Isospin effects on the decay of $^{118,122,134}Ba^{*}$ isotopes

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Introduction

One of the importance of studying the nuclear reaction is to study the effects of isospin degree of freedom on reaction mechanism that is the effect of the incoming channel N/Z ratio on the outgoing fragments in a given channel. The effect of N/Z ratio of the compound nucleus is studied here by considering $^{118,122,134}Ba^{*}$ isotopes formed in the reaction of $^{78,82,86}Kr+^{40,40,48}Ca$ at centre of mass energies, E_{cm} =264.41, 268.85 and 308.06 MeV, which corresponds to 10 MeV/nucleon energy [1]. The study is done by using dynamical cluster decay model, DCM ([2] and references there in), where $\overline{\Delta R}$ is the only parameter of the model and is fixed arbitrarily at 1.01 fm for all isotopes of barium. Out of all possible fragments combination, the outgoing channel contains only the energetically favoured combination. In the calculations of decay cross-sections, the number of partial waves to be included are obtained by plotting the preformation probability P_0 or σ as a function of angular momentum ℓ and from the plot it is found that at a particular value of ℓ, below critical angular momentum ℓ_c, the $P_0 \to 0$ or $\sigma \to 0$. This angular momentum is called ℓ_{max} and gives the number of partial waves to be included in the decay cross-section. It is well established that the compound nucleus formed carries large angular momentum and is in excited state. The de-excitation of the CN takes place with the emission of both light particles (LPs: Z$\leq$ 2) and intermediate mass fragments (IMFs: $2 < Z \leq 15$, here). Here, in this work we have calculated the decay cross-section for both LPs and IMFs and a comparison is made between the three isotopes of Ba under study.

Formalism

The decay cross-section defined by DCM ([2] and references there in) is,

$$\sigma(E_{cm},\ell) = \frac{\pi\hbar^2}{2\mu E_{cm}} \sum_{\ell=0}^{\ell_c} (2\ell+1) P_0 P \qquad (1)$$

where, P_0 is the preformation probability related to η-motion and is obtained from the solution of stationary Schrödinger equation in η-coordinate with temperature dependent collective fragmentation potentials (which include sum of binding energies, proximity [3], Coulomb and centrifugal potential terms) at a fixed $R = R_a = C_t(\eta,T) + \overline{\Delta R}(T)$, given as

$$P_0(A_i) = |\psi(\eta(A_i))|^2 \sqrt{B_{\eta\eta}} \left(\frac{2}{A}\right) \qquad (2)$$

where ($C_t = \sum C_i$, the Süssman central radii) $i = 1, 2$ for two out going fragments, the penetrability P, referring to R-motion, is WKB integral solved analytically with R_a and R_b as the first and second turning point, satisfying $V(R_a) = V(R_b) = Q_{eff}$, the effective Q-value for outgoing fragments, given as

$$P = \exp\left[-\frac{2}{\hbar}\int_{R_a}^{R_b} \{2\mu[V(R) - Q_{eff}]\}^{1/2} dR\right] \qquad (3)$$

The critical angular momentum ℓ_c in terms of incident energy E_{cm}, reduced mass μ and the first turning point R_a of the entrance channel η_{in} is given by

$$\ell_c = \frac{R_a}{\hbar}\sqrt{2\mu(E_{cm} - V(R_a,\eta_{in},\ell=0))} \qquad (4)$$

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*Electronic address: `dsverma@cuhimachal.ac.in` with μ as the reduced mass and η_{in} as the entrance channel mass asymmetry.

Calculations and results

Barium isotopes considered for the study of isospin effects are $^{118,122,134}Ba^*$ andP_0, P and decay cross-section are the quantities on effects have been observed. The calculations have been done at fixed $\overline{\Delta R}$ =1.01 fm and the ℓ_c-values to the corresponding center of mass energies E_{cm} =264.41, 268.85 and 308.06 MeV are 153, 158 and 191$\hbar$. But, the cross-sections have been added up to the respective ℓ_{max} values i.e up to 76, 90 and 168 $\hbar$, because beyond ℓ_{max} the decay cross-section drops to zero. The Q_{in}-values are shown in Fig.2.

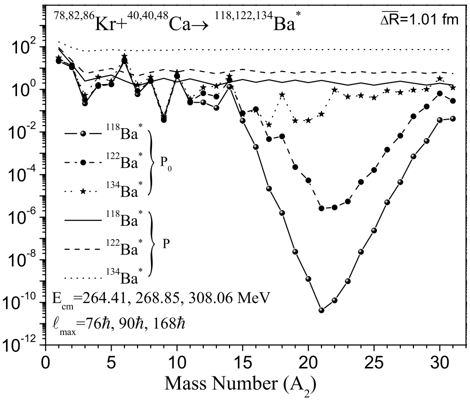

FIG. 1: The P_0 (shown by line plus symbol type) and P (shown by line types) are calculated by using DCM for the energetically favoured LPs and IMFs emitted from the decay of hot and rotating compound systems $^{118,122,134}Ba^*$ at centre of mass energies, E_{cm} =264.41, 268.85 and 308.06 MeV at $\overline{\Delta R}$ =1.01 fm.

Fig. 1, shows the P_0 and P for particles of mass A_2 = 1 - 31, which correspond to Z up to 15, emitted from the isotope of Ba^* compound system. From Fig. 1, we observe the following: (i) the P_0 for outgoing fragments from $^{118,122}Ba^*$ below mass $A_2 \leq 14$ is large compared to fragments of $A_2 > 14$ and (ii) both the P_0 and P increases with increase in N/Z ratio. (iii) the relative change for fragments of $A_2 > 14$ is more then for the fragments of $A_2 \leq 14$. As N/Z→ 1.39286, the P_0 for all the fragments comes almost with in an order of 2. In other words, the two windows of ($A_2 = 1 - 14$ and $A_2 = 15 - 31$) observed in case of $^{118,122}Ba^*$ almost disappears for $^{134}Ba^*$ (iv) the magnitude of P for $A_2 = 1 - 2$ is large by one order compare to the fragments of $A_2 > 2$ and hence the decay cross-section for $A_2 = 1 - 2$ is comparatively large (see Fig. 2) and for other observations for the decays cross-sections remains same as for P_0, see Fig. 2. Also, Figs.1 and 2, shows that the magnitude as well as structure of $P_0(A_2)$ and $\sigma(A_2)$ does not change much up to $A_2 = 14$, while for fragments $A_2 > 14$ there is considerable change with increase in N/Z ratio. So, we conclude that the two windows observed for $^{118,122}Ba^*$ disappear for $^{134}Ba*$ which is equivalent to the fact that with increase in N/Z-ratio there is comparatively large increase in the decay probabilities of mass range $A_2 = 15 - 31$ than for masses $A_2 \leq 15$.

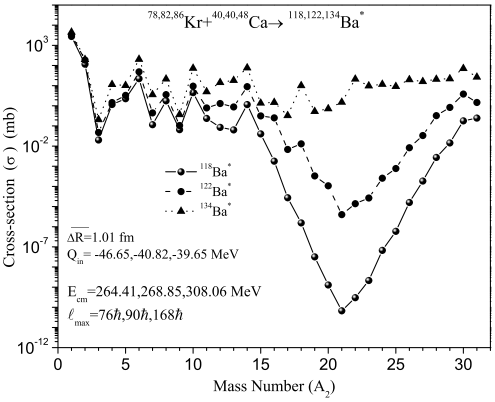

FIG. 2: Same as Fig.1, but for cross section σ.

References

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[3] J. Blocki, *et al.*, Ann. Phys. (NY) **105** 427 (1977).