Observation of breakup via 1^+ resonant state of ^{6}Li

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Introduction

Study of nuclear reactions with weakly bound projectiles are very very interesting due to the observation of many new features compared to the ones with strongly bound projectiles. The presence of projectile breakup channels and their coupling to elastic channel are the main reasons behind the above differences. Seveal particle-particle correlation measurements including ^{6}Li+^{209}Bi reaction at near barrier energies[1, 2] show the presence of not only the direct breakup of $^6\mathrm{Li}\rightarrow \alpha + d$ but also the sequential breakup via one of its resonance states (i.e., $^6\mathrm{Li}\rightarrow^6\mathrm{Li}^*(3^+) \rightarrow \alpha + d$) and transfer induced breakup like $^6\mathrm{Li}\rightarrow^5\mathrm{Li}\rightarrow \alpha + p$ and $^6\mathrm{Li}\rightarrow^8\mathrm{Be}\rightarrow \alpha + \alpha$. It has been found that the probability of breakup of the clustered projectiles or projectile like fragments like ^{6,7}Li into two or more fragments proceeding through their resonance states is quite large [1–4]. Therefore, for ^{6}Li case, one can expect its breakup through three resonance states i.e., (3^+,2.18 MeV), (2^+,4.31 MeV) and (1^+,5.65 MeV). So far there is no study available in the literature on the experimental breakup cross sections for ^{6}Li via its 1^+ resonance state. The excitation energy and width of this state being very large the cross section is expected to be less compared to other two (2^+ and 3^+) resonance states. Also, the relative energy of the breakup fragments proceeding via this resonance state being large (4.18 MeV) the detection cone angle becomes large ($\sim 56^\circ$). So, it would be interesting and challenging to measure the breakup cross section via 1^+ state along with 2^+ and 3^+ resonance states using a huge detector setup covering a large solid angle and find their relative contributions.

In this paper, the exclusive measurements of breakup cross sections in ^{6}Li+^{112}Sn reaction at E_{beam}=30 and 22 MeV have been presented. Cross sections for sequential breakup through resonance states of ^{6}Li have been compared with the continuum-discretized-coupled-channels (CDCC) calculations.

Experimental details

Exclusive measurements have been carried out for ^{6}Li+^{112}Sn reaction at E_{lab}= 30 and 22 MeV, using the 14-UD Pelletron-Linac facility in Mumbai. A self-supporting enriched ^{112}Sn target of thickness $\approx$ 540 μg/cm^2 has been used. Four Si strip telescopes with large angular coverage ($\sim$76°) were placed inside a 1.5-m diameter scattering chamber to detect the projectile like fragments in coincidence. Each strip telescope consists of two double-sided Si strip detectors with thickness of 60μm (as ΔE) and 1500μm (as E) respectively. Each detector has 16 vertical strips in its front side and 16 horizontal strips in its back side (256 pixels) with length and breadth of each strip being 50 mm and 3.1 mm respectively. Two surface barrier detectors (M_1 and M_2) of thickness 1 mm were placed at $\pm 20^\circ$ with respect to the beam direction for normalization and beam monitoring.

Analysis and results

The Q-value spectrum obtained for coincident α-d breakup fragments detected in any two strip detectors (Fig. 1(a)) at E_{beam} = 30 MeV clearly show three peaks at 2.18 MeV,

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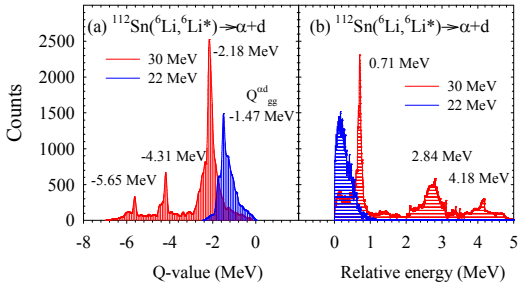

FIG. 1: (Colour online) Comparison of the yield distributions of α-d breakup as a function of Q-value and relative energy at two different beam energies i.e., 22 and 30 MeV.

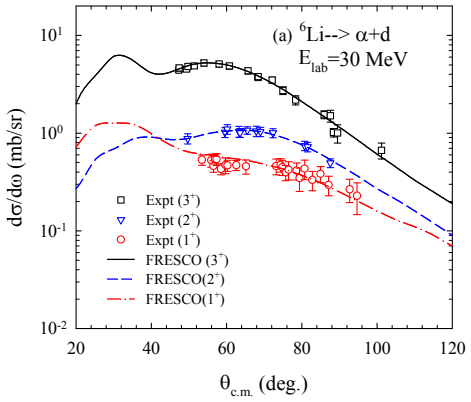

FIG. 2: (Colour online) Sequential $\alpha + d$ breakup cross section in centre-of-mass frame measured at 30 MeV. Squares, triangles and circles correspond to experimental differential cross sections for sequential $\alpha + d$ breakup through 3^+, 2^+ and 1^+ resonance states respectively. Solid, dashed and dash-dot lines represent respective results obtained from CDCC calculations.

4.31 MeV and 5.65 MeV that correspond to the resonance excitations of ^{6}Li at 3^+, 2^+ and 1^+ states respectively. The corresponding relative energy spectrum (Fig. 1(b)) also showing three peaks at 0.71 MeV, 2.84 MeV and 4.18 MeV confirms the observation of dominant sequential breakup of ^{6}Li via three resonance states. To our knowledge this is the first observation of α-d breakup via 1^+ resonance state of ^{6}Li in addition to its already known 3^+ and 2^+ resonance states at $E_{\rm beam}$ = 30 MeV. The direct breakup of ^{6}Li via its non-resonant states have been observed for both $E_{\rm beam}$=30 and 22 MeV. No significant cross sections for resonant breakup was observed at 22 MeV.

The experimental cross sections for the sequential α+d breakup through three resonance states of ^{6}Li have been obtained following the procedure described in Ref. [1]. An average of the cross sections obtained from the two (low and high energy) peaks of particular coincidence spectrum corresponding to two very similar centre-of-mass angles has been obtained for each of 3^+ and 2^+ breakup. However, for 1^+ breakup, the cross sections obtained for each of two coincidence peaks have been plotted independently as the difference in centre-of-mass angles corresponding to two peaks is large ($12^\circ - 22^\circ$). Differential cross sections for sequential α+d breakup via 3^+, 2^+ and 1^+ resonance shown in Fig. 2 are represented by squares, triangles and circles respectively. Although the resonant breakup cross sections via 3^+ and 2^+ states of ^{6}Li in reactions involving a few targets have been measured and described earlier, the cross section for 1^+ state is measured for the first time in the present reaction. The results of CDCC calculations similar to Ref. [1] are represented by lines in Fig. 2, explain the experimental cross section very well and thus confirm the observation of above resonant breakup.

References

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