Study of α-cluster transfer reactions with ^{7}Be

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1. Introduction

The rate of the radiative capture reaction ^{12}C(α, γ)^{16}O is a key input to the determination of the abundance ratio of C to O in the stars after helium-burning cycle. The formation of elements heavier than oxygen and the course of evolution of a star is crucially dependent on the above mentioned abundance ratio. Hence, the quest for precise measurement of this "holy grail of nuclear astrophysics" [1] is now going on for more than five decades. There have been several attempts to investigate the reaction by direct method, but the extremely low cross section $\sim 10^{-17}$ barn at 300 keV renders it impossible to measure with the present technology. In this situation, the indirect asymptotic normalization constant (ANC) method [2] serves as an accurate tool for this investigation. Reactions with ^{7}Be show no threshold anomaly and it has a weak breakup coupling at low energies. Therefore, the ^{7}Be nucleus is a suitable candidate for such studies.

2. Experiment

The experiment was carried out at HIE-ISOLDE, CERN, using a 35 MeV ^{7}Be beam with an energy spread of 168 KeV. The average beam intensity of the beam on target was about 5×10^5pps. A CD_2 target of thickness 15 μm was used as the primary target, along with a 15 μm CH_2 and a 1 mg/cm^2 ^{208}Pb for background measurements and normalization, respectively. The detector set up consisted of five 16×16 double-sided Micron W1 silicon strip detectors (DSSD) in the shape of a pentagon covering $\theta = 40° - 80°$ in lab. They are backed by MSX25 unsegmented silicon pad detectors. The forward angles from $8° - 25°$ were covered by a Micron S3 annular detector. The back angles from $127° - 165°$ were covered by two 32×32 Micron BB7 DSSDs, backed by MSX40 unsegmented silicon pads. Further detail of the experimental set up is given in Ref. [3, 4].

3. Analysis

The elastic ^{7}Be peak was unambiguously detected at the forward angles. We could detect ^{7}Be from elastic as well as inelastic scattering from the 4.439 MeV state of ^{12}C, in the pentagon detectors. The elastic data in this work also include the contribution of the bound excited state of ^{7}Be at 0.429 MeV ($1/2^-$), which is negligible. Analysis of the data were carried out using the code FRESCO [5] to obtain the optical model potential (OMP) parameters [3]. The Fig. 1 shows the ^{7}Be + ^{12}C elastic scattering angular distribution at 35 MeV. The work

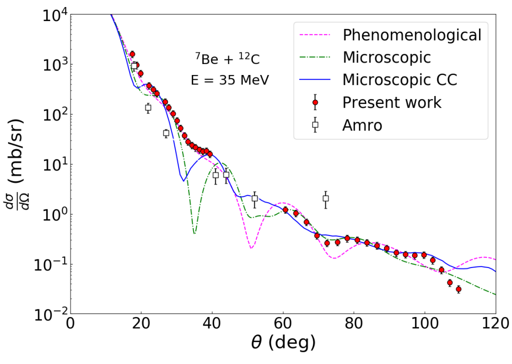

FIG. 1: Elastic scattering angular distribution of ^{7}Be + ^{12}C at E = 35 MeV. The data are taken from Ref. [3, 6].

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of Amro *et al.* [6] at 34 MeV are also shown for comparison. Both phenomenological and microscopic calculations are shown in the figure. The coupled channel calculations performed for the elastic and elastic channel explains the data more accurately. Also, the comparison of reduced total reaction cross section with Wong's calculations [7] indicate low breakup contribution.

In the transfer reaction $^{12}C(^{7}Be,^{3}He)^{16}O$, the reaction products corresponding to different excited states of ^{16}O are identified, as illustrated in the figure 2. The relevant angular distribution were obtained. The present work investigates the contribution of the two subthreshold resonances 6.92 (2^+) and 7.12 (1^-) MeV of ^{16}O to the capture cross section, as α-capture in the reaction $^{12}C(\alpha,\gamma)^{16}O$ proceeds predominantly through these states [8].

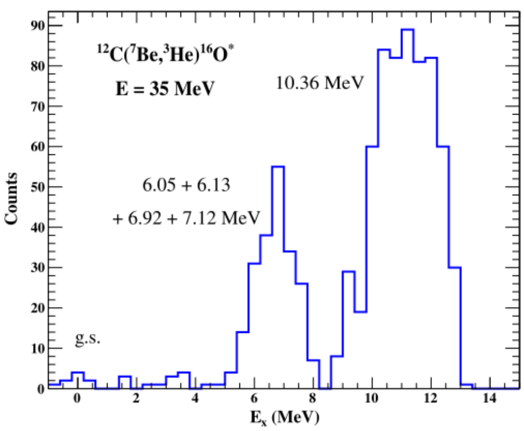

FIG. 2: Excitation energy spectra of ^{16}O from $^{12}C(^{7}Be,^{3}He)^{16}O^*$ reaction at E = 35 MeV

The model parameters required in the DWBA calculation include the OMP of the entrance channel ^{7}Be + ^{12}C [3], the exit channel ^{3}He + ^{16}O [9], the core-core ^{3}He + ^{12}C [10] potential and the α+^{3}He [11] and α+^{12}C [12] binding potentials respectively for ^{7}Be and ^{16}O. The alpha spectroscopic factors (S_α) for states of ^{16}O were extracted by normalizing the theoretical calculations for $^{12}C(^{7}Be,^{3}He)^{16}O^*$ with the experimental data and then the corresponding ANCs were calculated. These ANC values can be used to obtain α-widths of the corresponding ^{16}O states, which contribute to the reaction rate of radiative capture $^{12}C(\alpha,\gamma)^{16}O$.

4. Outlook

In summary, the elastic and transfer reaction studies were carried out for ^{7}Be + ^{12}C at 35 MeV. A reliable set of OMPs were obtained from the elastic scattering data over a wide angular range. These parameters are indispensable for the analysis of the transfer reaction data. The ^{7}Be breakup cross section is estimated to be less than 10% of the reaction cross section. Further work on the transfer data is in progress to determine the ANC of the relevant states of ^{16}O in the context of the $^{12}C(\alpha,\gamma)^{16}O$ radiative capture reaction.

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