Influence of neutron addition on the decay of light mass composite nuclei $^{29-30}$Si* formed in $^{17-20}$O+^{12}C reactions

Navjot Kaur[1,2], BirBikram Singh[2,*] and Sukhjeet Singh[1]
[1]*Department of Physics, Akal University, Talwandi Sabo, Punjab 151302 and*
[2]*Department of Physics, Pondicherry University, Puducherry 605014*

Introduction

During last one decade the decay of light mass composite nuclei (CN) having A $\sim$ 30 have been extensively studied within the quantum mechanical fragmentation theory (QMFT) based dynamical cluster decay model (DCM) [1–6]. While extending the application of DCM to this mass region for the first time the CN $^{20-22}$Ne* formed in $^{10-11}$B+$^{10-11}$O reactions were studied for their binary symmetric decay. Followed by study of the decay of CN ^{32}S* and ^{31}P*, respectively, formed in ^{20}Ne+^{12}C and ^{19}F+^{12}C reactions to investigate their C-like yields. The dynamics of α and non-α cluster formation in the decay of N = Z and N $\neq$ Z CN, respectively, ^{20}Ne*, ^{28}Si*, ^{40}Ca* and ^{21,22}Ne*, ^{39}K*, was explored [2]. It is important to mention here that the results for the clustering aspects of α-conjugate nuclear system ^{20}Ne investigated within macroscopic QMFT are in line with the microscopic approach of relativistic mean field theory [3].

A comparative analysis of intermediate mass fragments (IMFs) and light particles (LPs) was carried in the decay of $^{26-29}$Al* fromed in the ^{16}O+$^{10-11}$B and ^{18}O+$^{10-11}$B reactions [4]. Further, the enhanced cross sections of IMFs within the collective clusterization framework of DCM was shown to be dominant for the α-cluster fragments in the exit channels of ^{13,12}C+^{12}C reactions [5]. This study was further extended to investigate the role of pairing coefficient and level density parameter in the given reaction dynamics [6]. The dynamics of neutron-rich light-mass CN $^{24-27}$Mg* formed in $^{12-15}$C+^{12}C fusion reactions was also explored at different centre-of-mass energies ($E_{c.m.}$).

In the present work, the formalism of DCM is employed to systematically investigate the decay of CN $^{29-32}$Si*, formed in $^{17-20}$O+^{12}C reactions at $E_{c.m.}\sim$ 12 MeV. Here, within DCM the focus is to explore the impact of neutron addition in the projectile $^{17-20}$O (or variations in the N/Z ratio of the CN $^{29-32}$Si*) on the reaction dynamics. It is relevant to mention here that experimental analysis of these reactions has also been carried out recently [7, 8]. The study made by V. Singh et. al. [7] exclusively demonstrate the fusion enhancement for ^{19}O+^{12}C reaction in comparison to the reaction induced by ^{18}O, across the Coulomb barrier. A very recent study by S. Hudan et. al. [8] calls for further theoretical investigations of the $^{16-20}$O+^{12}C reactions to explain the underlying phenomenon of fusion enhancement/ suppression with increasing neutron number (N).

Methodology

The DCM [1–6] is worked out in terms of collective co-ordinates of mass (and charge) asymmetries, which give, for ℓ-partial waves, the compound nucleus decay cross-section

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

Where, $\mu = [A_1 - A_2/(A_1 + A_2)]m$, is the reduced mass, with m as the nucleon mass and ℓ_{max} is the maximum angular momentum. Where P is the WKB barrier penetration probability and P_0 is the preformation probability which is evaluated by solving stationary Schrödinger wave equation.The structure information in P_0 enters through the fragmentation potential $V(\eta, R)$ as shown in Fig. 1.

*Electronic address: birbikram.singh@pondiuni.ac.in;drbirbikramsingh@gmail.com

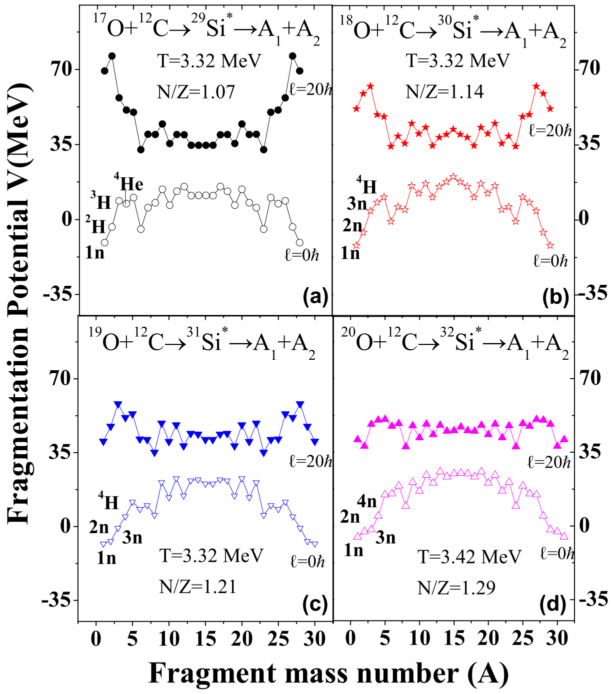

FIG. 1: The fragmentation potneital V (MeV) vs A for CN (a) ^{29}Si* (b) ^{30}Si* (c) ^{31}Si* (d) ^{32}Si*.

Results and Discussions

Fig. 1(a-d) present, respectively, the variation of the fragmentation potential V (MeV) with fragment mass no. A for isotopic chain of CN ^{29,30,31,32}Si* formed with ^{17,18,19,20}O projectile incident on ^{12}C target at similar $E_{c.m.}$ $\sim$ 12 MeV. It will help to explore the effect of neutron addition or N/Z ratio which is respectively 1.07, 1.14, 1.21 and 1.29 for the CN $^{29-32}$Si*, formed at similar excitation energies. Fig. 1(a-d) show that potential energy surface (PES) is highly affected with increasing N/Z ratio of the CN under study.

From fig. 1(a), it is seen that LPs (or equivalently evaporation residues) are dominant at $\ell = 0\ \hbar$ while IMFs become dominant at higher ℓ-value, in the decay of ^{29}Si*. However, with the addition of neutrons, PES of $^{30-32}$Si* (fig. 1(b-d)) show that the LPs have now more neutron or neuron rich particles minimized. It is interesting to note that further addition of neutron brings the LPs not only dominating at $\ell = 0\ \hbar$ but in competitive mode with the IMFs at higher ℓ-value. These preliminary results, present quite interesting and motivating scenario to further explore the role of the collective clusterization procedure to calculate probability of the preformed fragments and their subsequent penetrability across the potential barriers, for the comparative analysis of the decay of CN $^{29-32}$Si*. Further work is in progress.

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