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Measurement of the differential cross sections of ${}^{nat}\text{Li}(\text{d},\text{d}_0)$ for EBS purposes

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Abstract In the present work, the ${}^{6,7}\text{Li}(\text{d},\text{d}_0){}^{6,7}\text{Li}$ elastic scattering differential cross sections were measured in the energy range $E_{lab} = 900 - 2000$ keV for EBS purposes, using thin lithium targets, made by evaporating ${}^{nat}\text{LiF}$ and isotopically enriched ${}^6\text{LiF}$ powder on self-supporting carbon stripping foils, with an ultra-thin Au layer on top for charge normalization purposes. The experiment was carried out in deuteron beam energy steps of 5 to 30 keV, depending on the fine structure of each studied cross section, and for the laboratory scattering angles of 125°, 140°, 150°, 160°, and 170°.

INTRODUCTION

Lithium is an element frequently found in nature (trace amounts of lithium are present in all organisms) and has several applications in various fields, namely in nuclear physics, optics, organic and polymer industry. Notably, lithium and its compounds are used for heat-resistant glass and ceramics, lithium grease lubricants, steel and aluminium production and lithium batteries. Due to its low atomic number and the fact that it is a highly reactive element emerges a great need for the determination of lithium depth profile distributions in complex matrices. A well-established IBA (Ion Beam Analysis) technique for the depth profiling of light elements and the accurate quantitative determination of elemental concentrations is the Elastic Backscattering Spectroscopy (EBS). Furthermore, it is crucial to mention here that there is a lack of deuteron elastic backscattering data for EBS analysis. Therefore, in the present work, the ${}^{6,7}\text{Li}(\text{d},\text{d}_0){}^{6,7}\text{Li}$ elastic scattering differential cross sections were measured for EBS purposes.

EXPERIMENTAL SETUP

The experiment was carried out at the 5.5 MV Tandem Accelerator of N.C.S.R. “Demokritos”, Athens, Greece. The deuterons, accelerated to $E_{lab} = 900 - 2000$ keV with a variable step of 5 – 30 keV, depending on the fine structure of each studied cross section, were led to a cylindrical chamber of large dimensions ($R \approx 40\text{cm}$). The targets were placed in

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the center of the chamber and were perpendicular to the beam. A Faraday cup was mounted behind the targets for a second check on the charge measurements.

The detection system consisted of five silicon surface barrier (SSB) detectors, along with the corresponding electronics, placed at 125° , 140° , 150° , 160° , and 170° , with respect to the beam direction, and at a distance of ~ 10 cm from the target. An orthogonal tantalum slit was placed in front of each detector, thus defining the measured angles with an accuracy of $\sim 1^\circ$. The spectra from all the five detectors were simultaneously recorded and the procedure was repeated for every deuteron beam energy.

A thin nat LiF target and an isotopically enriched 6 LiF one were used for the cross section measurements. The nat LiF and the enriched 6 LiF (94% in 6 Li) powder was evaporated on self-supporting carbon stripping foils and then an ultra-thin Au layer was evaporated on top of each target for charge normalization purposes. Moreover, two thick targets were implemented for benchmarking purposes, namely an unpolished crystalline wafer of LiAlO_2 and a highly pressurized, high-purity LiF pellet, also with an ultra-thin layer Au evaporated on top.

PRELIMINARY RESULTS

The excitation functions were produced while the experiment was carried out and for 6 Li and 7 Li are presented in figs. 1a, 1b and 1c, along with the only existing measurement of the differential cross section of the $^7\text{Li}(\text{d},\text{d}_0)$ elastic scattering [1].

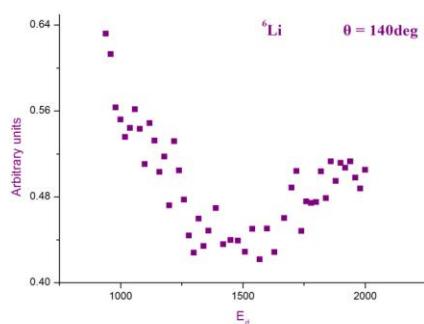


Fig. 1a. Excitation function for ^6Li at 140° .

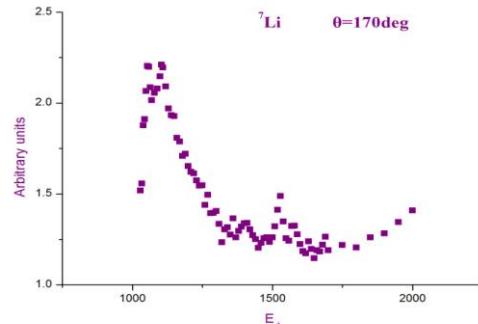


Fig. 1b. Excitation function for ^7Li at 170° . There is a resonance at $E_d = 1120$ keV, corresponding to the excited level of compound nucleus $^8\text{Be}^*$ at 17495 KeV.

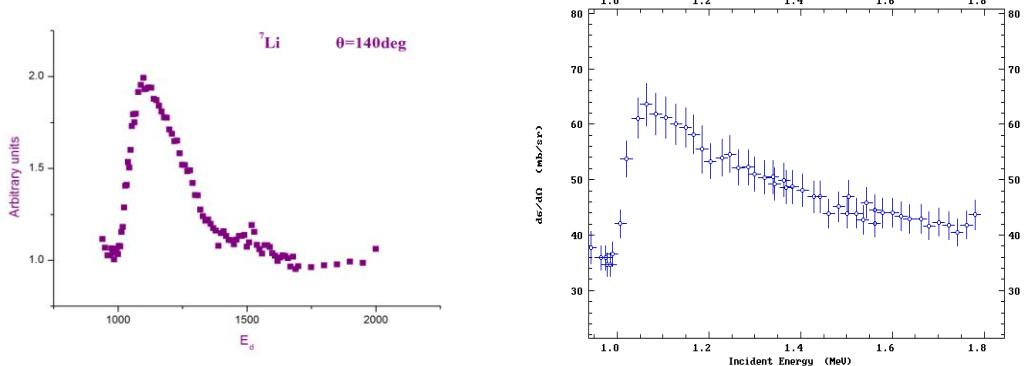


Fig. 1c. The excitation function of ${}^7\text{Li}$ at 140° along with the cross section measurement by J.L.C.Ford [1] at 125° (1964, the only existing differential cross section measurement in literature [1]).

DATA ANALYSIS

The determination of the differential cross section values for ${}^{6,7}\text{Li}$ will be carried out using the relative measurement technique[2]. The procedure includes the formula for the absolute measurement of the ${}^{6,7}\text{Li}$ and ${}^{197}\text{Au}$ differential cross sections at each deuteron beam energy and their subsequent division, meaning:

$$\left(\frac{d\sigma}{d\Omega} \right)_{\theta, {}^{6,7}\text{Li}} = \frac{Y_{{}^{6,7}\text{Li}}}{(Q\Omega)N_{t, {}^{6,7}\text{Li}}} \quad \text{and} \quad \left(\frac{d\sigma}{d\Omega} \right)_{\theta, \text{Au}} = \frac{Y_{\text{Au}}}{(Q\Omega)N_{t, \text{Au}}}$$

where Y corresponds to the experimental yield (integrated peak counts), Q to the number of impinging deuterons, Ω to the solid angle subtended by the detector set to angle θ , and $N_{t,i}$ to the i- target thickness in at/cm^2 .

So, by dividing one gets the following formula:

$$\left(\frac{d\sigma}{d\Omega} \right)_{\theta, {}^{6,7}\text{Li}} = \frac{\left(\frac{d\sigma}{d\Omega} \right)_{\theta, \text{Au}} Y_{{}^{6,7}\text{Li}}}{Y_{\text{Au}}} \left(\frac{N_{t, \text{Au}}}{N_{t, {}^{6,7}\text{Li}}} \right)$$

Where $\left(\frac{d\sigma}{d\Omega} \right)_{\theta, \text{Au}}$ is well-known from Rutherford's formula, $\left(\frac{d\sigma}{d\Omega} \right)_{\theta, {}^{6,7}\text{Li}}$ and $\left(\frac{d\sigma}{d\Omega} \right)_{\theta, {}^{6,7}\text{Li}}$ correspond to the measured yields and the ratio $\left(\frac{d\sigma}{d\Omega} \right)_{\theta, \text{Au}} / \left(\frac{d\sigma}{d\Omega} \right)_{\theta, {}^{6,7}\text{Li}}$ will be determined from target measurements with a proton beam at several beam energies (e.g. 1200, 1600, 1700 keV).

Typical experimental spectra of the ${}^{\text{nat}}\text{LiF}$ and enriched ${}^6\text{LiF}$ targets on self-supporting stripping carbon foils with Au on top are depicted in figs. 2a and 2b, as shown below:

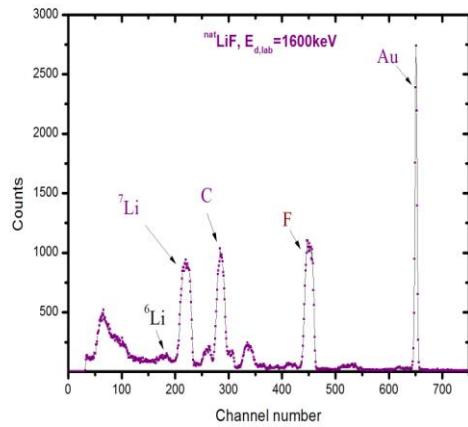


Fig. 2a. Experimental spectrum of the ^{nat}LiF target taken at 140° and $E_{d,lab}=1600$ keV along with the corresponding elastic scattering peak identification.

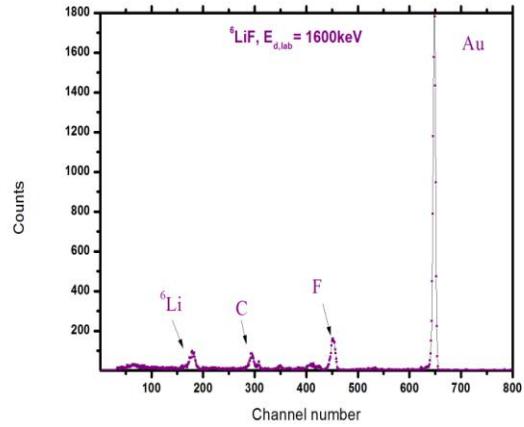


Fig. 2b. Experimental spectrum of the enriched 6LiF target taken at 140° and $E_{d,lab}=1600$ keV along with the corresponding elastic scattering peak identification.

CONCLUSIONS

In the present work differential cross section data of the reactions $^{6,7}Li(d,d_0)^{6,7}Li$ will be derived at 5 angles for the deuteron energy range between 0.9 and 2 MeV. The determination of the reaction cross section in this region is very important, as there is a considerable lack of such data in literature. The work is still in progress.

References

- [1] J.L.C. Ford, Physical Review, Vol.136, p.B953 (1964)
- [2] N. Patronis et al., Nucl. Instr. and Meth. B337, p. 97-101 (2014)