Secondary emission of fragments produced in the decay of $^{47}V^*$ formed via $^{20}Ne+^{27}Al$ reaction at E_{lab}=218 MeV

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Introduction

The heavy ion reactions (HIRs) are of great interest as they may effectively aid in producing new isotopes beside providing relevant information related to nuclear structure and associated dynamics. These heavy ion induced reactions are greatly influenced by the mass and energy of incident beams. At energies near the Coulomb barrier, compound nucleus (CN) reactions like complete fusion (CF), fusion fission (FF) etc. are the dominant decay mechanisms whereas, at energies much higher than the Coulomb barrier (V_{CB}), these processes are suppressed due to some other competing non compound nucleus (nCN) processes like quasi fission (QF), deep inelastic collision (DIC) etc. Furthermore, in reactions with much higher beam energy than V_{CB}, the primary decay fragments may also persist some excitation energy sufficient for them to decay further and this process is termed as secondary decay [1]. The yields corresponding to these secondary decays might affect the contribution of fragments obtained through fusion fission. In order to have a comprehensive picture of final emitting fragments, it is essential to study or identify the fragments obtained through secondary decay of primary fragments.

The main objective of the present work is to study the decay of binary fragments obtained through $^{20}Ne+^{27}Al\rightarrow^{47}V^*$ reaction with respect to the experimental data [1] as an extension of our previous work [2] on $^{47}V^*$ nucleus, where the primary decay for the same was examined via FF and DIC decay modes. Here, we choose to apply the collective clusterization approach of dynamical cluster decay model (DCM) [2] to study the subsequent decay of primary fragments (emitted in fusion fission) having equal number of protons and neutrons (N=Z) i.e. ^{12}C, ^{16}O, ^{20}Ne etc. Furthermore, the preformation probability (P_0) for all the fragments obtained through secondary decay channel is also calculated.

Methodology

DCM [2] is based on quantum mechanical fragmentation theory (QMFT), worked out in terms of collective coordinates of mass asymmetry, $\eta_A = (A_1 - A_2)/(A_1 + A_2)$ (1 and 2 represents, heavy and light fragments respectively) and relative separation R. The decay cross-sections are calculated in terms of barrier penetrability (P) and preformation factor (P_0). Here, P refers to the R-motion and is calculated by using WKB integral and P_0 is solution of stationary Schrödinger equation in η-coordinate, which is given as:

$$\left[-\frac{\hbar^2}{2\sqrt{B_{\eta\eta}}}\frac{\partial}{\partial\eta}\frac{1}{\sqrt{B_{\eta\eta}}}\frac{\partial}{\partial\eta}+V(\eta)\right]\psi^{\nu}(\eta)=E^{\nu}_{\eta}\psi^{\nu}(\eta) \quad (1)$$

where $B_{\eta\eta}$ represents smooth hydrodynamical masses and $V(\eta)$ in above equation represents the fragmentation potential and is defined as:

$$V_R(\eta,T) = \sum_{i=1}^{2}[V_{LDM}(A_i,Z_i,T)]+\sum_{i=1}^{2}[\delta U_i]\times \exp(-T^2/T_0^2)+V_C+V_P+V_\ell. \quad (2)$$

The first and second term represents the liquid drop binding energy and shell corrections, while V_C, V_P and V_ℓ are respectively the T -dependent Coulomb, nuclear proximity, and centrifugal potentials for deformed and oriented nuclei. This fragmentation potential helps to understand the structural information

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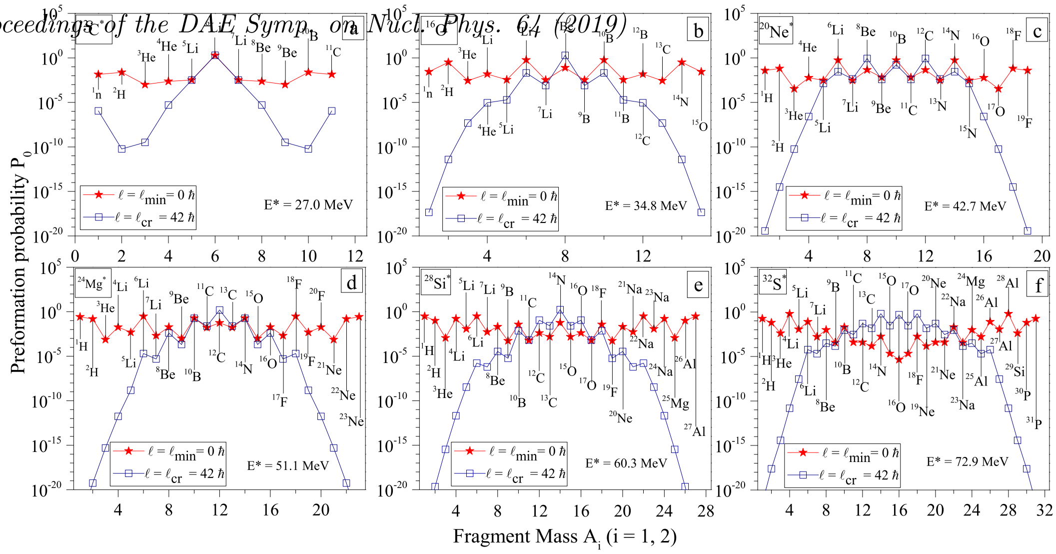

FIG. 1: Preformation probability of fragments emitting in secondary decay of primary binary fragments formed in the decay of ^{47}V* produced in ^{20}Ne+^{27}Al reaction at extreme values of angular momentum and maximum beam energy (E$_{Lab}$ = 218 MeV) as reported in experimental data [1].

via preformation probability given by the solution of Eq. (1) and is defined as follows:

$$P_0 = \mid \psi(\eta(A_i)) \mid^2 \sqrt{B_{\eta\eta}} \frac{2}{A_{CN}} \qquad (3)$$

where A_{CN} is mass of compound nucleus.

Results and discussions

In present work, the subsequent decay of primary fragments obtained in the decay of ^{20}Ne + ^{27}Al → ^{47}V* reaction has been studied using collective clusterization approach of DCM. The calculations are done using β_{2i}-deformed choice of outgoing fragments and optimum orientation approach. Before proceeding further, it is important to mention here that the fragments/nuclei chosen to study the decay analysis have equal number of protons and neutrons (N=Z). The mass range of selected Primary Binary Fragments (PBF) vary from A$_{PBF}$ = 12 to 32. Now, the decay of these primary fragments is examined by calculating the preformation probability of fragments emitting in secondary decay as shown in Fig. 1.

Fig. 1 shows the preformation structure at minimum and critical value of angular momentum (ℓ=ℓ_{min} and ℓ_{cr}) for the decay of primary fragments produced in ^{20}Ne + ^{27}Al reaction at maximum excitation energy (E$_{lab}$=218 MeV) reported by Dey *et al.* in [1]. It is clearly evident from the figure that the emission of light particles is more prominent at ℓ=ℓ_{min}=0 $\hbar$ in comparison to that at ℓ=ℓ_{cr} for all selected primary fragments. A careful look on Fig. 1 reveals that for the decay of lightest primary fragment (^{12}C*), the contribution of symmetric fragments is equally probable at both ℓ-values. However, with increase in mass of primary fragment, the value of P$_0$ for symmetric fragments at ℓ_{min} start decreasing than that of its value at ℓ_{cr}. Thus, in the decay of heaviest mass (^{32}S*), P$_0$ of symmetric fragments at ℓ_{min} is much lower than that of its value at ℓ_{cr}. Moreover, it is also important to mention here that the mass range of nuclei identified in decay of these primary fragments is in agreement with [1]. Along with N=Z fragments, compound system may also decay into N≠Z clusters/fragments. It will be of interest to analyze the fragmentation profile of N≠Z primary fragments and draw corresponding comparison with N=Z case. Beside this, the secondary fragmentation of such fragments at relatively lower incident energies may also impart further useful insights.

References

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