Alpha-production channels in ^{6}Li+^{159}Tb at energies around the Coulomb barrier

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The recent increasing availability of beams of radioactive nuclei has caused a great interest in investigating the fusion mechanism involving weakly bound nuclei, both stable and unstable [1]. Now, in collision with weakly bound nuclei different processes can take place. When the projectile as a whole fuse with whole of the target, the process is known as complete fusion (CF). If the projectile breaks up prior to fusion and one of the fragments fuses with the target while the other escapes with the beam velocity, then the process is known as incomplete fusion (ICF). If neither of the fragments are captured by the target, the process is known as non-capture breakup (NCBU). The existence and role of breakup process on fusion involving such nuclei, particularly ^{6,7}Li and ^{9}Be, have been studied extensively in different target mass regions [1]. Recently we have carried out fusion measurements by the characteristic γ-ray method for the systems ^{11,10}B+^{159}Tb and ^{7}Li+^{159}Tb at energies around the respective Coulomb barrier [2]. For the reactions ^{10}B+^{159}Tb and ^{7}Li+^{159}Tb, it was observed that ICF products were produced with the α-particle emitting channel being the favoured ICF process. To investigate this further we have measured inclusive α-particle cross sections for the system ^{6}Li+^{159}Tb at energies near the Coulomb barrier [3], as ^{6}Li is the most weakly bound nucleus among the four projectiles. Since this is as inclusive measurement several processes may contribute to the α-particle yields. These are: (1) breakup of ^{6}Li into α plus *d*, which could be both resonant and non-resonant, (2) α-particles resulting from the capture of *d* with ^{159}Tb, following breakup or a one-step *d*-transfer, (3) single-neutron stripping (or pickup) from ^{6}Li will produce unstable ^{5}Li (or ^{7}Li), that will subsequently decay to α plus a proton (or a triton), (4) a single-proton transfer can also result in α-particles. Measurements and/ or theoretical calculations are very important in order to have a better understanding of each of these processes. In order to investigate what are the dominant processes that might contribute to the inclusive α-particle channels, very recently measurements have been performed by the characteristic γ-ray method for the system ^{6}Li+^{159}Tb at energies below and above the Coulomb barrier (V_B = 26.9 MeV).

^{6}Li beam was provided from the 14UD BARC-TIFR Pelletron Accelerator at TIFR, Mumbai, in the energy range 23-39 MeV, bombarded on a self-supporting ^{159}Tb target of thickness 1.59 mg/cm^2. The γ-rays emitted from the residual nuclei were detected in a Compton suppressed clover detector placed at 125^o with respect to the incident beam direction. A HPGe detector was also placed at 125^o relative to the beam direction to cross check the data. Both in-beam and off-beam γ-spectra were recorded during each beam exposure. To determine the number of incident beam particles, the total charge during each beam exposure was measured by using a 1 *m* long Faraday cup placed after the target. Target thickness was measured by using the 137.5 keV Coulomb excitation line of ^{159}Tb. Absolute efficiency of the detectors was measured by using the standard calibrated radioactive sources placed at the same geometry as that for target. From the γ-ray spectra, by identifying the γ-lines, CF products (^{163}Er, ^{162}Er,

^{161}Er, ^{160}Er), ICF products (^{160}Dy, ^{159}Dy, ^{158}Dy, ^{161}Ho) and two 1*n* transfer products (^{158}Tb and ^{160}Tb) are found to be produced and their cross sections are measured. The cross sections of the even-even residues were obtained by measuring the γ-ray cross sections σ(J) for the various transitions in the ground state rotational band of the relevant nucleus and extrapolating it to J=0 The cross sections for the odd-mass nuclei were obtained by summing the cross sections of the γ-rays that feed the ground state. In Fig. 1, the measured cross sections of various α*xn* channels corresponding to the *d*-capture ICF process are shown. The total *d*-capture cross sections, Σα*xn* are also shown in the Fig. 1. The measured *d*-ICF may also include contribution from *d*-transfer to the target. In Fig. 2, the measured cross sections of the 1*n* pickup and 1*n*-stripping transfer channel are shown and also their sum.

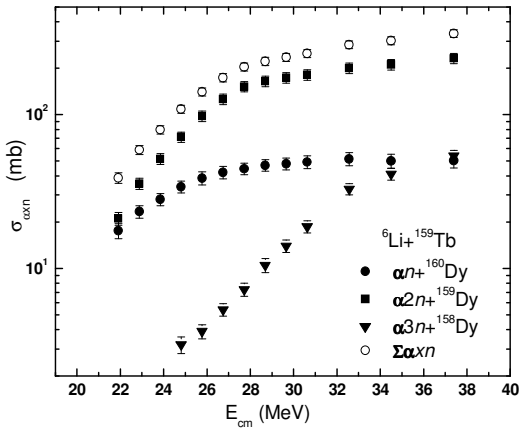

Fig. 1 Measured various αxn channel cross sectons for the reaction ^{6}Li+^{159}Tb.

Theoretical calculations have been done using the CDCC method to estimate the breakup cross sections of ^{6}Li into α+*d* [3]. This CDCC method is able to predict the breakup cross sections when none of the breakup fragments are captured by the target, i.e. NCBU process. Fig. 3 compares the sum of measured α*xn* channels & total 1*n*-transfer channels with the measured inclusive α-particle cross sections and is found to be very close to the inclusive α-yield. As this is an inclusive measurement, we do not have the measured α+*d* (NCBU) cross sections. Only a theoretical estimate has been obtained from the CDCC calculations. It appears that if we add these theoretical NCBU cross sections to the measured *d*-capture & *n*-transfer cross sections, the inclusive α-yield will be reproduced. So we observe that for the system ^{6}Li+^{159}Tb, *n*-transfer processes are one of the significant channels, from which the resulting α-particles contribute significantly to the total inclusive α-yield.

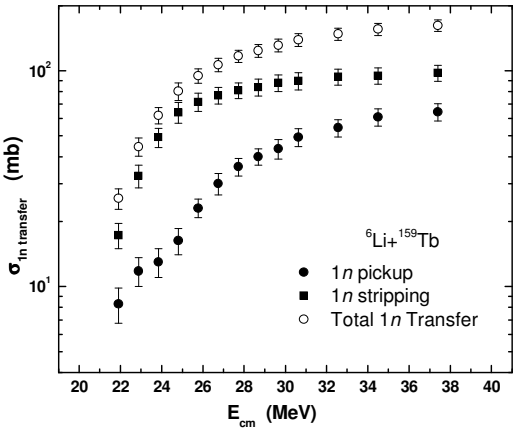

Fig. 2 Measured 1*n* transfer channel cross sections for the reaction ^{6}Li+^{159}Tb.

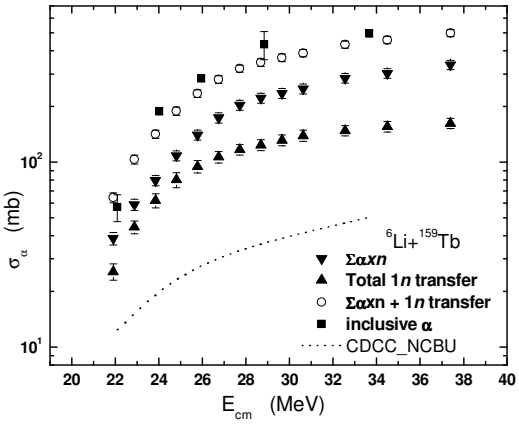

Fig. 3 Comparison of measured cross sections of α-particles from various processes for the reaction ^{6}Li+^{159}Tb.

References

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