Total fusion and inclusive alpha in ^{6,7}Li+^{238}U: Role of projectile breakup

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Introduction

Experimental data on fission excitation functions for reactions involving weakly bound projectiles with actinide targets show a large enhancement in the fission cross sections at sub-barrier energies for ^{6}Li induced reactions (e.g., ^{6}Li+^{232}Th,^{235,238}U) compared to those for ^{7}Li induced reactions (e.g. ^{7}Li+^{232}Th,^{235,238}U)[1, 2]. Itkis *et al.*[3] have explained the energy dependence of the ratio of fission cross sections for ^{6}Li+^{232}Th to ^{7}Li+^{232}Th in terms of continuum discretized coupled channels (CDCC) calculations concluding that lower breakup threshold of ^{6}Li compared to ^{7}Li is the main reason for the enhanced contribution in breakup induced fission cross section for the former.

We propose that the above energy dependence can also be understood by an indirect method by measuring the inclusive breakup alpha yields for the two reactions. It is known that the alpha particles produced in the reactions involving weakly bound projectiles are peaked around the beam velocity and they are mostly due to projectile breakup [4]. That means, the inclusive breakup alpha which is linearly proportional to the projectile breakup probability should in turn be proportional to the breakup induced fission. Here, we present the results of inclusive alpha measurements and CDCC calculations to understand the above energy dependence on fission excitation function and the effect of breakup threshold energy of ^{6,7}Li.

Measurements and analysis

The inclusive alpha yield for ^{6,7}Li+^{238}U reactions has been measured at energies in the range of 28-44 MeV, in steps of 4 MeV, using the BARC-TIFR Pelletron facility in Mumbai. Four telescopes (ΔE-E) of Si surface barrier (SSB) detectors placed at fixed angles of 60°, 70°, 80° and 90° are used for detecting light charged particles with Z=1,2 and 3. Two monitors of single SSB detectors placed at ±15° are also used for normalization of the incident flux and beam monitoring.

To understand the energy dependence of the breakup/transfer induced fission cross sections the ratio of fission cross sections of reaction induced by ^{6}Li to that of ^{7}Li with a particular target has been obtained from the experimental data available in Refs.[1] and [2] as shown in Fig. 1. The filled circles, filled stars and filled triangles-up symbols in the figure correspond to the ratio of fission data by Freiesleben *et al.*[2] with ^{238}U target and by Parihari *et al.*[1] with ^{238}U and ^{235}U targets respectively. It can be observed that at energies above the Coulomb barrier the ratio is close to unity but it starts increasing as we go down in the beam energy. This behavior is independent of the target one chooses. It implies that the relative contribution of breakup/transfer induced fission cross section for reactions induced by ^{6}Li (compared to ^{7}Li) increases with the decrease of beam energy.

The ratio of the alpha yields measured for two reactions has been extracted and also shown in Fig. 1 as squares and diamonds. In the first case (squares) the alpha yields of just one detector placed at 90^0 was used and in the second case the total alpha yields of 4 detectors placed at 60^0, 70^0, 80^0 and 90^0 are used. The energy dependence behavior for both the cases show an increasing trend in their values with the decrease in beam en-

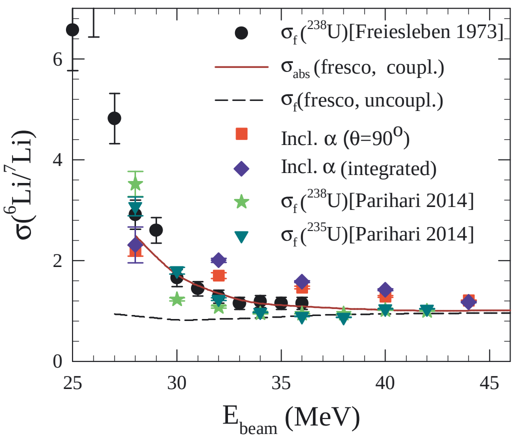

FIG. 1: Ratio of cross sections for fission data[1, 2] and inclusive alpha (present data) for reactions induced by ^{6}Li to those by ^{7}Li with the same target (^{235}U or ^{238}U). Results of FRESCO calculations for fusion cross sections with (without) breakup couplings are shown as a solid (dashed) line (see text for details).

ergy. This observation further confirms that projectile breakup is the main reason behind the above behavior in the energy dependence of the integrated fission cross section for the present reactions involving weakly bound ^{6,7}Li projectiles.

Calculations

To estimate the total (= complete + incomplete) fusion for the above reactions, continuum discretized coupled channels (CDCC) calculations using FRESCO are performed using cluster-folded potentials. Coupling scheme and potentials used in the calculations for breakup states is similar to Parihari et al. in Ref. [1]. Projectile breakup was assumed to be the most dominant direct reaction channel. Cumulative absorption cross section due to short range imaginary potentials calculated in the CDCC calculations equals to total fusion cross section. The ratio of the total fusion cross sections thus calculated for ^{6}Li+^{238}U reaction to that of ^{7}Li+^{238}U reaction with (without) breakup coupling is shown as a solid (dashed) line in Fig. 1. Although the uncoupled results do not show any dependence on beam energy, the results with breakup coupling show a trend in the energy dependence similar to the one observed in the ratio of fission cross sections for the two systems thus reassuring the role of breakup induced fusion/fission in the same.

Summary

Inclusive breakup alpha yields for ^{6,7}Li+^{238}U reactions have been measured at energies around the Coulomb barrier to understand the energy dependence of the ratio of the angle integrated fission cross sections available in the literature. The energy dependence of the ratio of the alpha yields for reactions induced by ^{6}Li to that by ^{7}Li shows a trend similar to the fission excitation function, thus explaining the dominant role that projectile breakup play specially at sub-barrier energies. The ratio of total fusion cross sections, same as fission cross sections, calculated by CDCC method for ^{6}Li+^{238}U to ^{7}Li+^{238}U reactions including breakup channels also show similar energy dependence and further confirms the role of projectile breakup in the observed energy dependence.

References

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