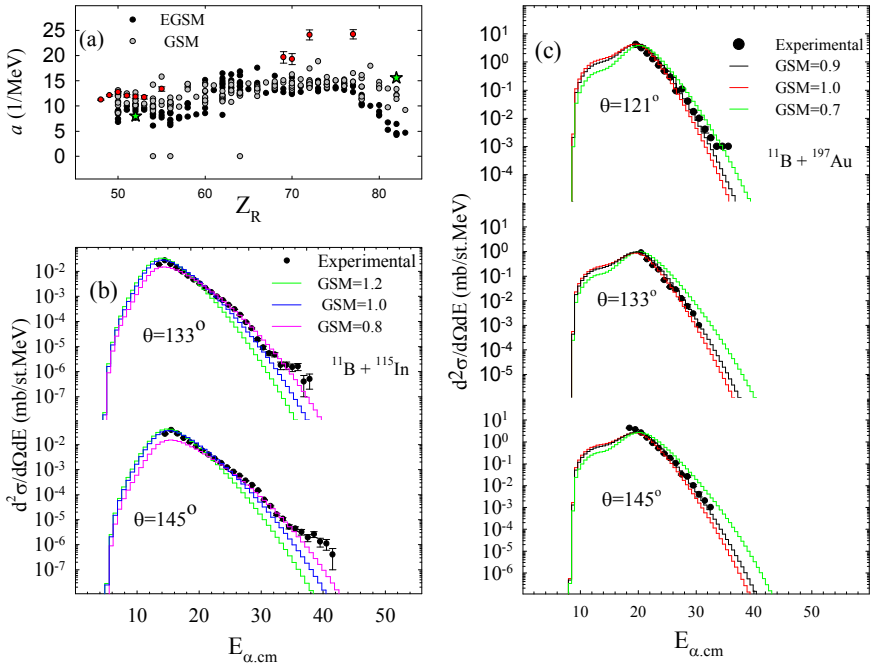

FIG. 1: Alpha particle energy spectra in center of mass system along with result of EMPIRE code calculation (solid histogram) for ^{11}B + ^{115}In system in Fig.1(b) and for ^{11}B + ^{197}Au system in Fig.1(c). In Fig.1(a) experimental level density parameter a systematics as a function of Z of residual nuclei are shown.

where J is the spin and σ^2_{eff} is the effective spin cut off parameter and Det is given by

$$Det = 144a^3T^5/\pi. \quad (2)$$

The code uses the following form of asymptotic value of level density parameter $\tilde{a}$

$$\tilde{a} = \alpha A + \beta A^{2/3}, \quad (3)$$

where α= 0.103 and β= -0.105.

The experimentally measured alpha particle spectra after converting to center of mass system and that simulated by using Empire code with GSM options are given in Fig.1 (b) and (c). For comparison of high energy tails or slopes, yield normalization factors were used for the simulated spectra. The derived NLD parameter a for A $\sim$ 122 and A $\sim$ 204 systems from GSM model are 8.0 and 15.6 respectively. The present results are shown by stars in Fig.1(a) and these are consistent with results from the literature. The detailed analysis and results will be presented.

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References

[1] Y.K. Gupta *et al.,* Phys. Rev C **80**, 05461 (2009).
[2] Bency John *et al.,* Phys. Rev C **63**, 05430 (2001).
[3] M.Herman *et al.,* Nuclear Data Sheet **108**, 12 (2007).
[4] A. Gavron, Phys. Rev C **21**, 1 (1980).
[5] M. Mayer, AIP Conf. Proc. **475**, 541 (1999).