Analysis of carbon fragments emissions in the decay of light mass composite nuclei

BirBikram Singh*
Department of Physics, Sri Guru Granth Sahib World University, Fatehgarh Sahib-140406, India.

Introduction

In recent works, we have investigated extensively the decay of number of light mass compound systems (CS) formed in heavy ion reactions. The collective clusterization approach of dynamical cluster decay model (DCM) [1–5] has been extended successfully to study these very light mass CS i.e. ^{20,21,22}Ne* [1], ^{26,27,28,29}Al* [2], ^{31}P* and ^{32}S* [3], ^{28,30,31}Si* [1, 4]. Considering nuclei with quadrupole deformed and compact configurations, a comparative decay analysis of these systems had been undertaken for the emission of different intermediate mass fragments (IMFs) or clusters. The clustering effects in decay of ^{20}Ne* has been exclusively explored within the quantum mechanical fragmentation theory (QMFT) followed by DCM to address decay of the same at higher excitation energies. The results are very well supported by the relativistic mean field theory and the Ikeda diagrams [1].
Further, the study reveals the presence of competing reaction mechanisms of compound nucleus (fusion-fission, FF) and of non-compound nucleus origin (deep inelastic orbiting, DIO) in the decay of these CS ^{20,21,22}Ne*, ^{28}Si* and ^{32}S*, at different excitation energies. The DIO contribution in the IMF cross section σ_{IMF} is extracted for these composite systems, σ_{IMF} is given as the sum of FF cross section σ_{FF} and DIO cross section σ_{DIO}. The study of CS ^{26,27,28,29}Al* and ^{31}P* shows the presence of FF component in the σ_{IMF}, the contribution of non-compound nucleus effects has not been observed for these systems. The DCM calculated σ_{FF} are in good agreement with the available experimental data for these light mass CS. Here, in the decay of CS, the decaying fragments are first preformed with certain probability P_0, and then tunnel the potential barrier with penetration probability P. The preformation probability P_0 carries the information about the competition of various decaying fragments, which in turn depends upon their minimized fragmentation potential. This means that P_0 carries the significant information about nuclear structure which is missing in the statistical models. Furthermore, P affects the decay cross section of IMFs emissions. Note that P_0 and P are the main contributors for the calculation of decay cross section.
It is interesting to mention here that in the above mentioned studies, IMF Z =6 is quite prominent as compared to its neighboring fragments which is also observed in the experimental data. In this work we have explored the systematics of the DCM calculated σ_{IMF} for Z=6 i.e. decay cross section of carbon fragments σ_C at different compound nucleus excitation energies ($E_{CN}{}^*$), for the CS ^{20,21,22}Ne* and ^{26,27,28,29}Al*.

Methodology

The DCM [1–5] is worked out in terms of collective co-ordinates of mass (and charge) asymmetries, for ℓ-partial waves, gives the compound nucleus (CN) decay cross-section 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, $\mu=[A_1A_2/(A_1+A_2)]m$ is the reduced mass, with m as the nucleon mass and ℓ_{max} is the maximum angular momentum. P is penetrability of interaction barrier (of the preformed clusters with preformation probability P_0), calculated as the WKB tunneling probability, around the Interaction barrier.

*Electronic address: birbikram.singh@gmail.com

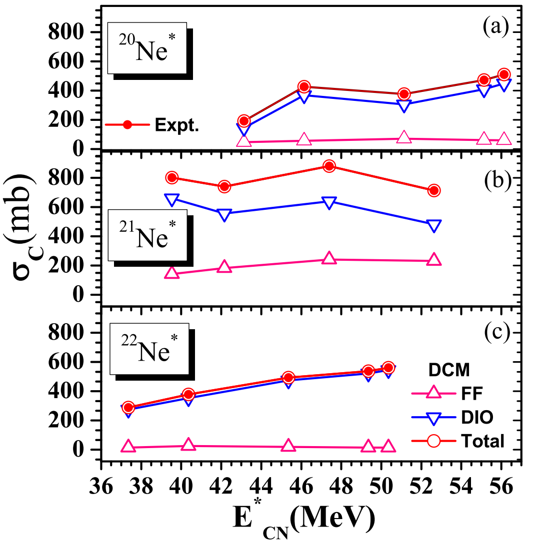

FIG. 1: The variation of σ_C as a function of ${E_{CN}}^*$ for the decay of CS a) ^{20}Ne*, b) ^{21}Ne*, c) ^{22}Ne*.

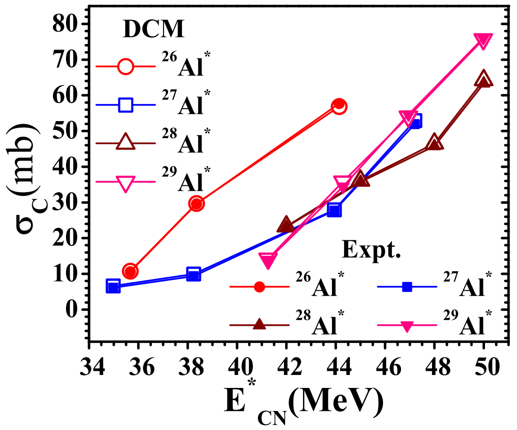

FIG. 2: Same as Fig. 1, but for CS ^{26,27,28,29}Al*.

Calculations and Discussions

Fig. 1 shows the variation of σ_C with ${E_{CN}}^*$ of CS a) ^{20}Ne*, b) ^{21}Ne*, c) ^{22}Ne*. In Fig. (a) we see that in the decay of composite system ^{20}Ne*, σ_C has a very small contribution from FF process whereas DIO process contributes the most. However, there is competition between both the processes for the decay of ^{21}Ne* (Fig. 1 (b)), as σ_C in this case having noticeable contribution from FF process though it is smaller than that of DIO process. Fig. 1(c) presents the totally dominating scenario by the DIO process, as σ_C has almost all the contribution from this process. It is important to point out here that experimental verification of these results will be highly interesting as the contribution from both the processes has been evaluated within DCM [1]. Fig. 2 gives results for σ_C in the decay of ^{26,27,28,29}Al* CS, due to FF process only as the contribution of non-compound nucleus effects has not been observed for these systems, mentioned in the introduction also. It is relevant to mention here that earlier investigations have revealed that the Z=6 (carbon) fragments are strongly favored of all the IMFs in case of all the isotopes of Al^*, i.e having largest values of P_0 [2]. In Fig. 2 we find that σ_C increases with rise in ${E_{CN}}^*$ for all Al^* isotopes. Moreover, at fixed ${E_{CN}}^*\sim$44 MeV, we find that σ_C is maximum for ^{26}Al* and least for ^{27}Al* composite system. These results are in good agreement with the experimental data. The present investigation is highly motivating to further study the σ_C in the decay of few more CS in this mass region, before reaching the final conclusion.

References

[1] B. B. Singh *et al.*, Proc. DAE Symp. **59**, 516 (2014); EPJ Web of Conf. **86**, 00048 (2015); Proc. DAE Symp. **60**, 586 (2015); **60**, 592 (2015); JPS Conf. Proc. **6**, 030001 (2015); Phys. Rev. C **95**, 014611 (2017); Proc. DAE Symp. **62**, 88 (2017); **62**, 506 (2017); JNPMSRA **5** 319 (2018).

[2] B. B. Singh *et al.*, Proc. DAE Symp. **56**, 474 (2011); **57**, 550 (2012); **60**, 588 (2015); **62**, 522 (2017); Nucl. Phy. A **969**, 14 (2018).

[3] B. B. Singh *et al.*, Proc. DAE Symp. **59**, 346 (2014); J. Phys.: Conf. Ser. **569**, 012030 (2014); EPJ Web Conf. **86**, 00049 (2015).

[4] M. Kaur *et al.*, AIP Conf. Proc. **1953**, 140113 (2018); Proc. DAE Symp. **63**, (2018) *Communicated*.

[5] R. K. Gupta *et al.*., PRC **71**, 014601 (2005); IJMPE **15**, 699 (2006); PRC **77**, 054613 (2008); JPG:NPP **36**, 085105 (2009); PRC **80**, 034618 (2009); PRC **90**, 024619 (2014).