Role of projectile Breakup in Fusion Reactions induced by ^{9}Be on ^{64}Zn and ^{208}Pb targets

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Investigating the static and dynamic effects arising because of low breakup threshold of the weakly bound nuclei on various reactions dynamics is a current area of research in nuclear physics. Unlike tightly bound nuclei, owing to low breakup threshold of these nuclei breakup becomes an important reaction channel. In recent years, various efforts [1-3 and Ref. therein] have been made to investigate the effects of couplings to this channel on dynamics of various reactions, but the complete understanding of the subject is still not achieved. Breakup of weakly bound projectile leads to various possibilities like (I) Elastic Breakup (EBU) or Non Capture Breakup (NCBU), where none of the fragments of projectile after breakup gets captured by the target, (II) Incomplete Fusion (ICF), where any one of the fragments gets captured by the target and (III) Sequentially Complete Fusion (SCF), where all of the fragments gets captured by the target one after another resulting in the formation of a compound nucleus which is same as that produced by Direct Complete Fusion (DCF). Thus, complete fusion consists of direct complete fusion and sequential complete fusion and sum of complete fusion and incomplete fusion is termed as total fusion.

Since the beams of ^{9}Be can be easily produced with reasonable intensities at different energies in various RIB facilities available worldwide, it has attracted special attention. Thus in the present work, we have studied the effects of breakup coupling on the fusion process for ^{9}Be + ^{64}Zn and ^{9}Be +^{208}Pb systems at near and above barrier energy region.

The ^{9}Be nucleus is a stable weakly bound Borromean nucleus having two alphas and one neutron but for simplicity in theoretical calculations it can be treated as a two body projectile say (^{8}Be + n) or (^{5}He + ^{4}He) with separation energies of just 1.667MeV or 2.45MeV respectively. We have also taken it as a ^{8}Be core surrounded by a weakly bound neutron with a separation energy of 1.667MeV. We have used the CDCC (Continuum Discretized Coupled Channel) approach introduced by G. Rawitscher first [4] to include breakup effects of the weakly bound projectile ^{9}Be by using the code 'FRESCO' developed by I. J. Thompson[5]. In CDCC method, Breakup is considered equivalent to inelastic excitations to the continuum. The coupled channel calculations are performed by considering both the bound state of the projectile as well as its continuum of unbound states. To include the unbound states, discretization is required to be done as it forms the continuum. The Binning method has been used for discretization [6]. Effects of resonant states of projectile is not taken in to consideration for the present calculations. Maximum excitation energy of 7MeV above the breakup threshold is used for truncating the continuum. The neutron- ^{8}Be interaction potential which is used to generate ^{9}Be wave function is taken from reference[7]. The ^{8}Be-^{208}Pb and n- ^{208}Pb optical potentials used in the calculations are taken from Ref.[8] and ^{8}Be-^{64}Zn and n- ^{64}Zn optical potentials are taken from Refs. [9,10] respectively.

In particular, the calculations are performed for three sets of optical potentials (A) where imaginary part of the complex optical potential is retained for both fragments of the projectile (core and valence neutron) relative to target (B) where imaginary part is retained only for valence- target part and (C) where imaginary part is retained for core-target part only. So the total absorption cross-sections obtained from the calculations (B) and (C) reduces by an amount equal to incomplete fusion cross-section of that particular fragment. By performing these calculations total fusion, complete fusion, total incomplete fusion and incomplete fusion cross sections of individual fragment of the projectile have been calculated. The results of the calculations along with the experimental data are presented in Figs. 1 and 2.

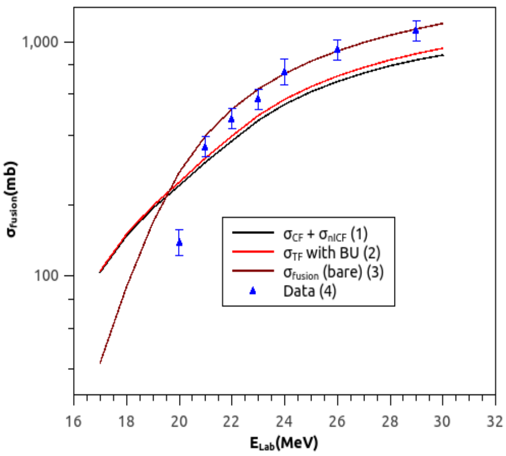

Fig. 1 (Color online) Fusion excitation function for ^{9}Be + ^{64}Zn system considering no couplings and breakup couplings only. Experimental data are taken from Ref.[11].

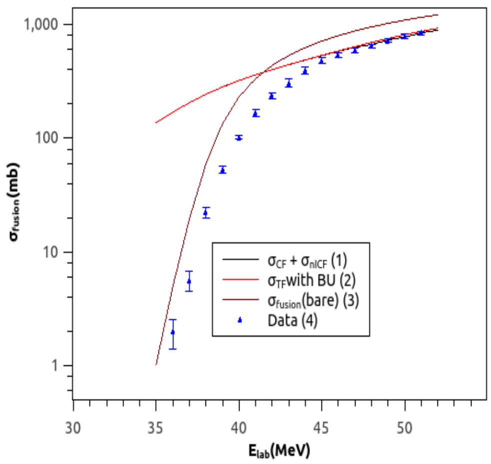

Fig. 2 (Color online) Fusion excitation function for ^{9}Be + ^{208}Pb system considering no couplings and breakup couplings only. Experimental data are taken from Ref. [12].

It can be clearly analyzed from the Fig. 1 that in case of Zinc target, calculations done without considering any coupling match well with the the experimental data except for lower energy region suggesting breakup is not so important channel. However the data are substantially underestimated by predictions made when the breakup effects are taken in to account. But this is not the case for Lead target as can be seen from Fig. 2. Bare calculations have not any resemblance with the data however calculations done by considering coupling to breakup channel match well with the experimental data at above barrier energies. It may be ascribed to the fact that the heavy mass of Lead target is responsible for high Coulomb repulsion and hence Coulomb breakup of the projectile while there is comparatively very less repulsion for Zinc target. However at sub barrier energies the agreement between data and predictions are not so good. This discrepancy might be get resolved by including resonant states in breakup couplings and all other direct reaction couplings which are not included in the present calculations. Further the comparison of curves (1) and (2) in both the figures clearly indicates that contribution of ^{8}Be captured incomplete fusion is negligibly small.

REFERENCES

[1] L.F. Canto et al., Phys. Rep. 596 , 1 (2015).
[2] B.B. Back, et al., Rev. Mod. Phys. 86, 317 (2014).
[3] N. Keeley et al., Prog. Nucl. Part. Phys. 59, 579 (2007).
[4] H.G. Rawitscher, Phys. Rev. C 9, 2210. (1974)
[5] I.J. Thompson, Comput. Phys. Rep. 7, 167 (1986).
[6] I.J. Thompson and Filomena N. Nunes, Nuclear Reactions and Astrophysics, Cambridge University Press, 2009.
[7] J. Lang et al., Phys. Rev. C 16, 4 (1977).
[8] V. Jha et al., Phys. Rev. C 89, 034605 (2014).
[9] A.D. Pietro et al.,Phys. Rev. Lett. 105, 022701 (2010).
[10] A.J. Koning and J.P. Delaroche, Nucl. Phys. A 713, 231 (2003).
[11]P.R.S. Gomes et al.,Phys. Rev. C 71 , 034608 (2005).
[12] M. Dasgupta et al., Phys. Rev. C 70, 024606 (2004)