Measurement of projectile breakup cross-section in ^{6,7}Li+^{112}Sn reactions

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Study of projectile breakup in the field of a target nucleus is a topic of increasing interest [1], particularly due to recent advent of the availability of weakly bound exotic beams. Very few measurements for direct and sequential breakup cross-sections in reactions involving weakly bound stable projectiles having $\alpha + x$ cluster structures like ^{6,7}Li and ^{9}Be are available in the literature [2–4]. The cluster structure of a light nucleus plays an important role in predicting possible breakup channels. The ^{6}Li(^{7}Li) as a cluster of α and d(t) with a binding energy of only 1.47 MeV (2.47 MeV) is very well known. For the ^{6}Li case, one can expect its breakup through all three resonance states corresponding to L = 2, i.e., (3^+, 2.18 MeV), (2^+, 4.31 MeV), and (1^+, 5.65 MeV) [5]. Similarly for ^{7}Li, the breakup into $\alpha + t$ can take place through all possible resonance states corresponding to L=3 [5] i.e., ($7/2^-$,4.63 MeV) and ($5/2^-$, 6.67 MeV). Direct breakup of ^{6}Li(^{7}Li) into $\alpha + d(\alpha + t)$ and sequential breakup via the first two resonance states (first resonance state of ^{7}Li) of the cluster have been measured for several systems. But there is no measurement available on the sequential breakup corresponding to the 1^+ resonance state for ^{6}Li and similarly for $5/2^-$ resonance state of ^{7}Li. So, detecting these new breakup channels and measuring their cross sections is one of the prime motivations of the present thesis work.

Apart from the well-known $\alpha + x$ cluster, ^{6}Li, ^{7}Li also exhibit some additional cluster structures, such as ^{6}Li exhibits ^{3}He+t with breakup threshold $\sim$ 16 MeV and ^{7}Li shows ^{6}Li+n and ^{6}He+p structures with breakup threshold 7.25 and 9.97 MeV respectively. Investigation of the breakup channel ^{7}Li $\rightarrow$ ^{6}He + p will shed light on the possibility of the third cluster structure of ^{7}Li.

Apart from α + d(t) breakup, the α particles can be produced by transfer triggered breakup. For example, the transfer reactions of (^{7}Li,^{6}Li), (^{7}Li,^{5}Li), (^{7}Li,^{8}Be), (^{7}Li,^{6}He), and (^{7}Li,^{5}He) followed by breakup into $\alpha + d$, $\alpha + p$, $\alpha + \alpha$, $\alpha + 2n$, and $\alpha + n$, respectively, can contribute individually to the inclusive α production. Several studies on heavy and light targets pointed out different conclusions regarding the dominance of particular breakup mode over other [2–4]. Motivated by the above mentioned objectives, the breakup phenomena is further probed involving ^{6,7}Li as a projectile with a medium mass target (^{112}Sn) at above barrier energy to confirm the target dependence if any. The breakup phenomenon of ^{6}Li by ^{112}Sn have also been carried out at two different energies to see the energy dependence of these breakup probabilities.

In this thesis, the results of experimental investigation of the existence of (i) ^{6}Li(^{7}Li) breakup into α +d(t) via its all possible resonance states and (ii) direct breakup of ^{7}Li into ^{6}He + p were reported. In addition, the different transfer induced breakup has also been investigated. Experimental cross sections have also been compared with the results of coupled-channel calculations via FRESCO [6].

Based on the above mentioned motivations, several measurements were carried out involving weakly bound projectiles ^{6}Li and ^{7}Li with ^{112}Sn target using 14UD BARC -TIFR Pelletron-Linac facility with an array of maximum five-strip telescopes [7, 8].

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Using the energies and laboratory detection positions of two breakup fragments of each co-incident event, the values of 'θ,ϕ' of outgoing projectile-like fragment (for α + x breakup), 'Q-Value' and 'α-x relative energy 'E_{rel}' were reconstructed and corresponding efficiency of the detector array has been obtained by a Monte-Carlo simulation. Various breakup processes, breakup of ^{6}Li (^{6}Li* → α + d) together with 1d-pickup followed by breakup (^{6}Li → ^{8}Be → α + α) and 1n-stripping followed by breakup (^{6}Li → ^{5}Li → α + p) were disentangled by using the 3-body kinematics method. Although 3^{+} and 2^{+} resonance states were identified earlier, the observation of 1^{+} state was observed for the first time [7]. Similarly, for ^{7}Li, the direct breakup into α+t and ^{6}He+p, resonant breakup into α+t via the resonance states $7/2^{-}$ and $5/2^{-}$ together with the 1p-pickup followed by breakup (^{7}Li → ^{8}Be → α + α) and 1n-stripping followed breakup (^{7}Li → ^{6}Li → α + d) were identified through relative energy reconstruction [8, 9]. The breakup of ^{7}Li into α+t via the second resonance state i.e. via $5/2^{-}$ state was identified for the first time. The observation breakup into ^{6}He+p was also for the first time indicates the possibility of additional cluster state of ^{7}Li. The angular distribution of each of the breakup channels were estimated and compared with the coupled channel calculations via FRESCO [6].

From the present work, it has been observed that the breakup of ^{6}Li into α + d is much larger as compared to ^{6}Li→^{5}Li→ α + p breakup at above barrier energy and they are comparable at around barrier energy. This conradicts to the observation made by Luong *et al.* [4], where they claimed that α + p breakup is dominant for all the targets (^{207,208}Pb,^{209}Bi) irrespective of the reaction Q-Value. In addition to exclusive breakup measurements, the inclusive breakup α cross sections for ^{6}Li+^{112}Sn reaction have also been measured at several energies (22, 24, 26, 28 and 30 MeV) around the Coulomb barrier. The cross section for the inclusive α was found to be a significant fraction of the total reaction at all the energies, and at sub-barrier energies it exhausts almost whole of the reaction cross section. The different breakup channels responsible for high inclusive α were identified. It has been observed that apart from the direct and resonant breakup, the cross-sections of different transfer breakup channels (e.g., 1p stripping followed by breakup into $\alpha + n$, 1n stripping followed by breakup into $\alpha + p$, 1d pickup followed by breakup into $\alpha + \alpha$) have significant contribution to the inclusive α production. It is found that the total breakup α along with the evaporated α explains about 24% to 27% of the total inclusive-α. This implies that the rest of the contribution may originate from d-capture reaction as observed in [10].

The results on direct, resonant, and transfer breakup of ^{6,7}Li by ^{112}Sn presented here provide a good foundation toward the comprehensive understanding of the reaction mechanisms of the projectile breakup as well as the production of large inclusive α in a reaction involving a weakly bound stable or unstable light projectile.

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