

Study of ${}^7\text{Be}(d, \alpha){}^5\text{Li}(p\alpha)$ and ${}^7\text{Be}(d, p){}^8\text{Be}^*(p\,{}^7\text{Li})$ 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 ${}^7\text{Be}$. This is due to the reason that primordial ${}^7\text{Li}$ was primarily produced from the β -decay of ${}^7\text{Be}$. The production channels of the ${}^7\text{Be}$ are well studied, while further studies are required for the destruction channels. Several experiments studying the destruction channels of ${}^7\text{Be}$ 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 ${}^7\text{Be}(d, \alpha){}^5\text{Li}(p\alpha)$ 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 ${}^8\text{Be}$ up to ~ 16 MeV from the ${}^7\text{Be} + d$ reaction. The states above 16 MeV are studied in the present work. The excited states above 18 MeV may decay into $p_0 + {}^7\text{Li}$ or $p_1 + {}^7\text{Li}_{0.478}^*$ channels. It may be noted that, Hayakawa *et al.* [6] reported about 10% decrement in the primordial ${}^7\text{Li}$ abundance from ${}^7\text{Be}(n, p_1){}^7\text{Li}_{0.478}^*$ and ${}^7\text{Be}(n, p_0){}^7\text{Li}$ reactions, studied indirectly from measurements of the ${}^7\text{Be} + d$ reaction at 3.16 MeV/u. In the present work, the ${}^7\text{Be}(d, \alpha){}^5\text{Li}(p\alpha)$ reaction is also studied in further details along with ${}^7\text{Be}(d, p){}^8\text{Be}^*(p\,{}^7\text{Li})$.

Results and Discussion

The experiment was carried out at HIE-ISOLDE, CERN, with a 5 MeV/u ${}^7\text{Be}$ 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 ${}^7\text{Be}(d, \alpha){}^5\text{Li}(p\alpha)$ 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.

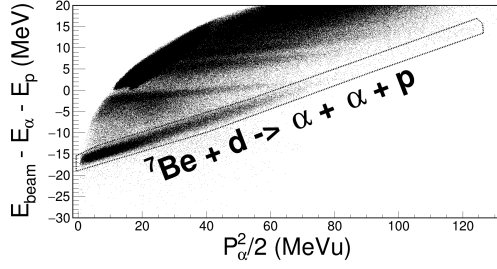


Fig 1: The Catania plot to identify ${}^7\text{Be} + d \rightarrow \alpha + \alpha + p$ reaction. The dotted curve intercepts with the y-axis at about -16.8 MeV and has a slope of $1/m_\alpha$ ($m_\alpha =$ mass of α -particle). The dotted cut represents events from ${}^7\text{Be} + d \rightarrow \alpha + \alpha + p$ 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 ${}^5\text{Li}$ is obtained as shown in Fig 2.

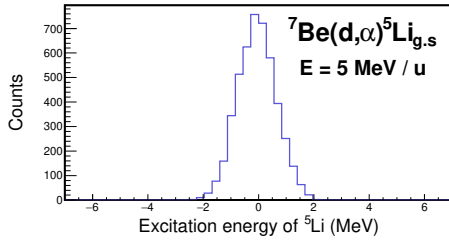


Fig 2: Excitation energy spectrum of ${}^5\text{Li}$

To study the ${}^7\text{Be}(d, p){}^8\text{Be}^*(p\,{}^7\text{Li})$ reaction, two protons at the pentagon detectors in coincidence with one hit at the forward angle S3 detector are considered. The Q values of ${}^7\text{Be}(d, p){}^8\text{Be}^*(p_0\,{}^7\text{Li})$ and ${}^7\text{Be}(d, p){}^8\text{Be}^*(p_1\,{}^7\text{Li}_{0.478}^*)$ 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 ${}^7\text{Li}$ nucleus, confirming the ${}^7\text{Be}(d, p){}^8\text{Be}^*(p\,{}^7\text{Li})$ channel.

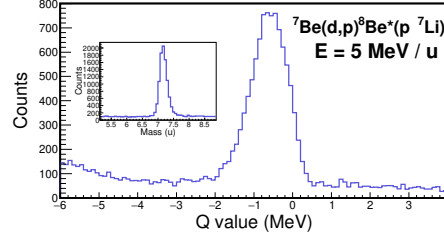


Fig 3: The Q value spectrum of the ${}^7\text{Be}(d, p){}^8\text{Be}^*(p\,{}^7\text{Li})$ reaction. The inset shows the mass of the unknown hit at S3.

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

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