Fusion suppression in ^{20}Ne induced reaction

Sabir Ali[1],* Muntazir Gull[2], Tauseef Ahmad[2], I. A. Rizvi[2], and Avinash Agarwal[3]
[1] *MANUU Polytechnic Darbhanga, Maulana Azad National Urdu University, Hyderabad 500032, INDIA*
[2] *Department of Physics, Aligarh Muslim University, Aligarh 202002, INDIA and*
[3] *Department of Physics, Bareilly College, Bareilly 700098, INDIA*

Introduction

In recent past study of fusion reaction induced by α cluster projectile have created a resurgent in the study of nuclear reaction [1, 2]. Fusion reaction induced by α cluster projectile provides an ample opportunity for exploring the detail structure and properties of the incident projectile. The α cluster nature of the incident projectile is quite helpful in the study of massive transfer reaction as well as in exploring the parameters influencing the degree of fusion suppression. Classically, fusion reaction takes place when incident projectile with kinetic energy sufficiently above the Coulomb barrier interacts with the target nucleus either directly or indirectly. Direct complete fusion (DCF) reaction involves the fusion of incident projectile as a single entity with the target nucleus resulting in total transfer of incident momentum to the intervening compound system. However, it is also possible that incident projectile breakup into fragments prior to fusion with the target nucleus due to excessive Coulomb repulsion. Sequential complete fusion (SCF) involves the fusion of all the breakup fragments with the target nucleus one after the other. On the other hand incomplete fusion (ICF) reaction involves the fusion of only a part of the incident projectile with the target nucleus while the remaining fragments moves in the forward direction with the same velocity as that of incident beam. As SCF and DCF results in same compound nucleus with same degree of momentum transferred, thus the complete fusion (CF) is the algebraic sum of SCF and DCF i.e. $\sigma_{CF} = \sigma_{SCF} + \sigma_{DCF}$,.

*Electronic address: `sabir@manuu.ac.in`

Results and Discussion

It was reported by M. Dasgupta *et al.* that breakup of the incident projectile prior to fusion results in loss of flux which ultimately leads to suppression in fusion cross section with respect to coupled channels calculations [3]. In order to estimate the degree of fusion incompleteness in ^{20}Ne induced reaction over different targets, dimensionless physical quantity F(x) and x has been formulated as,

$$F(x) = \frac{2E_{c.m}}{R_b^2 \hbar w}\sigma_{CF}, \qquad x = \frac{E_{c.m} - V_b}{\hbar w} \quad (1)$$

using the CF cross section, as prescribed by Canto *et al.* [4]. Here R_b, V_b and $\hbar w$ denotes the radius, height and curvature of the potential barrier, respectively. In order to compare the fusion cross section data of a given projectile over different targets, it is necessary to completely eliminate a) the static effects of the interacting nuclei viz. size and Coulomb barrier and b) the dynamic effect of bound inelastic states and transfer coupling from the CF cross section. Formulation of dimensionless variable F(x) and x completely eliminate the static as well as dynamic effects between the different fusing systems and makes them comparable. On simplifying the Wong's formula [5], F(x) reduces to

$$F_0(x) = ln[1 + exp(2\pi x)] \quad (2)$$

which is known as Universal Fusion Function (UFF). In the offline observation of the residues, several evaporation residues (ERs) were not detected due to their too short/long half lives. The cross section of the missing

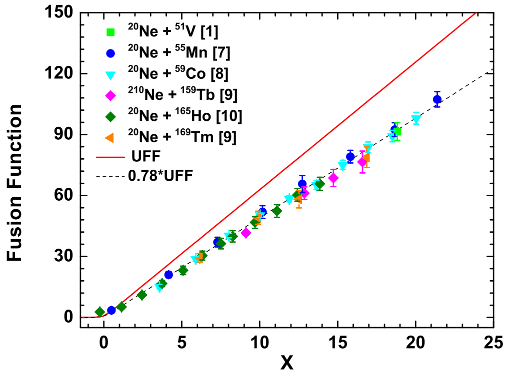

FIG. 1: The CF fusion function F(x) as a function of x for the ^{20}Ne induced reaction over different targets. The solid line represents the UFF and dotted line is the UFF multiplied by a factor of 0.78.

CF channel were accounted using the code PACE4 [6]. By using the code PACE4, ratio R = $\Sigma\sigma^{PACE4}_{xn+pxn}/\sigma^{PACE4}_{fus}$ is calculated and using this ratio experimental CF cross section is calculated as $\sigma^{exp.}_{CF} = \Sigma\sigma^{exp.}_{xn+pxn}$/R [1]. The fusion function F(x) for the α cluster projectile ^{20}Ne over different targets, namely ^{51}V [1], ^{55}Mn [7], ^{59}Co [8], ^{159}Tb [9], ^{165}Ho [10] and ^{169}Tm [9], as a function of x is illustrated in Fig. 1. For ^{20}Ne projectile the most favorable breakup channel is $^{20}\mathrm{Ne} \Rightarrow {}^{16}\mathrm{O} + \alpha$ with $E_{B.U}$ value of 4.2 MeV. In Fig. 1, solid line represent the UFF given by eq. (2). Suppression in CF fusion function with respect to UFF can be noted from Fig. 1 for all the six systems. This suppression in F(x) with respect to UFF is likely to be arising from breakup of ^{20}Ne projectile into fragments owing to its low $E_{B.U}$ value.

Conclusion

In the present work a systematic study of fusion suppression involving the ^{20}Ne projectile over different targets have been carried out. Fusion function has been extracted from the CF cross section of ^{20}Ne induced reaction over the ^{51}V [1], ^{55}Mn [7], ^{59}Co [8], ^{159}Tb [9], ^{165}Ho [10], and ^{169}Tm [9] targets. UFF when scaled down by a factor of 0.78 overlap with the extracted fusion functions. Thus, it can be concluded that fusion function for the ^{20}Ne induced reaction is suppressed by 22% with respect to UFF.

Acknowledgment

One of the author (Sabir Ali) is thankful to UGC, New Delhi (INDIA) and MANUU, Hyderabad (INDIA) for providing financial assistance in the form of Minor Research Project grant (MANUU/Acad/F.404/2016-17/217) for carrying out this work. Author (Sabir Ali) is also thankful to Principal, MANUU Polytechnic, Darbhanga (INDIA) for his conducive support and providing the basic facilities to carry out this work.

References

[1] Sabir Ali *et al.*, Eur. Phys. J. A **54**, 56 (2018).
[2] Muntazir Gull *et al.*, Phys. Rev. C **98**, 034603 (2018).
[3] M. Dasgupta *et al.*, Phys. Rev. Lett. **82**, 1395 (1999).
[4] L. F. Canto *et al.* Nucl. Phys. A **821**, 51 (2009).
[5] C. Y. Wong, Phys. Rev. Lett. **31**, 766 (1973).
[6] A. Gavron, Phys. Rev. C **21**, 230 (1980).
[7] Rahbar Ali *et al.*, J. Phys. G: Nucl. Part. Phys. **37**, 115101 (2010).
[8] D. Singh *et al.*, Phys. Rev. C **83**, 054604 (1980).
[9] J. Cabrera *et al.*, Phys. Rev. C **68**, 034613 (2003).
[10] D. Singh *et al.*, Nucl. Phys. A **879**, 107 (2012).