Fusion and break-up cross section of alpha cluster projectiles on ^{51}V target

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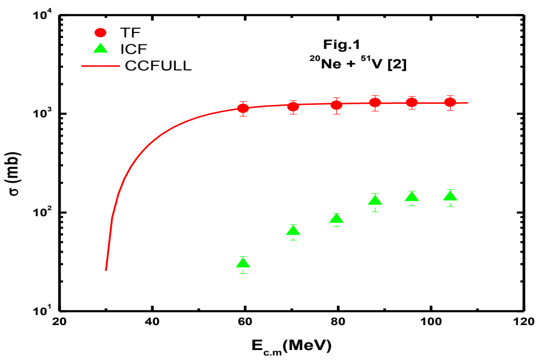
Recent development of radioactive isotope accelerators has provided an opportunity to investigate, on the earth, the fusion reaction that forms heavy elements in the cosmos. These involve reactions of nuclei far from stability line, the most exotic of which are very weakly bound. Breakup of weakly bound nuclei is thus an important process in collisions with other nuclei[1]. Cluster type nuclei with small separation energies have a large breakup probability when they interact with a heavy target. As a first step towards the understanding of the small binding energies of cluster type nuclei, it is convenient and quite instructive to induce fusion reactions with the high intensity beam of alpha cluster stable projectile that should have a reasonable breakup probability. The suitable candidates for this kind of study are ^{20}Ne, ^{12}C and ^{16}O that have threshold breakup energies from 4.73 MeV to 7.37 MeV.

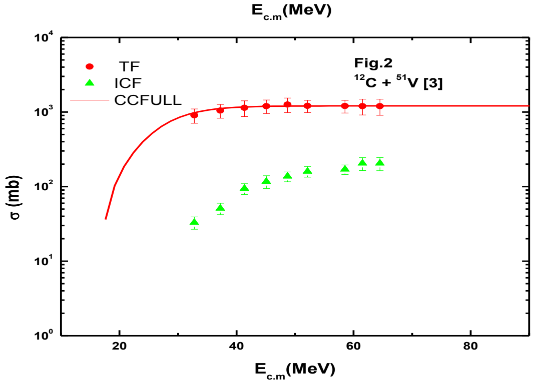
Following breakup of the projectile several scenarios are possible: (i) One of the fragment is captured resulting into Incomplete Fusion (ICF), (ii) All the breakup fragments are captured leading to a nucleus which is the same as that formed by complete fusion called Sequential Complete Fusion (SCF). A first aspect to be considered when one performs experiment to measure fusion cross section with the alpha cluster projectile is the separation between the Complete Fusion (CF) and ICF process. Usually the residues following both processes are very similar or identical and, therefore, the measurement of residues by charged particle detector was not able to distinguish between them. Even when this separation was possible, one cannot distinguish between CF and SCF. Another aspect to be considered was that it was very difficult to distinguish experimentally the ICF from direct transfer channels leading to the same compound nucleus, Q– value consideration and exclusive experiments might help to distinguish them, but if the two processes are present a misinterpretation of the data might come out.

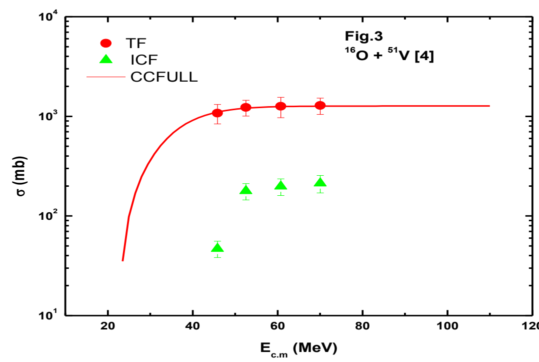
In this paper we have tried to give an overall view of the subject, for energies near and above the Coulomb barrier, for a medium mass target (^{51}V). The interpretation and conclusion were based on experimental data. Our group have already presented some data on CF and ICF for $^{20}Ne + ^{51}V$ [2] as well as there are some other published work on CF and ICF for $^{12}C + ^{51}V$ [3] and $^{16}O + ^{51}V$ [4] systems.

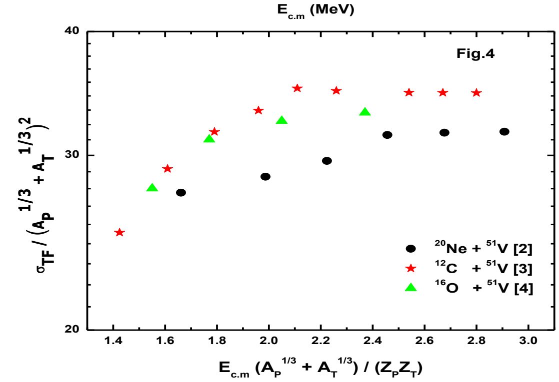
From the total fusion measurement performed with the gamma ray method, it was possible to estimate the ICF of one alpha particle with the target (α-ICF) as described in Ref.[2]. The prediction of the statistical Code PACE [5] was compared with the evaporation cross section for Ref.[2] where as Cascade Code was used for Ref.[3] and [4]. The α- ICF cross section was determined as the difference between the experimental data and the PACE prediction for the fusion of the three systems. The results are shown in Fig.1, 2 and 3 respectively. One can see that the estimated α- ICF cross section is less than 11%, 14% and 16% of the total fusion cross section for the three systems respectively. The solid line in each figure is the result of CCFULL [6] calculation. The CCFULL calculation does not take into account any possible breakup effect on the fusion cross section. A good fit of the total fusion excitation function is obtained, showing that there is no fusion suppression or enhancement, compared with prediction from the bare potential of the CCFULL Code. Hinde et al.[7] have proposed that the probability for α- ICF scales almost linearly with the atomic number of the target, Z_{Target}, and predicted that α- ICF for ^{20}Ne + ^{51}V, ^{12}C + ^{51}V and ^{16}O + ^{51}V should be 16 %, 21% and 24% respectively of TF which agrees well with our estimations.

We believe that the best way to compare the TF cross section of the given three system is by plotting the "reduced cross section" and "reduced energy", dividing σ_{TF} by $(A_P^{1/3} + A_T^{1/3})^2$ and $E_{c.m}$ by $Z_P Z_T/(A_P^{1/3} + A_T^{1/3})$, instead of the usual way of dividing them by πR_B^2 and V_B respectively. The reason behind this is to wash out possible effects such as different r_0 values derived for ^{20}Ne, ^{12}C and ^{16}O projectiles. The results are shown in Fig.4. In summary, we conclude that for the fusion of ^{20}Ne, ^{12}C and ^{16}O with medium mass target (^{51}V), the TF are not affected by the breakup, at least within the experimental uncertainties and α– ICF is very small as compared to TF.









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