Study of ^{7}Be(d,α)^{5}Li($p\,\alpha$) and ^{7}Be(d,p)^{8}Be*($p\,^{7}$Li) reactions at 5 MeV/u

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Introduction

The lithium abundance anomaly [1] is a well-known problem in nuclear astrophysics. The nuclear physics aspect of the problem involves the production and destruction reactions of ^{7}Be. This is due to the reason that primordial ^{7}Li was primarily produced from the β-decay of ^{7}Be. The production channels of the ^{7}Be are well studied, while further studies are required for the destruction channels. Several experiments studying the destruction channels of ^{7}Be with neutrons and charged particles were carried out [2–5]. However, all of them failed to alleviate the lithium anomaly. The destruction channels (d,α) and (d,p) were particularly studied in recent times in this regard. Rijal *et al.* [3] measured the ^{7}Be(d,α)^{5}Li($p\,\alpha$) reaction at relevant big-bang nucleosynthesis (BBN) energies and claimed that the (d,α) channel dominates over the (d,p) channel at all energies. On the contrary, Angulo *et al.* [4] and Ali *et al.* [5] did not find any signature of predominance of the (d,α) channel. Ali *et al.* [5] studied the contribution of the excited states of ^{8}Be up to $\sim$ 16 MeV from the ^{7}Be + d reaction. The states above 16 MeV are studied in the present work. The excited states above 18 MeV may decay into p_0 + ^{7}Li or p_1 + ^{7}Li$^{*}_{0.478}$ channels. It may be noted that, Hayakawa *et al.* [6] reported about 10% decrement in the primordial ^{7}Li abundance from ^{7}Be(n,p_1)^{7}Li$^{*}_{0.478}$ and ^{7}Be(n,p_0)^{7}Li reactions, studied indirectly from measurements of the ^{7}Be + d reaction at 3.16 MeV/u. In the present work, the ^{7}Be(d,α)^{5}Li($p\,\alpha$) reaction is also studied in further details along with ^{7}Be(d,p)^{8}Be*($p\,^{7}$Li).

Results and Discussion

The experiment was carried out at HIE-ISOLDE, CERN, with a 5 MeV/u ^{7}Be beam of intensity $\sim 5{\times}10^{5}$ pps. A CD_2 target of thickness 15 µm was used. A silicon detector array in the shape of a pentagon was used to detect the charged particles. The experimental details are available in Ref. [5]. To study the ^{7}Be(d,α)^{5}Li($p\,\alpha$) reaction, coincidence detection of a proton and an α-particle is considered. A Catania plot [7] is generated to identify the events yielding $\alpha + \alpha + p$ in the outgoing channel (Fig 1). This type of plot gives a unique straight line that intercepts the y-axis at $y = -Q$ and has a slope of $1/m$, where Q is the reaction Q value and m is the

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mass of the undetected particle for each channel.

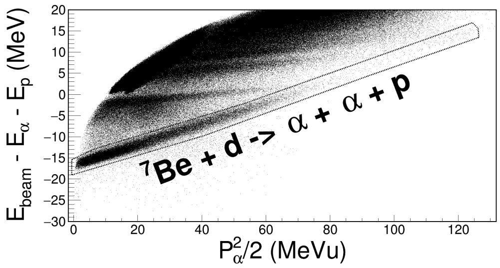

Fig 1: The Catania plot to identify ^{7}Be$+ d \to \alpha +$ $\alpha + p$ reaction. The dotted curve intercepts with the y-axis at about -16.8 MeV and has a slope of $1/m_\alpha$ (m_α = mass of α-particle). The dotted cut represents events from ^{7}Be $+ d \to \alpha + \alpha + p$ reaction.

The selection of events with $\alpha + \alpha + p$ in the exit channel is shown by the dotted curve in Fig 1. Now, the end products of both (d, p) and (d, α) channels are α, α and p. Therefore, a two-dimensional plot of the relative energies of $E_{\alpha\alpha}$ vs $E_{\alpha p}$ is generated to differentiate between the two channels. At the end, the excitation energy of ^{5}Li is obtained as shown in Fig 2.

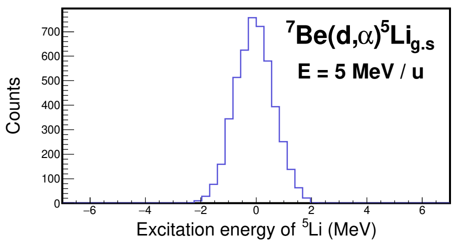

Fig 2: Excitation energy spectrum of ^{5}Li

To study the ^{7}Be$(d, p)^8$Be$^*(p\,^7$Li$)$ reaction, two protons at the pentagon detectors in coincidence with one hit at the forward angle S3 detector are considered. The Q values of ^{7}Be$(d, p)^8$Be$^*(p_0\,^7$Li$)$ and ^{7}Be$(d, p)^8$Be$^*(p_1\,^7$Li$^*_{0.478})$ are respectively -0.580 MeV and -1.058 MeV. The Q value spectrum is shown in Fig 3. The inset in Fig 3 represents the reconstructed mass of the unknown hit at S3 and the peak at 7.1u correspond to the ^{7}Li nucleus, confirming the ^{7}Be$(d, p)^8$Be$^*(p\,^7$Li$)$ channel.

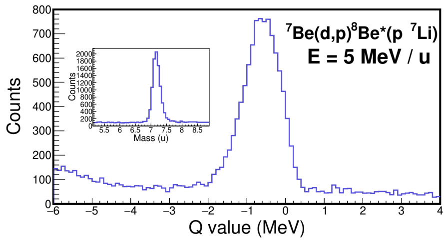

Fig 3: The Q value spectrum of the ^{7}Be$(d, p)^8$Be$^*(p\,^7$Li$)$ reaction. The inset shows the mass of the unknown hit at S3.

In conclusion, the present work clearly identifies ^{7}Be$(d, \alpha)^5$Li$(p\,\alpha)$ and ^{7}Be$(d, p)^8$Be$^*(p\,^7$Li$)$ reaction channels from the ^{7}Be $+ d$ reaction at 5 MeV/u. Further analysis is in progress.

Acknowledgments

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