The ANC of the subthreshold 2^+ (6.92 MeV) and 1^-(7.12 MeV) states of ^{16}O using $^{12}C(^6Li,d)^{16}O$ transfer reaction at 20 MeV

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Introduction

The $^{12}C(\alpha,\gamma)^{16}O$ capture reaction at 300 keV (Gamow Energy) [1] in competition with the 3α process determines the ratio of ^{16}O to ^{12}C abundance at the end of helium burning in stars. Direct measurement of this reaction at 300keV is almost impossible. The lowest energy at which this reaction has been measured is at 1 MeV [2]. The measured rate of this reaction has a large uncertainty at this energy owing to the very low cross-section (~nb). The cross-section at the Gamow Energy is obtained by extrapolation of available data at higher energy. Due to the unavailability of measured cross-section with low uncertainty an alternate method (indirect method) is used where a different reaction with much higher cross-section is utilized. Breakup [3] has been utilized for this reaction as an indirect method but is restricted to above threshold states. Alpha transfer reaction on ^{12}C is more suitable as an indirect method for the $^{12}C(\alpha,\gamma)$ reaction as they can be extended to subthreshold states of ^{16}O (S_α=7.62 MeV). The subthreshold states are very important from the point of $^{12}C(\alpha,\gamma)$ reaction as the capture process essentially proceeds through two subthreshold states of ^{16}O. The subthreshold states viz. 2^+(6.92 MeV) and 1^-(7.12 MeV) play a crucial role in the E1 and E2 capture of the reaction. If the alpha width or ANC (Asymptotic Normalization Constant)[4] of these states can be determined from the transfer angular distributions then the astrophysical S-factor [4] can be obtained at the Gamow energy. The determination of ANC requires however the theoretical transfer cross-section that suffers from strong dependence of optical potentials. It is a prime problem in the ANC method to get rid of the uncertainty from nuclear potentials. Brune et al [5] suggested from a measurement of total cross-section that if the transfer cross-section is measured at deep sub barrier energies then the cross-sections are dependent on the Coulomb potentials only. However recently [6] it has been shown that measurement of angular distributions instead of total cross-section is more complete and essential for a better extraction of the ANC. Belhout et al [7] has extracted the ANC using $^{12}C(^6Li,d)$ reaction at energies well above the barrier. At above barrier energies transfer cross-section increases and contribution of one step transfer is expected to be dominant. Moreover the potential dependence of the ANC at this energy has not been studied before. The motivation of the present work is to investigate the potential dependence of the DWBA calculations at energies above barrier. The entrance channel elastic scattering has been also performed to determine the optical potential.

Experimental Details

The experiment was carried out at the GPSC facility of the IUAC Pelletron, New Delhi using $^{12}C^{2+}$ beam at 20 MeV. Three ΔE-E telescopes were setup in the 1.5 m scattering chamber. Two telescopes were setup for the transfer products whereas the other telescope was to measure the elastically scattered products. Two monitor detectors were positioned at 10 degrees on either side of the beam for monitoring and evaluation of absolute cross-section. A ^{12}C target was used for the reaction. Detailed angular distributions for the alpha transfer products were measured from 26 degrees to 132 degrees at intervals of 5 degrees. Similarly the $^{12}C(^{6}Li,^{6}Li)$ elastic scattering angular distributions were measured from 22 degrees to 98 degrees at steps of 2 degrees upto 74 degrees and at 98 degrees.

Results and Discussions

The measured spectrum for the $^{12}C(^{6}Li,d)^{16}O$ reaction at 40 degree is shown in figure 1. The population of the different excited states in ^{16}O can be seen clearly in the figure. The astrophysically important 6.92 and 7.12 MeV states are shown. The 6.92 MeV state has a strong cluster structure and is therefore expected to show enhanced alpha transfer cross-section. However, these states can as well be populated by compound nuclear process.

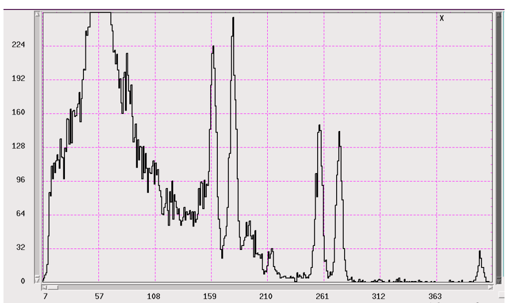

Fig. 1 Experimental spectrum of $^{12}C(^{6}Li,d)$ reaction at 40 degrees. The 6.92 and 7.12 MeV states are shown.

In figure 2 we show the experimental spectrum of elastically scattered products from the $^{12}C(^{6}Li,^{6}Li)$ reaction at 40 degree. The elastic scattering data will be analyzed to obtain the entrance channel optical potential.

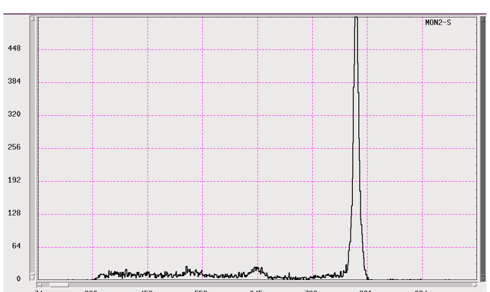

Fig. 2 Experimental spectrum of $^{12}C(^{6}Li,^{6}Li)$ elastic scattering at 40 degrees.

The ANC (Asymptotic Normalization Constant) of the states of ^{16}O can be determined from a comparison of the measured angular distributions with the DWBA calculations. However there are several sources of uncertainty in the extracted ANC [6]. One of the dominant source of uncertainty is from the entrance channel potential. This is exhibited using DWBA (code FRESCO v2.4) calculations in figure 3. The entrance channel potentials are adopted from [8]. We are presently investigating the exit channel dependence including the coupling of the excited states.

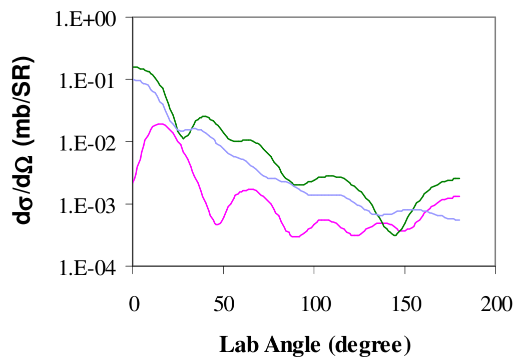

Fig. 3 FRESCO calculations of the transfer angular distribution using three different potential sets A(pink), B(green) and C(blue) of [8].

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