Role of entrance channel mass asymmetry in the decay of ^{80}Zr*, ^{80}Kr* and ^{80}Sr* formed at same E^*_{CN}~47 MeV in low energy heavy ion reactions

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Introduction

The decay dynamics of compound system formed in low energy heavy ion induced reactions is significantly influenced by the entrance channel parameters such as projectile energy, mass of projectile and target combination, angular momentum, mass asymmetry etc. The mass asymmetry of entrance channel (η) plays a crucial role in the process of compound nucleus formation probability in the synthesis of super heavy elements (SHE) [1]. The study shows that among the different mass asymmetric reactions leading to the same composite system, for the asymmetric reaction there is increased compound nucleus fusion probability compared to case of symmetric reaction. In the ref. [2], the different mass asymmetric reactions leading to the composite systems with same Z_{CN}=108 is explored, which shows that the shape of mass distribution depend strongly upon the η.

It is highly motivating to study the role of η when different mass asymmetric reactions lead to the composite systems with same A_{CN}. In the present work, we tend to investigate the role of mass asymmetry of entrance channel in the decay of compound systems, in the light mass region, with A_{CN}=80 (^{80}Kr*, ^{80}Sr* and ^{80}Zr*) having the same excitation energy E^*_{CN}~ 47 MeV in reference to experimentally available data [3]. For this we choose three reactions with different entrance channel mass asymmetries (η) of 0, 0.2, 0.6, where all lead to the compound systems with A = 80 (i.e. having same total number of nucleons). We compare their decays within the framework of of dynamical cluster decay model (DCM) of Gupta and Collaborators [4], following its collective clusterization approach. It is to be noted here that though we have A_{CN}=80 for each compound systems under study, but their Z values are different, so isospin (N/Z ratio) may also influence the reaction dynamics.

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Methodology

The DCM based on quantum mechanical fragmentation theory, is worked out in terms of collective coordinate of mass asymmetry η =(A_T-A_P)/(A_T+A_P), relative separation (R), multiple deformations $\beta_{\lambda i}$ (λ=2,3,.., i= 1,2,..) and orientation θ_i of two nuclei. In terms of these collective coordinates, using ℓ-partial waves, the decay cross-section is defined as

$$\sigma = \frac{\pi}{k^2}\sum_{\ell=0}^{\ell_{max}}(2\ell+1)P_0P;\ k=\sqrt{\frac{2\mu E_{c.m.}}{\hbar^2}} \quad (1)$$

where preformation probability P_0 refers to η motion, penetrability P refers to R motion and ℓ_{max} is maximum angular momentum defined for light particles, LP cross-section such that $\sigma_{LP}\rightarrow$ 0. Within DCM, the fusion cross-section is defined as σ_{fus}= σ_{ER}+σ_{IMF}+σ_{FF}+σ_{nCN} where σ_{ER}, σ_{IMF}, σ_{FF}, σ_{nCN} refer to evaporation residue or LP, intermediate mass fragments IMF, fusion-fission FF (heavy mass fragments HMF + symmetric fragments SF), non compound nucleus nCN, cross-sections, respectively.

Calculations and discussions

The nuclear structure effects in the decay of compound systems having A_{CN}=80,

TABLE I: The DCM calculated cross-sections for the emissions of LP, IMF and FF fragments in the decay of ^{80}Kr*, ^{80}Sr* and ^{80}Zr* formed at the same E^*_{CN}~47 MeV, and comparison with the data [3].

Reaction	$E_{c.m.}$ (MeV)	ℓ_{max} ($\hbar$)	ΔR (fm)	σ_{LP} (mb)	σ_{IMF} (mb)	σ_{FF} (mb)	σ^{DCM}_{Fus} (mb)	σ^{Expt}_{Fus} (mb)
^{40}Ca+^{40}Ca $\rightarrow$ $^{80}Zr^*$	62.14	48	1.5	152.14	44.03	249.68	445.85	438±69.44
^{32}S +^{48}Ca $\rightarrow$ $^{80}Kr^*$	39.80	52	0.72	1.35	0.013	0.001	1.364	1.26±0.26
^{16}O +^{64}Zn $\rightarrow$ $^{80}Sr^*$	48.0	44	1.72	409.75	409.65	271.06	1090.45	1095±110

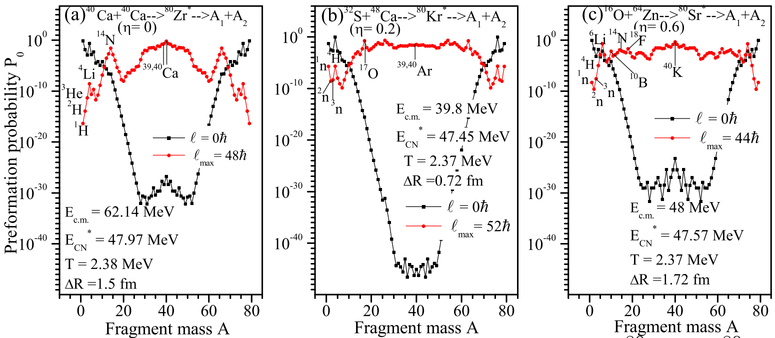

FIG. 1: The variation of P_0 with fragment mass A for the decay of (a)^{80}Zr* (b)^{80}Kr* (c)^{80}Sr* with the consideration of quadrupole deformations and orientations of nuclei.

formed in the reactions having different entrance channel mass asymmetries, at same E^*_{CN}~47 MeV, are analyzed through their P_0 profile for different fragments within the process of collective clusterization, as shown in Fig. 1. We observe that in the decay of (a) ^{80}Zr*, the LP ($^{1,2}H$, ^{3}He, ^{4}Li) dominate at $\ell = 0\ \hbar$ but with increase in angular momentum, for $\ell = \ell_{max}$, the SF ($A_{CN}/2\pm10$) are strongly preformed and among the IMF, ^{14}N has significant P_0. For the (b) ^{80}Kr*, the LP have significant prefomation value at both $\ell = 0\ \hbar$ and $\ell = \ell_{max}$, moreover, the LP are n-rich $^{1,2,3}n$ and ^{4}H and the n-rich IMF ^{17}O is also most probable among IMFs. The maxima in SF window (as seen in case of ^{80}Zr*) disappears and the HMF are in strong competition with SF fragments. In the case of (c) ^{80}Sr*, the n-rich LPs are significantly preformed at both $\ell = 0\ \hbar$ and $\ell = \ell_{max}$. The SF are in strong competition with IMF (^{6}Li, ^{10}B, ^{14}N, ^{18}F).

These results are further reflected in Table 1 which shows the DCM calculated fusion cross-section $\sigma_{Fus}(=\sigma_{LP}+\sigma_{IMF}+\sigma_{FF})$, for the systems under study, having contribution from LP, IMF, FF fragments and comparison with the experimental data for σ_{Fus} [3]. We have predicted here the contributions of different decays in the σ_{Fus} of the compound systems A = 80. It is clear that in case of, (a) ^{80}Zr*, the σ_{FF} followed by σ_{LP} contributes mainly to the total σ_{Fus}, (b) ^{80}Kr*, the LP contribute prominently and due to decreased penetrability, IMF and FF fragments have very small contribution to the total σ_{Fus}, (c) ^{80}Sr*, both the LP and IMF contribute towards the total σ_{Fus} along with significant contribution of FF fragments. Thus, we observe that the entrance channel mass asymmetry as well as isospin (N/Z ratio) largely influence the reaction dynamics of the compound systems.

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