Effect of reduction methodology on reaction cross section induced in medium-mass systems

N.N. Deshmukh[1], S. Mukherjee[1], B.K. Nayak[2], D.C. Biswas[2], E.T. Mirgule[2], S. Santra[2], A. Saxena[2], R. K. Choudhury[2], J. Lubian[3] and P. R. S. Gomes[3]

1 Department of Physics, Faculty of Science, The M.S. University of Baroda, Vadodara, India
2 Nuclear Physics Division, B.A.R.C. Mumbai-400085. India.
3 Instituto de Fisica, Universidade Federal Fluminense, Niterói, R.J. 24210-340, Brazil

Introduction

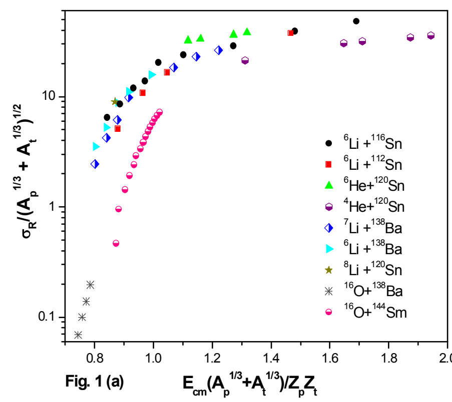
Study of nuclear reactions with weakly bound nuclei is of considerable interest nowadays [1]. The effect on fusion and breakup reactions using the stable and unstable projectiles in the last decade has attained a great attention along with variety of theoretical approaches. In the case of weakly bound projectiles there is smaller breakup threshold due to which the breakup cross section may be quite large near the Coulomb barrier and also strongly affects the fusion cross section. Of considerable interest is the study of elastic scattering on light, medium and heavy targets that play a leading role towards the understanding of the dissociation of the weakly bound systems. From this, it is important to study the elastic scattering on different projectile target combinations with varying asymmetry, in order to understand more complicated reactions. The cross-section of elastic scattering can help to obtain an optical potential which is necessary to understand the entrance and exit channel potentials of some transfer reactions. Breakup effects also play an important role in the scattering mechanism, affecting the interaction potential. One of the important points of investigation is whether the effect of breakup is essential to increase the total reaction cross-section. Therefore, it is important to investigate the dependence of the breakup and total reaction cross-sections near the barrier energies.

Reduction Methodology

In order to perform a systematic study of total reaction cross-sections with different weakly bound projectiles with several targets, it is necessary to compare the cross-sections for systems with different Coulomb barriers.

For this purpose, it is necessary to suppress the differences arising from the size and charges of the systems. This can be done in different ways. The two most frequently used reduction procedures are to normalize the collision energy with respect to the barrier height and to divide the cross-section by its geometrical value, i.e., to plot $\sigma_R/\pi R_B^2$ against $E_{c.m.}-V_B$ or $E_{c.m.}/V_B$, where R_B and V_B are, respectively, the s-wave barrier radius and height and should be evaluated using a realistic treatment of the optical potential similar to the folding model. However, this procedure does not consider the important influence of the barrier curvature at the sub-barrier energies [3]. It has been pointed out [2] that when weakly bound projectile nuclei are involved, care should be taken in order to preserve the static effects arising from the low breakup energy of the projectile. So, the reduction method should remove the dependence on the masses and charges of the collision partners but not specific features of the projectile density. The proposed reduction method [2] is to plot $\sigma_R/(A_p^{1/3}+A_t^{1/3})^2$ versus $E_{c.m.}(A_p^{1/3}+A_t^{1/3})/Z_p Z_t$. This method has been extensively used to investigate the role of breakup of weakly bound nuclei on the fusion and reaction cross-sections for a variety of systems (see, for example, refs. [4-6]) and is shown in Fig.1 (a). However, it was recently pointed out [3] that the above-mentioned reduction procedures fail to remove appropriately the static effects on the fusion reactions of different systems. In the newly proposed methodology [3], this is achieved. This methodology was later extended to be used with total reaction cross-sections [7]. The procedure takes into account not only the height and radius of the Coulomb barrier, but also its curvature represented by the quantity $\hbar\omega$. The collision energy and the cross-section are reduced, as $F_F(x) = (2E_{c.m.}/\hbar\omega R_B^2)\sigma_F$ and $x = (E_{c.m.} - V_B)/\hbar\omega$. Here, V_B , R_B and $\hbar\omega$ are the height, radius and curvature parameter of the Coulomb barrier, respectively. Similarly, for total reaction cross-sections one uses $F_{TR}(x) = (2E_{c.m.}/\hbar\omega R_B^2)\sigma_{TR}$. The barrier parameters are extracted from the optical potential used. $F_F(x)$ was called fusion function and $F_{TR}(x)$ was called total reaction function. It has been shown [3] that this fusion function is system independent when σ_F is accurately described by Wong's formula [8]. In this case F(x) becomes $F(x) \rightarrow F_0(x) = \ln [1 + \exp (2\pi x)]$. Note that $F_0(x)$ depends exclusively on the dimensionless variable x. It is a universal function which is the same for any system. For this reason it is called the Universal Fusion Function (UFF), which is shown in Fig. 1 (b), and it can be used as a benchmark to which renormalized data should be compared [3]. In the present work we compare the total reaction cross sections derived from our experimental elastic scattering data for the ^{6}Li + $^{112,\ 116}$Sn systems with other systems involving tightly bound, stable weakly bound and radioactive and halo projectiles with targets in the same mass range. We use both the above mentioned procedures.

Our systematic study of reaction function on medium-mass targets leads to the general conclusion that reaction function for the weakly bound nuclei is consistently larger than those for stable systems.



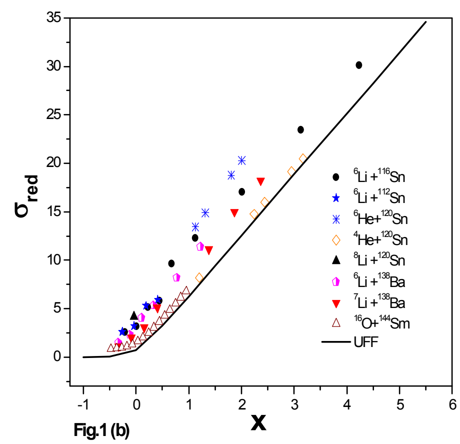


FIG. 1 (a) & (b) . Reduced reaction cross section versus reduced energy for the ^{6}Li + ^{112,116}Sn systems. For details see text.

References

1. L.F. Canto et al., Phys. Rep. 424, 1 (2006).
2. P.R.S. Gomes et al., Phys. Rev. C 71, 017601 (2005).
3. L.F. Canto et al., J. Phys. G: Nucl. Part. Phys. 36, 015109 (2009).
4. J.J. Kolata, E.F. Aguilera, Phys. Rev. C 79, 027603(2009).
5. E.F. Aguilera et al., Phys. Rev. C 80, 044605 (2009).
6. E.A. Benjamim et al., Phys. Lett. B 647, 30 (2007).
7. J.M.B. Shorto et al., Phys. Lett. B 678, 77 (2009).
8. C.Y. Wong, Phys. Rev. Lett. 31, 766 (1973).