‘Unexpected’ nuclear temperature from ^{6}Li fragment spectra in heavy ion nuclear reactions

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Introduction

The temperatures of the residual nuclei obtained by fitting progressively heavier evaporation fragment spectra should be significantly lower because the heavier fragments take away significantly more kinetic energy than those carried away by the lighter ones. This is also apparent from the formula given by

$$U_{Thermal}(residual) = (E_{c.m.} - Q) - \frac{\lambda(\lambda+1)\hbar^2}{2I} - E_{rot}(spin) \quad ....(1)$$

where $E_{c.m.}$, Q, $E_{rot}(spin)$, I and λ denote the entrance channel center of mass energy, Q-value of the reaction, spin rotational energy of the nuclei, moment of inertia and orbital angular momentum of the system, respectively. Our measured values with A=105 compound nuclear system (^{105}Ag) formed by two different entrance channels $^{16}O+^{89}Y$ and $^{12}C+^{93}Nb$ [1,2], however, do not follow [3,4] this expected trend. As could be seen from the straight linear least square fits to both, experimentally observed values and those from CASCADE code calculations, as displayed in figure Fig. 1, the temperatures obtained from heavier fragment spectra are found to be significantly higher. Most strikingly, the extracted temperatures from ^{6}Li fragment spectra are found to be anomalously higher than those extracted from both heavier and lighter fragments in the immediate neighborhood. With an aim to check and verify this striking behavior, we carried out an experiment with $^{16}O+^{93}Nb$ system in the same mass region (A~100).

The experiment

The experiment[1]was carried out at VECC, Kolkata, India. A 5 pnA 116 MeV ^{16}O beam from the Variable Energy Cyclotron was bombarded on a 1.2 mg/cm^2 thick ^{93}Nb target. Emitted particles from alpha to oxygen were detected using ΔE-E tescopes in the angular region from $\theta_{c.m.}$=100^o to 150^o.

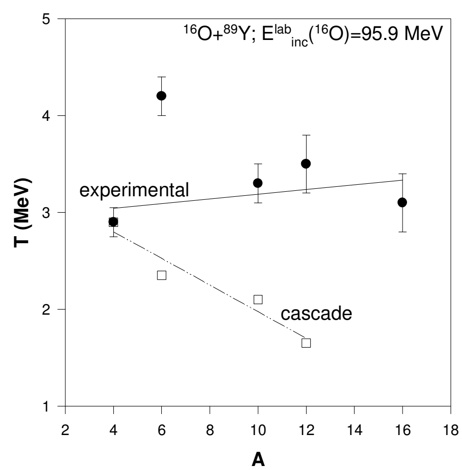

Fig 1: Temperature as a function of evaporation fragment mass number for $^{16}O+^{89}Y$ reaction at $E_{c.m.}$=81.4 MeV. Solid sphere and open square correspond to experimental and CASCADE calculation, respectively. In the case of experimental distribution, data point for ^{6}Li has been excluded from the straight linear least square fit.

Results and discussions

Angle integrated cross-sections as a function of exit channel kinetic energy in the center of mass system were fitted with Moretto’s algebraic formula [5] for statistical emission of particles as given below:

$$P(x) \propto \exp\left(-\frac{x}{T}\right) erfc\left(\frac{p-2x}{2\sqrt{pT}}\right) \quad \dots \quad (2)$$

Where

$x = E_{kin}(c.m.) - V_C$, and $E_{kin}(c.m.)$, V_C, p, T and, $P(x)$ are the exit channel center of mass kinetic energy, Coulomb barrier, amplification parameter, temperature of the ensemble of the residual nuclei and the corresponding probability of the emission of the particle, respectively. Typical fits for ^{6}Li spectrum is shown in Fig. 2. The temperatures obtained by fitting different fragment spectra with eq.(2) are displayed in Fig. 3. Again it is surprising to note that the temperature derived from the ^{6}Li spectra is significantly higher than those exhibited by the neighboring fragments.

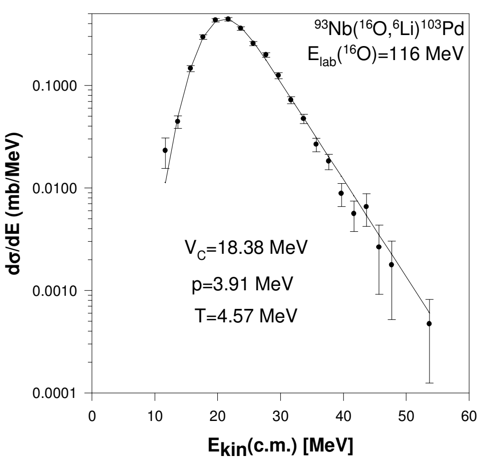

Fig 2: Experimental angle integrated ^{6}Li spectrum from ^{16}O+^{93}Nb reaction at $E_{c.m.}$ = 99 MeV; the smooth curve corresponds to eq. (2).

Among the different ejectiles studied, e.g., alpha, ^{6}Li, ^{9}Be, ^{10}B, ^{12}Cand ^{16}O, alpha particle is the most stable one and ^{6}Li is the one highly crowded with low-lying excited states. This structural point of view may be a factor in understanding the observed temperature anomaly from ^{6}Li spectra. However, for a clear picture on the problem involved, it seems important to extend investigations involving other systems including lighter ones (A~50). Detection and consequent study on fragment proton spectra seems to be important for better understanding on the nature of variation of the temperature as a function of ejectile.

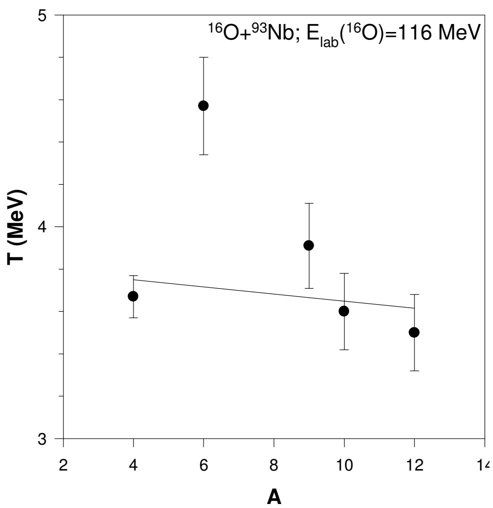

Fig 3: Temperature as a function of evaporation fragment mass number for ^{16}O+^{93}Nb reaction at $E_{c.m.}$=99 MeV. Solid sphere corresponds to experimental data and the smooth curve is the straight liner least square fit to the data. Data point for ^{6}Li has been excluded from the fit.

Acknowledgement

A. De acknowledges the support received from UGC (ref No. F.PSW-011/07-08(ERO)) and collaborative research scheme no. UGC-DAE-CSR-KC/CRS/2009/NP-TIFR02.

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