Fusion cross sections measurement for $^{6}Li+^{159}Tb$

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Introduction & Motivation

Fusion process between two heavy ions has been studied extensively over the last few decades. The main motivation was to explore the effect of coupling of their relative motion to collective degrees of freedom (e.g. vibration, rotation) and inelastic excitation, transfer, etc at energies around the Coulomb barrier where the effect of couplings is expected to be strong. A significant enhancement of fusion cross sections at sub-barrier energies is often observed when compared to the predictions of one-dimensional barrier penetration model calculations and this is attributed in terms of the dynamical processes arising from coupling to collective inelastic excitations of the target and projectile [1]. However, in case of reactions where at least one of the colliding nuclei has a low binding energy so that breakup process becomes an important reaction channel, controversies among different experimental results and also in the theoretical model calculations have been reported [2]. The recent increasing availability of beams of radioactive nuclei has caused a great interest in this subject and the interest is focused on investigating the effect of their unusual properties (halo/skin structures and very low binding energies) on fusion mechanism. Experimentally due to the relatively low intensities of radioactive beams precise measurement of fusion cross sections is still difficult though some results have started coming in. On the other hand understanding fusion reactions with easily available and high intensity weakly bound stable nuclei which have low binding energies will be an important reference for understanding similar studies of reactions involving weakly bound radioactive nuclei. For this reason over the last few years considerable efforts have been devoted towards the fusion studies at near barrier energies using the weakly bound stable projectiles ^{6}Li, ^{7}Li and ^{9}Be which have breakup threshold energies between 1.45 to 2.5 MeV [2].

In fusion with loosely bound projectiles, following the breakup of the projectile in the field of the target, one of the fragments may be captured by the target with the other escaping with beam velocity. This process is known as incomplete fusion process (ICF) and the process in which the whole of the projectile fuses with whole of the target is known as complete fusion (CF).

Fusion measurements of $^{6,7}Li$ and ^{9}Be projectiles with heavy targets like ^{208}Pb, ^{209}Bi show suppression of CF cross sections at energies above the respective Coulomb barrier. In order to investigate the effect of projectile breakup threshold energy on fusion in mass region around A~170, we have carried out a systematic investigation of the fusion (both CF and ICF) cross sections for the systems ^{11}B,$^{10}B+^{159}Tb$ and $^{7}Li+^{159}Tb$ at energies near and close to the barrier where ^{11}B was considered to be a strongly bound nucleus. The nucleus ^{10}B has a α-separation energy of 4.5 MeV. The measurements show that the extent of suppression of CF cross sections is correlated with the α-separation energies of the projectiles [3]. As a further continuation of this work, we have recently carried out fusion excitation function measurement for the system $^{6}Li+^{159}Tb$ (Coulomb barrier 27 MeV) at energies near and close to the barrier.

Experimental details & Results

^{6}Li beams in the energy range E_{lab}= 20-40 MeV, provided by the 14UD BARC-TIFR Pelletron Accelerator Facility at TIFR, Mumbai, bombarded a self-supporting ^{159}Tb target of thickness ~2. mg/cm^2. The emitted γ-rays from the evaporation residues were detected in an absolute efficiency calibrated Compton suppressed clover detector placed at 125^{o} with respect to the incident beam direction. Two monitor detectors were placed at ±30° w.r.t. the beam direction. The compound nucleus $^{165}Er^*$ formed in this reaction is found to predominately decay by neutron evaporation channels. The evaporation residues are identified by their characteristic γ-rays. The statistical model calculations also predict the predominantly the production of neutron evaporation channels as has been done by the code PACE2 [4]. The complete fusion cross sections have been obtained from the sum of the *xn* evaporation residue cross-sections. For the even-even ERs, the γ-rays cross sections, σ_γ (J), for various transitions in the ground state rotation band of the relevant nucleus have been obtained using the measured γ-rays yield after correcting for the internal conversion. The cross sections of the even-even ERs were then extracted from the extrapolated value of the γ-ray cross section at J = 0. The cross sections for reaction channels producing the final odd-mass nuclei were obtained by summing the yield of the γ-rays transitions in the low-lying levels as in these cases the γ-decay may proceed through several competing rotational bands. Only low energy part of the CF excitation function is shown in Fig. 1. The solid line shows the fusion cross sections predicted by the one-dimensional barrier penetration model (1-D BPM) calculations. The CF cross sections are seen to decrease from the 1-D BPM calculations, from $E_{c.m.} \geq 27$ MeV. Cross sections for the dominant αn channel, following ICF/transfer, were also obtained. Analysis of the data at energies $E_{c.m.} > 29$ MeV is still under progress and the detailed results will be presented at the symposium. However, a preliminary analysis of the high-energy data shows suppression of CF cross sections. The suppression seems to be more than that observed for the system $^{7}Li+^{159}Tb$ in Ref. [3].

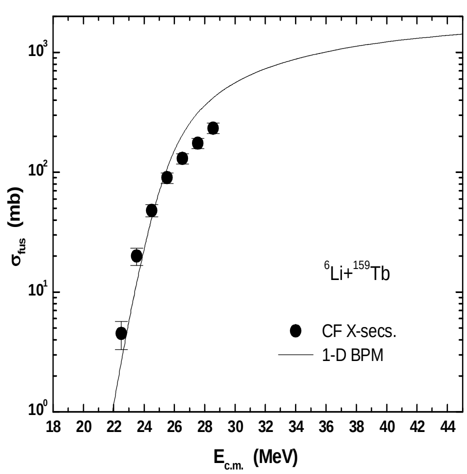

Fig. 1 Measured and calculated fusion cross sections for the system $^{6}Li+^{159}Tb$.

References

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