Isospin effects on the mass and charge distributions in the decay of $^{118,134}Ba^*$ compound systems

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Introduction

Enormous literature has shown that the compound nucleus formed in low energy heavy-ion reactions is hot and has high angular momentum. Its decay populates the whole mass/charge range from the evaporated light particles (LPs: n, p, α, and γ), intermediate-mass fragments (IMFs: $3 \leq Z \leq 15$) to fission fragments (FFs: $Z > 15$). To understand the complex aspect of disintegration of the compound nucleus, number of theoretical approaches have been developed. The emission of LPs can be nicely understood in Hauser-Feshbach approach, where emphasis has been given to the role of phase space available at each step of whole cascade. Further, to understand the fragment emission mechanism, a number of approaches has been developed, e.g. multistep HF model and transition state model for IMFs emission, dinuclear model etc. ([1] and references there in). In these models LPs and fragment emission are treated separately. But, in the dynamical cluster decay model (DCM) ([2] and references there in), the emission of LPs, IMFs and FFs is treated on equal footings i.e. first the fragments are formed inside the nucleus and then they penetrate through the interaction barrier.

In this paper, isospin effects have been studied on the mass and charge distributions of the decay of $^{118}Ba^*$ (called neutron poor) and $^{134}Ba^*$ (called neutron rich) systems formed in the reactions ^{78,86}Kr+^{40,48}Ca at 10 MeV/A using DCM. Here, in DCM we have used new bulk and asymmetry constants of Seeger's formula fitted by one of us DSV *et al.* [3] to reproduce the recent experimental [4] and theoretical [5] (where experimental values are not available) mass excess for the ground state of 9318 nuclei. The empirical estimates of Myers and Swaitecki [6] is used for the shell corrections with shell closures for proton and neutrons at 2, 8, 14, 28, 50, 82, 126, 184 and 2, 8, 14, 28, 50, 82, 126, 184, 258, respectively. The calculated charge distribution of decay cross-section of $^{118}Ba^*$ and $^{134}Ba^*$ is compared with the experimental data [7].

Formalism

The decay cross-section is defined as

$$\sigma = \frac{\pi}{k^2}\sum_{\ell=0}^{\ell_c}(2\ell+1)P_0P; \quad k=\sqrt{\frac{2\mu E_{cm}}{\hbar^2}} \quad (1)$$

where, P_0 is the preformation probability and is obtained from the solution of stationary Schrödinger equation in mass asymmetry coordinate η for the fragmentation potential (which is sum of binding energies, proximity potential, Coulomb potential and centrifugal potential of the interacting nuclei), P is the penetrability, refers to R-motion and ℓ_c is the critical angular momentum given in term of reduced mass μ, incident energy E_{cm}, entrance channel mass asymmetry coordinate η_{in} & first turning point R_a as

$$\ell_c = R_a\sqrt{2\mu[E_{cm} - V(R_a,\eta_{in},\ell=0)]}/\hbar \quad (2)$$

Calculations and results

First of all we have calculated the fragmentation potential of $^{118}Ba^*$ and $^{134}Ba^*$ as a function of light fragment mass number A_2 (for both LPs and IMFs) (not shown here) and

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*Electronic address: `dsverma@cuhimachal.ac.in` it is found that the outgoing channels changes with isospin e.g. fragments of $^{118}Ba^*$ system at A_2 = 1, 9, 17, 19, 21 and 27 changes from ^1H, ^9B, ^{17}F, ^{19}Ne, ^{21}Na and ^{27}Si to ^1n, ^9Be, ^{17}O, ^{19}F, ^{21}Ne and ^{27}Al of $^{134}Ba^*$ system, respectively.

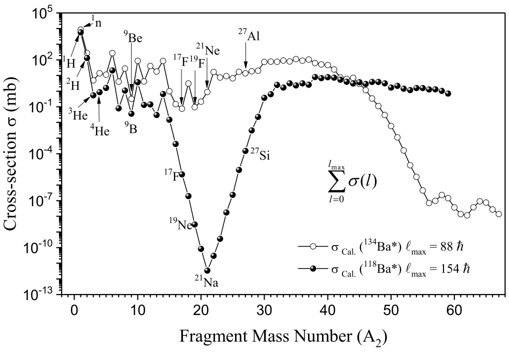

FIG. 1: Mass distribution of the decay cross section of $^{118}Ba^*$ & $^{134}Ba^*$, summed up to ℓ_{max}-values.

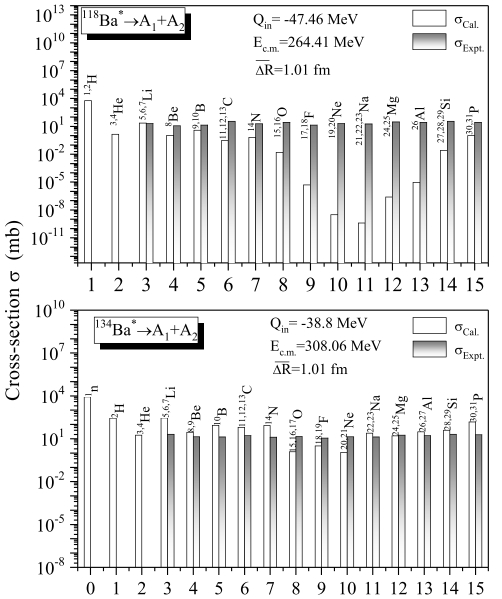

FIG. 2: The charge distribution of the calculated and experimental decay cross section for $^{118}Ba^*$ and $^{134}Ba^*$ systems

Fig. 1 shows the calculated mass distribution of the decay cross-section $\sigma(A_2)$, summed over all angular momentum up to ℓ_{max} (=ℓ-value at which $P_0 \to 0$) for $^{118}Ba^*$ (line with solid sphere) and $^{134}Ba^*$ (line with empty circle) systems. The comparison of the mass distribution of decay cross-section shows that the magnitude as well as structure of $\sigma(\mathrm{A}_2)$ for LPs and IMFs upto A_2=15 remains nearly same for both systems. Beyond A_2=15, there is a sudden fall in σ-values upto A_2=21, by an order of around 10^9, and regain the same order over mass range nearly $A_2 = 22 - 31$ for $^{118}Ba^*$, while for $^{134}Ba^*$ the magnitude of decay cross-section remains almost same till A_2=46 and then there is a sudden fall, by an order of $\approx 10^6$. In other words, with the increase in isospin asymmetry the asymmetric fission is more probable than symmetric one.

Fig. 2 shows the charge distribution of decay cross-section for the fragments of charge Z=0-15 of hot and rotating nuclei $^{118}Ba^*$ and $^{134}Ba^*$. The comparison of Fig. 2 (a) and (b) shows that (i) neutron is emitted in neutron rich system in place of proton in neutron poor system. (ii) Isotopic contribution changes from neutron poor to neutron rich system. The contributing isotopes for each charge number is shown in the histogram.

Finally, we conclude that isospin influences both charge and mass distributions in the decay of the compound systems and our calculations ($\sigma_{Cal.}$) reproduces the experimental ($\sigma_{Expt.}$) charge distribution nicely, except for few decay channels ($Z_2 = 9 - 13$) of $^{118}Ba^*$ compound system.

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