Study of excitation energy dependence of nuclear level density parameter

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Introduction

Nuclei with magic number of nucleons are more stable than the neighboring nuclei. This stability comes because of shell correction. Shell correction modifies the energy levels and causes deviation from the predictions of the liquid drop model (LDM) as well as alters the nuclear level density (NLD). Calculations by Ramamurathy *et al.* [1] show that the entropy of the nucleus with shell correction can be defined as $S = 2\sqrt{(a \pm \Delta_a(E_x))(E_x \pm \Delta_E(E_x))}$ where, "a" is the NLD parameter of the nucleus and "E_x" is the excitation energy. "$\Delta_a(E_x)$" and "$\Delta_E(E_x)$" are corrections in the NLD parameter and excitation energy due to shell effect. Later, Ignyatuk *et al.* [2] prescribed an expression for NLD parameter as

$$a = \tilde{a}\left[1 - \frac{\Delta_S}{E_x}(1 - e^{-\gamma E_x})\right]$$

where, $\tilde{a}$ is the asymptotic value of NLD parameter, Δ_S is the shell correction energy and γ is the damping parameter. The shell effect on NLD is more at the lowest excitation energy and then vanishes gradually as the energy increases. It is important to know experimentally how the NLD parameter changes with energy, especially for a closed shell nuclei. For lower excitation energies several measurements have been reported but measuring NLD parameter in the range of 30 – 40 MeV excitation energy is difficult through compound nucleus (CN) fusion. Heavy ion fusion populates CN at a higher excitation energy leaving this region less accessible. In a recent study by P.C. Rout *et al.* [3] transfer induced reaction was used to populate nucleus at 19 – 23 MeV excitation energy and effect of shell closure at this energy range was observed. In the present study, we have populated CN by fusion reaction and excitation energy of the intermediate nuclei is determined after first chance α-emission to investigate excitation energy dependence of the NLD parameter. Evaporated neutron spectra were measured following alpha evaporation for obtaining NLD parameter for the reaction ^{11}B + ^{197}Au, populating CN ^{208}Po. This CN after evaporating an α-particle populates intermediate nucleus ^{204}Pb. The ^{204}Pb has magic number of Z=82. Our aim is to study the excitation energy dependence of NLD parameter for closed shell nuclei.

Experimental detail

The experiment was carried out at the BARC-TIFR Pelletron-LINAC facility. Pulsed beam of ^{11}B at energy of 63 MeV was bombarded on a 2.8 mg/cm^2 thick Au target. For charged particle detection, two (ΔE, E) telescopes having silicon strip detectors (5.0×5.0 cm^2, each with 16 strips) were placed at ±150^o angle with respect to the beam direction. The ΔE detectors were 50 μm thick whereas E detectors had thickness of 1.5 mm. The α-particles were clearly separated from other charged particle by ΔE-E spectra as is shown in Fig.1. Neutrons were detected, in coincidence with charged particle, using 15 liquid scintillator detectors, placed at a distance of 70 cm covering angular range of 58.3^o to 143.3^o with respect to beam direction. To block fission fragments from reaching the ΔE telescope detector, 4.5 mg/cm^2 thick Al foils were kept in front of the strip detectors. Neutron time-of-flight (TOF) was recorded with respect to the beam pulsing signal

RF. The time of flight information was converted to the energy of the neutron. To distinguish between neutrons and γ, pulse shape discrimination (PSD) technique was used. In TOF versus PSD spectra neutrons were clearly separated from the γ (shown in Fig. 2).

Analysis and result

For calculating the neutron energy, TOF was obtained by taking the γ peak as reference. Neutron energy was further converted to centre of mass energy and spectra for all the 15 detectors were then added to obtain the neutron energy spectrum. The neutron spectra were then corrected to take care of the energy dependent efficiency of the neutron detectors. The telescope detectors (E, ΔE) were calibrated using ^{229}Th source. Energy loss in the Al foil for α-particle

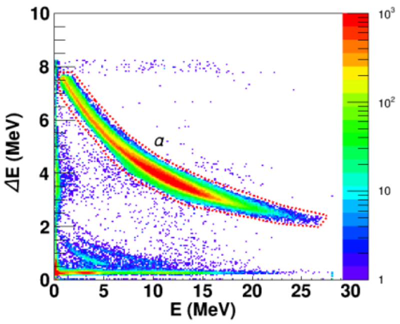

Fig. 1 ΔE vs. E spectrum for a single strip.

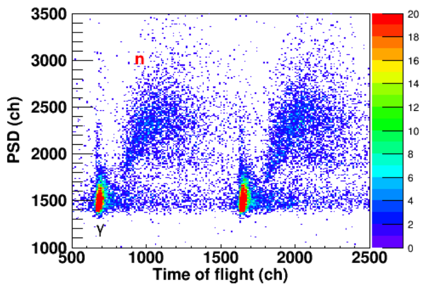

Fig. 2 Time of flight vs. PSD spectrum.

is taken into consideration while obtaining the α-spectrum. A tight gate on α was put to select neutrons that are in coincidence with α. Depending on the α energy, excitation energy of ^{204}Pb was in the range 30-40 MeV. Events on the right side of the α peak come mostly from first chance α emission. Different energy cuts on α spectrum on the right side of the peak were put to obtain neutron spectra at different excitation energies. In Fig. 3, α-particle energy spectrum as well as neutron spectra at excitation energies of 31.6 and 36.2 MeV are shown. These two neutron spectra do not show any significant difference in the slope though their excitation energies differ by 4.6 MeV. Theoretical calculations are in progress to obtain the NLD parameters as a function of excitation energy. Detailed analysis and results will be presented during the symposium

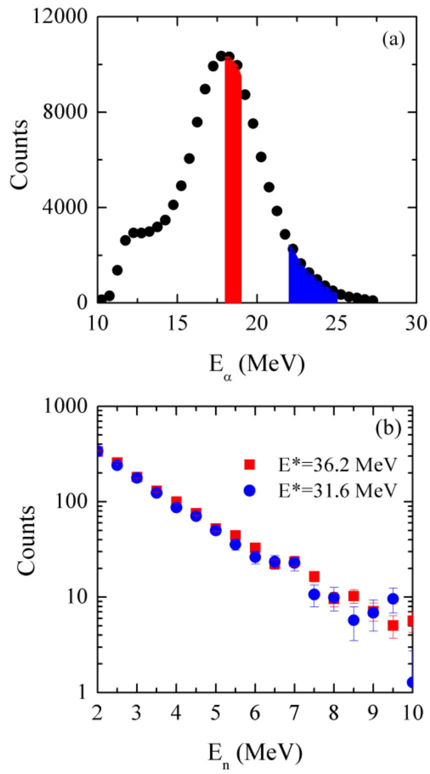

Fig. 3 (a) α-particle energy spectrum in centre of mass with two energy cuts shown by filled area. (b) Neutron energy spectra corresponding to two α-particle energy cuts shown in (a).

References

[1] V. S. Ramamurthy et al., Phys. Rev. Lett. 25, 6 (1970).

[2] A. V. Ignatyuk et al., Nucl. Phys. 21, 255 (1975).

[3] P. C. Rout et al., Phys. Rev. Lett. 110, 062501 (2013).