Projectile and target dependences on complete fusion in $^{6,7}Li+^{144,152}Sm$ reactions

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Introduction

Study of nuclear reactions involving weakly bound (stable or radioactive) projectile is a subject of current experimental and theoretical interest [1,2]. There are different conclusions about the enhancement or suppression of the fusion cross section σ_{fus} , over the predictions of single barrier fusion model, around the Coulomb barrier. Fusion cross section for ^{6}Li + $^{144,152}Sm$ reactions, that we have measured recently [3], was found to be enhanced compared to the uncoupled results at sub-barrier energies, but at above barrier energies they were suppressed by ~ 32% and 28% respectively. Our systematics of the fusion cross sections for the systems involving loosely bound projectiles [3] showed that this suppression factor increases with the Z of the target and decreases with the breakup threshold of the projectile. So, it would be interesting to study the fusion reaction involving ^{7}Li (another weakly bound nuclei) as a projectile with the above two targets, i.e., for $^{7}Li+^{144,152}Sm$ and compare with our earlier measurements to test the suppression factor dependence on breakup threshold in the above systematics. Since ^{7}Li has a higher breakup threshold (2.478 MeV) than ^{6}Li (1.478 MeV), it is expected that the complete fusion (CF) suppression factor for the above reactions would be less compared to $^{6}Li+^{144,152}Sm$. Secondly the choice of ^{152}Sm as a target was made to study the role of target deformation versus projectile breakup and their dominance over each other.

We have already measured the fusion cross sections for $^{7}Li+^{144}Sm$ [4], so in this work we report the new measurements on $^{7}Li+^{152}Sm$ and compare with our earlier measurements to discuss about both projectile as well as target dependence on CF cross sections.

Measurements

The fusion cross sections for ^{7}Li + ^{152}Sm reaction have been measured at energies near and above the barrier using ^{7}Li beam from 14UD BARC-TIFR pelletron facility at Mumbai. The details of experimental method is same as described in our earlier papers [3,4]. The excited compound nucleus formed in the fusion of ^{7}Li +^{152}Sm gets de-excited mainly by neutron evaporations. The unstable evaporation residues (ERs) decay to Gd isotopes by electron capture. The cross sections for the individual ER channels are measured by offline counting of the gammas emitted from the corresponding Gd nuclei.

Calculations and discussions

To understand the measured ER cross sections, statistical model (SM) calculations are performed using the code PACE [5] with default potential parameters. For energies below the barrier the SM calculations were carried out by feeding the ℓ distributions obtained from external coupled channels calculations by CCFULL. Since the combined contribution of 3n and 4n channels were found to be ~ 90-98% for most of the energies (23-40 MeV) of our measurement, the complete fusion cross sections were obtained by normalizing these values as per the procedure adopted in our previous papers [3].

The measured excitation function for complete fusion has been shown as filled circles in Fig. 1 (a). When compared with those for ^{7}Li + ^{144}Sm of Ref.[3] (open circles), it was observed that at sub-barrier energies the CF cross sections for the present system are largely enhanced whereas they are almost same at above barrier energies. Similar observations are also made for

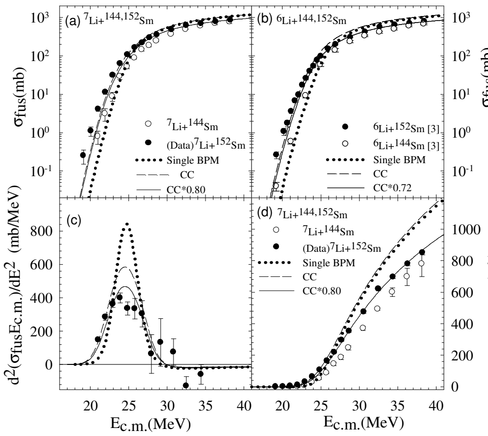

Fig.1 Effect of target deformation on CF cross sections for ^{7}Li+^{144,152}Sm reaction

^{6}Li induced reactions i.e., ^{6}Li + ^{144,152}Sm as shown in Fig.1(b). This enhancement is certainly the effect of target deformation. Experimental fusion barrier distribution for ^{7}Li+^{152}Sm was also obtained as shown in Fig. 1(c). Coupled channels calculations are performed by using the code CCFULL with potential parameters that reproduce the average experimental fusion barrier (~24.8 MeV). The full couplings included the coupling of the projectile ground state (3/2$^-$) and first excited state (1/2$^-$, 0.4776 MeV) with β_{00} (β_2 for the ground state reorientation) = 1.189, β_{01} (β_2 for the transition between the ground and the first excited states) = β_{11} (β_2 for the reorientation of the 1st excited state) =1.24. The target ^{152}Sm being a deformed nucleus in its ground state, both quadrupole (2+, 0.122 MeV) and hexadecapole (4+) rotational states with deformation parameters β_2=0.26 and β_4=0.05 are coupled. Coupling to the breakup channel is not included. It was observed that at sub-barrier energies, there is an enhancement in the fusion cross-sections calculated with only target couplings as well as target+projectile couplings (dashed line) compared to the uncoupled values (dotted line). However, at above-barrier energies, the calculated values of CF with or without full couplings are higher than the measured ones. Interestingly, the calculated CF when normalized by a factor of 0.8 reproduces the fusion as well as barrier distribution data at higher energies. Thus one can conclude that the CF is suppressed by ~ 20 % in this region, similar to ^{7}Li+^{144}Sm (~20%) but smaller than the ^{6}Li+^{152}Sm case (~28%). This is consistent with our systematics [3]. It also shows that the CF at sub-barrier energies is enhanced due to both target deformation as well as projectile excitation.

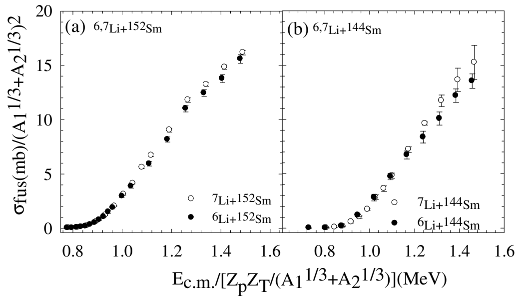

Fig.2 Projctile dependence of CF cross sections in ^{6,7}Li+^{144}Sm and ^{6,7}Li+^{152}Sm reactions

To investigate the projectile dependence, the CF cross sections induced by ^{6}Li and ^{7}Li with one particular target are compared in Fig. 2. It was observed that the CF cross sections at sub-barrier energies are same for both systems. However, at above barrier energies the CF is larger for ^{7}Li than ^{6}Li induced reactions implying that due to larger breakup threshold of the former the effect of breakup is lower, hence less suppression.

Thus, it can be concluded that the effect of both projectile breakup and target deformation coexist on the CF excitation function. The CF suppression at higher energies due to breakup in ^{7}Li and ^{6}Li induced reactions are found to be ~20% and ~30% respectively. CF at sub-barrier energies is enhanced by both target and projectile excitations and possibly by breakup too.

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