Comparison of fusion cross sections for $^{9}Be+^{89}Y$ with $^{12}C+^{89}Y$ and $^{4}He+^{93}Nb$

C.S. Palshetkar[1], S. Santra[1], A. Chatterjee[1], K. Ramachandran[1], Shital Thakur[2], S.K. Pandit[1], K. Mahata[1], A. Shrivastava[1], V.V. Parkar[2], and V. Nanal[2]

[1]Nuclear Physics Division, Bhabha Atomic Research Centre, Mumbai – 400 085, INDIA

[2]Department of Nuclear and Atomic Physics, Tata Institute of Fundamental Research, Mumbai – 400 085, INDIA

1. Introduction

To study the effect of breakup on different reaction channels, the reactions with weakly bound nuclei have recently been extensively investigated [1]. Particularly, in the case of fusion of the weakly bound stable ^{9}Be nucleus, a suppression of the complete fusion (CF) cross sections has been reported for the $^{9}Be+^{144}Sm$, $^{9}Be+^{208}Pb$ and $^{9}Be+^{209}Bi$ systems, as compared to the coupled channels (CC) calculations. This has been understood to be due to loss of flux from fusion channel due to breakup of the projectile. On the other hand, for fusion of ^{9}Be with light mass targets ^{27}Al and ^{64}Zn, no suppression of the measured fusion cross sections has been observed with the explanation that for these systems nuclear breakup, which occurs at short distances, is the dominant breakup process and thus does not inhibit fusion. To investigate this for fusion of ^{9}Be with a medium mass target, we had measured the fusion cross sections for $^{9}Be+^{89}Y$ system [2]. It was found that for this system the CF cross sections were suppressed compared to the ones obtained from the CC calculations by (20 $\pm$ 5)%. To further confirm this observation in the $^{9}Be+^{89}Y$ system, fusion measurements with tightly bound projectiles, namely, ^{4}He and ^{12}C were carried out with targets ^{93}Nb and ^{89}Y respectively. These systems were chosen because fusion of $^{12}C+^{89}Y$ and $^{4}He+^{93}Nb$ forms the compound nuclei ^{101}Rh and ^{97}Tc respectively, both nearby to the compound nucleus, ^{98}Tc, formed by fusion of $^{9}Be+^{89}Y$. Since these systems form nearby compound nuclei one would a priori expect their fusion cross sections to be similar at least at above barrier energies where the effects of coupling of bound inelastic and transfer states is expected to be negligible. Any differences observed in the cross sections could then be explained to be due to the weakly bound nature of the projectile.

2. Experimental Details

The fusion for the $^{12}C+^{89}Y$ and $^{4}He+^{93}Nb$ systems were measured at beam energies in the range of $0.82 \leq E_{cm}/V_b \leq 1.36$, using the 14 UD BARC-TIFR Pelletron Accelerator facility, by the offline gamma counting method. One HPGe detector with an energy resolution of ~1.7 keV for E_γ= 771 keV and ~2 keV for E_γ= 1408 keV of the standard ^{152}Eu source was employed for the offline counting. A scaler was utilized to record the beam current in steps of 1 min to correct the cross sections later for beam fluctuations. Aluminum catcher foils of ~1 mg/cm^2 thickness were used along with each target to stop the recoiling evaporation residues (ERs).

For the $^{12}C+^{89}Y$ fusion measurement, ^{89}Y foils of thickness ~1.1 mg/cm^2 each were irradiated using ^{12}C beam at energies between 32-47 MeV in steps of ~2 MeV. For the $^{4}He+^{93}Nb$ fusion measurement, ^{93}Nb foils of thickness ~1 mg/cm^2 each were irradiated with ^{4}He beam at energies between 10.5-17 MeV in steps of ~1-2 MeV.

3. Analysis

The fusion cross sections for the systems were obtained by taking the sum of the individual ER cross sections. The unaccounted cross sections due to formation of stable ERs were accounted for from the statistical model code PACE. For the $^{12}C+^{89}Y$ system the unaccounted cross section constitutes ~10% of σ_{fus} from PACE whereas for the $^{4}He+^{93}Nb$ system these constitute ~2% of σ_{fus} from PACE. The experimental ER cross sections along with the total fusion cross sections are plotted in Fig.1

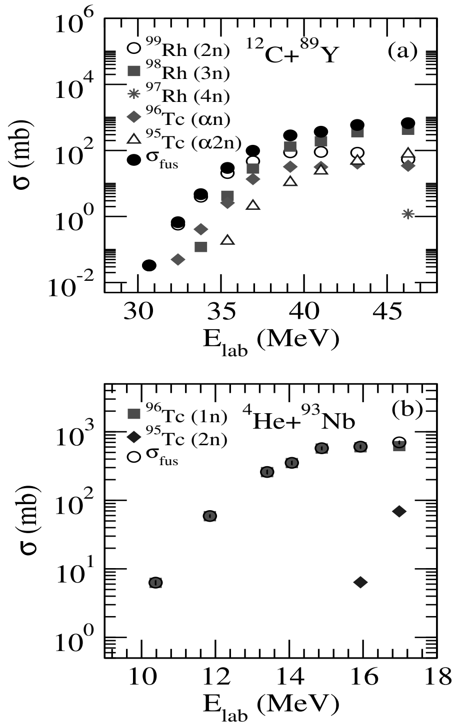

Fig. 1 Experimental ER cross sections along with the total fusion cross sections as a function of the projectile lab energy for the (a) $^{12}C+^{89}Y$ system and (b) $^{4}He+^{93}Nb$ system.

To compare the fusion cross sections for these two systems with that for the $^{9}Be+^{89}Y$ system, two reduction methods have been applied. In the first method, $\sigma_{fus}/\pi R_b^2$ versus E_{cm}/V_b has been plotted as shown in Fig. 2(a). In the second method the geometrical dependence has been eliminated in an approximate way by taking $R_b= r_o (A_p^{1/3}+ A_t^{1/3})$ and $V_b= Z_pZ_te^2/R_b$ [3]. Thus in Fig. 2(b), $\sigma_{fus}/(A_p^{1/3}+ A_t^{1/3})^2$ versus $E_{cm}(A_p^{1/3}+ A_t^{1/3})/Z_pZ_t$ has been plotted. In both the figures, the dashed line represents the cross sections obtained from the CC calculations for the $^{9}Be+^{89}Y$ system and reduced according the procedure mentioned above. The solid line represents the CC cross sections after their multiplication by 0.80.

For the former reduction procedure, Woods-Saxon parameterization of the Akyuz-Winther potential was used to get the values of V_b and R_b. For the $^{12}C+^{89}Y$ system, V_b=31.83 MeV, R_b=9.88 fm and for the $^{4}He+^{93}Nb$ system, V_b=11.38 MeV and R_b=9.18 fm.

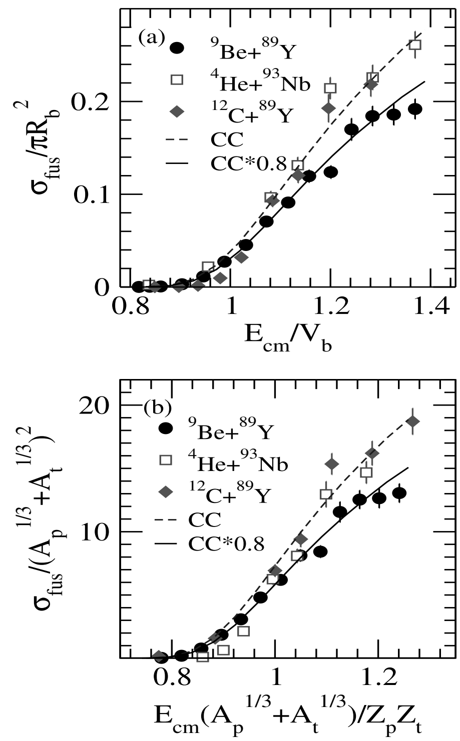

Fig. 2 Reduced cross sections for the $^{9}Be+^{89}Y$ system compared with those for the $^{4}He+^{93}Nb$ and $^{12}C+^{89}Y$ system.

4. Conclusion

As can be seen from Fig. 2, the fusion cross sections for the $^{9}Be+^{89}Y$ system, represented using both the reduction procedures, are less compared to those for the $^{12}C+^{89}Y$ and $^{4}He+^{93}Nb$ systems by 20% especially at above barrier energies. This again confirms our observation of suppression of CF cross sections for the $^{9}Be+^{89}Y$ system. Also as two different reduction procedures yield the same amount of suppression the above result is independent of the reduction method used.

References

[1] L.F. Canto et al., Phys. Rep. **424**, 1 (2006); N. Keeley et al., Prog. Part. Nucl. Phys. **59**, 579 (2007)

[2] C.S. Palshetkar et al., DAE Int. Symp. On Nucl. Phys. **B40**, 318 (2009).

[3] P.R.S. Gomes et al., Phys. Rev. C **71**, 017601 (2005).