Comparative decay analysis of ^{179}Re* and ^{189}Au* formed in the reactions ^{20}Ne+^{159}Tb,^{169}Tm with E_{lab}=8 MeV/A

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Introduction

The heavy ion induced reactions lead to the formation of composite systems, which subsequently decay because of high excitation energy and angular momentum. The study of decaying composite system facilitates to explore the number of nuclear characteristics and the reaction dynamics. The medium mass composite systems ^{164}Yb*, ^{176,182,188,196}Pt* and ^{200,202}Pb* have been studied successfully within the framework of dynamical cluster decay model (DCM) [1]. These studies show the emission of light particles, LP (or evaporation residues, ER), intermediate mass fragments, IMF, heavy mass fragments, HMF and symmetric fragments, SF along with signatures of quasi-fission, qf, process in their decay path. The decay of medium mass composite system ^{179}Re* has also been studied within DCM [2].

In the present work, we investigate the comparative decay of two medium mass composite systems ^{179}Re* and ^{189}Au* formed in the reactions with same projectile (^{20}Ne) having same E_{lab} (or same E/A) on two different targets ^{159}Tb and ^{169}Tm, for which the experimental data is available [3]. The motive of present work is two fold; (a) To analyze that how the fragmentation behavior or proportion of different decay processes changes with the addition of few nucleons to composite systems (or with same projectile on the different targets having slight difference of mass) within the process of collective clusterization of preformed clusters in the reactions under study (b) Secondly, to study the role of neck length parameter (Δ R) in both the reactions having similar entrance channel mass asymmetry ($\eta\sim$0.77). We want to explore the dynamical effects while fitting the ER cross-section and fission cross-section for the reactions with same ΔR, which is the only parameter of DCM.

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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=2,3,4..., i= 1,2,3..) and orientation θ_i of two nuclei/fragments. In terms of these collective coordinates, 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 and is given by sol. of stationary Schrödinger eq. in η, penetrability P refers to R motion and is calculated using WKB approximation, ℓ_{max} is the maximum angular momentum defined for LPs cross-section $\sigma_{LP}\rightarrow$ 0. The fusion cross-section, within DCM, is defined as σ_{fus}= σ_{ER}+σ_{IMF}+σ_{FF}+σ_{nCN} where σ_{ER}, σ_{IMF}, σ_{FF}, σ_{nCN} refer to ER, IMF, fusion-fission, non-compound nucleus nCN (qf etc.) cross-sections, respectively.

Calculations and Discussion

Fig. 1 and Fig. 2 show the preformation profile of ^{179}Re* and ^{189}Au* respectively at ℓ = 0 $\hbar$ and respective ℓ_{max} values. In comparison, we observe that for the decay of ^{179}Re*, the maxima is strong at symmetric fission fragments than at asymmetric fission fragments (or HMF), while for the decay of ^{189}Au*, the asymmetric fission fragments

TABLE I: The DCM calculated cross-sections for LP, HMF and SF along with comparison with the experimental data [3] for the decay of ^{179}Re* and ^{189}Au*. The calculated fission cross-section σ_f^{DCM} is sum of HMF and SF cross-sections (σ_f^{DCM}=σ_{HMF}+σ_{SF}). The value of qf has been calculated empirically σ_{qf}^{Emp}.

	LP			HMF		SF				
Reaction	ΔR (fm)	σ_{DCM} (mb)	σ_{Expt} (mb)	ΔR (fm)	σ_{HMF} (mb)	ΔR (fm)	σ_{SF} (mb)	σ_f^{DCM} (mb)	σ_f^{Expt} (mb)	σ_{qf}^{Emp}
^{20}Ne+^{159}Tb	1.99	705.35	711 ±46	1.32	104.14	1.32	65.80	169.94	641±25	471.06
^{20}Ne+^{169}Tm	1.99	334.64	351 ±59	1.32	36.26	1.32	8.46	44.72	1070±41	1025.28

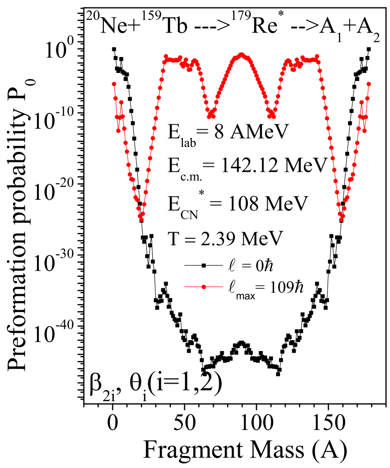

FIG. 1: TheP_0 as a function of fragment mass A for the decay of ^{179}Re* at ℓ=0$\hbar$ and respective ℓ_{max} value. The SF corresponds to A_2 = 79-89 and HMFs to A_2 =37-57, plus the complementary fragments A_1 = A_{CN} - A_2.

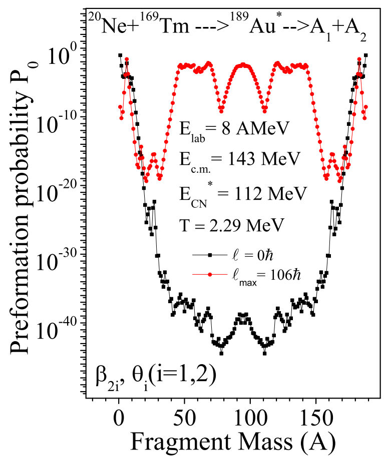

FIG. 2: Same as Fig.1 but for ^{189}Au* at ℓ=0$\hbar$ and respective ℓ_{max} value. Here, the SF corresponds to A_2 = 84-94 and HMFs to A_2 =47-67, plus the complementary fragments A_1 = A_{CN} - A_2.

maxima is stronger than at symmetric fission fragments. In ^{179}Re*, the ^6Li (IMF) is less prominent at both ℓ = 0 $\hbar$ and ℓ_{max} values while for ^{189}Au*, ^6Li shows significant preformation probability.

These results are more evident from Table 1 which presents the DCM calculated cross-sections along with their comparison with the experimental data and empirically estimated qf cross-section σ_{qf}^{Emp}=σ_f^{Expt}-σ_f^{DCM}. The calculations have been done by simultaneous fitting of ΔR for LP, HMF, SF in reference to available experimental data [3]. The values of ΔR for one reaction works on the whole for the second reaction (both having $\eta\sim$0.77). Preliminary results reveal that for the reactions with same projectile having, same E/A and fixed mass asymmetry, we are able to explain the experimental data with same ΔR(η,T) because of nearly same η, T values for both the reactions. To establish the fact more calculations need to be done. Further study is in progress.

References

[1] S.K. Arun et al., JPG: Nuc.and Part. Phys.**36**, 085105 (2009); S. Kanwar et al., IJMPE, **18**, 1453 (2009); M.K. Sharma et al., JPG: Nuc. and Part. Phys. **38**, 055104 (2011); Rajni et al., PRC **90**, 044604 (2014).

[2] M. Kaur, B.B. Singh, DAE Symp. on Nucl. Phys. **59**, 620 (2014).

[3] J. Cabrera et al., PRC **68**, 034613 (2003).