Exploring the reaction dynamics in ^{7}Li(α,n)^{10}B reaction

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1. Introduction

Nuclear reactions involving light mass nuclei have always been an area of interest among researchers. Several light mass nuclei are known to exhibit clustering phenomenon [1] for eg. ^{7}Li (α+t), ^{9}Be (2α+n), ^{12}C (3α) etc. ^{6,7}Li and ^{9}Be although being stable, are weakly bound having considerably low breakup threshold (1.48 - 2.55 MeV). As a result these nuclei are prone to break in the field of other nucleus during the nuclear reaction thereby influencing cross-section values. ^{7}Li(α,n)^{10}B reaction has been studied in the past mostly at around threshold energies (5 - 8 MeV) [2] focusing on the neutron energy distribution corresponding to the different energy levels of ^{10}B. Breakup channels and their cross-sections were not well studied for this reaction. In this work, measurements have been performed with higher alpha-energies to exclusively study the breakup contribution in ^{7}Li(α,n)^{10}B reaction.

2. Experimental details

Experiment was performed using ^{4}He beam of energy 26 MeV from K130 cyclotron at VECC, Kolkata and a natural Li target of thickness 2.8 mg/cm^{2} which was placed inside a 3 mm thick stainless steel reaction chamber. Ejected neutrons were detected using eight BC501A liquid scintillator detectors placed around the target chamber at a distance of 2 m and covering an angle of 25° to 150° with respect to the beam direction. Neutron energies were determined using Time Of Flight (TOF) technique with the “start” from cyclotron RF and “stop” from the individual neutron detector signals. Neutron and γ ray induced events were discriminated by Pulse Shape Discrimination (PSD) utilizing Zero Cross Over (ZCO) technique. Neutron TOF spectra were then converted to energy spectra using the “prompt” γ as time reference and applying standard Jacobian transformation.

3. Results and discussions

Double differential neutron energy spectra at 108° detection angle (centre of mass frame) is shown in Fig. 1. The neutron energy distribution appears continuous with small peaks which are more prominent at backward angles. This indicates the presence of quasi-monoenergetic neutron groups in the spectra along with evaporation, pre-equilibrium and breakup from continuum. These structures in the neutron energy spectra can give us an insight into the different exit channels governing the reaction mechanism.

Differential cross-section dσ/dΩ was determined from the neutron energy distributions at all the detection angles by dividing each spectra into three energy regions (a) below 5 MeV, (b) 5 - 10 MeV and (c) above 10 MeV. Integral area under the curve for each region was calculated using Simpson's $1/3^{rd}$ rule. The calculated areas in each region were plotted as a function of the centre of mass (CM) angle θ_{CM} for E$_{\alpha}$ = 26 MeV. Angular distributions thus obtained are shown in Fig. 2(a-c). Angular distributions at Fig. 2(b,c)

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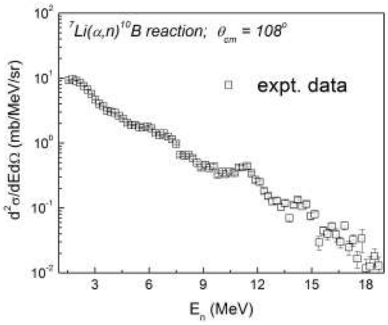

FIG. 1: Experimental double differential neutron energy spectra at 108° centre of mass angle. Data points have been represented by hollow symbols.

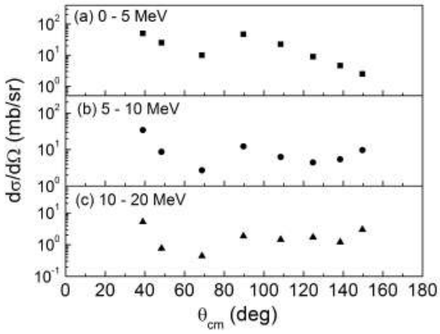

FIG. 2: Angular distribution of neutrons at E_α = 26 MeV. Panels (a), (b) and (c) represent the three energy regions as labelled in figure.

are symmetric around 90° thus indicating that neutrons may be emitted from an equilibrated source. However in the neutron energy range 0 - 5 MeV (Fig. 2a), the distribution is forward focused thus indicating the dominance of direct breakup process.

The experimental data was then compared with theoretical calculation from the statistical model code TALYS-v 1.95 [3]. All possible reaction channels like direct, pre-equilibrium and compound were considered. TALYS calculated double differential neutron energy spectrum along with the experimental data is shown in Fig.3 at 108° (θ_{cm}). As can be seen from the figure, TALYS calculations could not reproduce the experimental data mostly at the lower energy part of the neutron energy spectra where it was considerably underestimated. It is important to understand the origin of these low energy neutrons (1 - 8 MeV) which contribute significantly to the total reaction yield.

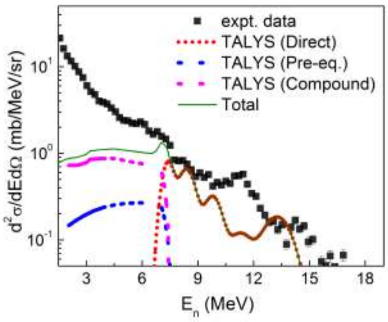

FIG. 3: Comparison of TALYS calculations (lines) with the experimental data (points) at 108° centre of mass angle.

In weakly bound light mass systems like ^{7}Li, nuclei breakup is a common phenomenon [4]. ^{7}Li* breakup upon inelastic excitation by the incident 'α' is a probable neutron producing exit channel (^{7}Li*→^{6}Li+n; E_{th} = 7.26 MeV and ^{7}Li*→^{2}H+α+n; E_{th} = 8.72 MeV). However TALYS does not consider direct breakup of target nuclei upon excitation. This can be a possible reason for the mismatch of the experimental and calculated data. So a different approach was taken to calculate the breakup cross-sections using Monte Carlo simulation details, of which shall be discussed during the symposium.

References

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