Study of $^{12}C(^{7}Li,t)^{16}O^{*}$ transfer reaction at 20 MeV

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Introduction

The $^{12}C(\alpha,\gamma)$ reaction at 300keV determines the ^{12}C to ^{16}O ratio at the end of helium burning in stars [1]. In order to determine the ratio accurately one needs to determine the rate of the $^{12}C(\alpha,\gamma)$ reaction with an accuracy of within 10%. However, with the present experimental capabilities it is almost impossible to measure the rate of the reaction at 300 keV with the desired accuracy. This is due to extremely low cross-section of the $^{12}C(\alpha,\gamma)$ reaction at 300keV (~10^{-17} barn). At present cross-sections have been measured down to only 1.2 MeV in the c.m. and extrapolated to 300 keV. Generally instead of the cross-section the astrophysical S-factor is extrapolated as it varies slowly with energy in comparison to the cross-section. In order to do this extrapolation one needs a suitable theory to calculate the astrophysical S-factor at low energies. The R-matrix method is the most suitable theory as at low energies as there may be presence of resonances. A much simpler theory is the potential model using which one can also calculate the S-factor at 300 keV. However, for both these theories one requires the knowledge of alpha reduced widths that can be extracted from alpha transfer reactions. The motivation behind the present work is to extract the alpha spectroscopic factor from the measured angular distributions and therefrom calculate the S-factor at 300 keV using the potential model. A similar work has been already done with the $^{12}C(^{6}Li,d)^{16}O^{*}$ reaction at 20 MeV [2]. At 20 MeV, there are very few measurements and we observed a new reaction mechanism to be dominant for the population for the ^{16}O bound states. In this paper we present a preliminary report on the measurement and analysis of the $^{12}C(^{7}Li,t)^{16}O^{*}$ reaction at 20 MeV.

Experimental Details

The experiment was carried out using the 14UD Pelletron facility of the Inter University Accelerator Center (IUAC) New Delhi. A $^{7}Li^{3+}$ beam at 20 MeV was bombarded on a 100μg/cm^2 self supporting natural Carbon target. The reaction products were detected in 2 ΔE-E Silicon telescopes (both 150μm-5mm) placed inside the 1.5 m General Purpose Scattering Chamber (GPSC) under high vacuum. The angular separation between the two telescopes was kept fixed at 24°. Angular distributions measurements were carried out from 18° to 124° in steps of 5°. Two monitors (300μm) were placed at ± 10 ° on either side of the beam for beam monitoring and cross-section normalization.

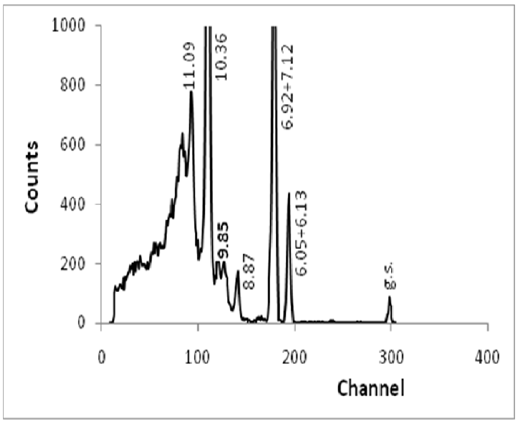

Fig. 1 Measured inclusive triton energy spectrum in the $^{12}C(^{7}Li,t)^{16}O^{*}$ reaction at E(^{7}Li)=20 MeV. The laboratory angle of this spectrum is 30°. The different states of ^{16}O populated in the reaction are marked in the figure.

Results and Discussions

In fig.1 we show the measured triton spectrum at 30^o. The different states of the residual nucleus ^{16}O are marked in the figure. The 6.92 and 7.12 MeV are not separated but can be so done by using a double Gaussian fit. As far as astrophysical implications are concerned the reduced alpha width of the 6.92 MeV and the ground state is important to calculate the E2 S-factor in the framework of a potential model. In this work we therefore present a preliminary analysis of the angular distribution data in terms of Coupled Reaction Channel theory [3]. The calculations are done in the framework of the coupled channel code FRESCO [4]. In this calculation the projectile and the final residual nuclei are modeled in terms of a two body picture. The ^{7}Li and ^{16}O are described in terms of α+t and $\alpha+^{12}$C structure respectively. The required interactions in the calculations are optical potentials for i) entrance channel (^{7}Li+^{12}C) ii) exit channel (t+^{16}O) and iii) core-core (t+^{12}C) and real binding potentials for α+t and $\alpha+^{12}$C. The depths of the binding potentials are adjusted to reproduce the binding energy of the concerned state. In the present CRC calculations we couple inelastically the bound states of ^{16}O. At present we do not include the unbound states (i.e states with E_x>7.16 MeV) as it requires a more complicated treatment in the calculation. The FRESCO calculations (solid line) are compared to the experimental triton angular distributions measured in this work. The experimental data and calculation in fig.2 is for the population of the ground state of ^{16}O. The spectroscopic amplitudes of the states (g.s, 6.13, 6.92 and 7.12 MeV) are all assumed to be unity. This is however a very preliminary assumption and adjustment of these factors may be required in more details when the angular distributions for the population of all the states of ^{16}O are analyzed together.

At angles beyond 60^o there is an underprediction and this is a similar to the observation we had for the ^{12}C(^{6}Li,d) case. This discrepancy there was removed by inclusion of coupling with the ^{6}Li breakup channels using a full Continuum Discretized Coupled Reaction Channel (CDCC-CRC) calculation. By full we mean when all the resonant and non resonant breakup states of ^{6}Li as well as the bound and unbound states of ^{16}O are coupled together. The spectroscopic amplitudes are then more difficult to extract but give more reliable values. These values can then be utilized in a potential model to calculate the astrophysical S-factor for the ^{12}C(α,γ) reaction at 300 KeV. A comparison of the present data and CRC or CDCC-CRC method can then be done with respect to recent works [5].

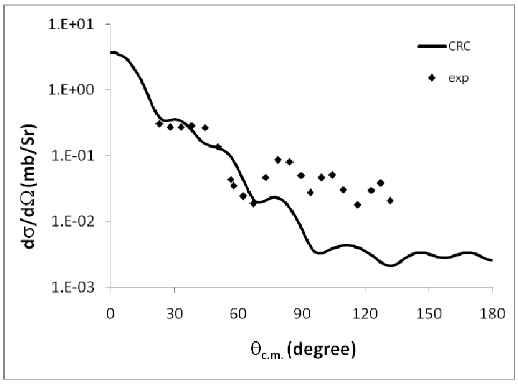

Fig. 2 Comparison of the measured angular distribution for the population of the ground state of ^{16}O with the CRC calculation. The calculation is done with FRESCO v2.9 and is shown by solid line.

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