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2015 J. Phys.: Conf. Ser. 590 012030

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Exploring the $^{12}\text{C}(^{18}\text{O},^{16}\text{O})^{14}\text{C}$ two-neutron transfer reaction at energies far above the Coulomb barrier

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Abstract. The $^{12}\text{C}(^{18}\text{O},^{16}\text{O})^{14}\text{C}$ two-neutron transfer reaction has been studied at an incident energy of 275 MeV and the ejectiles have been momentum analysed at forward angles by the MAGNEX spectrometer. The identification of the ^{16}O ejectiles was obtained by combining a standard $\Delta E-E$ technique with the simultaneous measurement of the angle and the position at the focal plane. The ^{14}C excitation energy spectra have been obtained and several known bound and resonant states of the residual nuclei have been identified. The results have been compared to a previous measurement of the same reaction at 84 MeV incident energy.

1. Introduction

In the last few years, a study of the structure of different nuclei was pursued at the Catania INFN-LNS laboratory by the $(^{18}\text{O},^{16}\text{O})$ two-neutron transfer reaction at 84 MeV on different targets ($^{12}\text{C},^{13}\text{C},^9\text{Be},^{11}\text{B},^{16}\text{O}$), using the MAGNEX spectrometer to detect the ejectiles. Thanks to its high resolution and large acceptance, high quality inclusive spectra were obtained, even in a largely unexplored region above the two-neutron emission threshold in the residual nucleus [1]. New phenomena appeared, such as the dominance of the direct one-step transfer of the two neutrons [2] and the presence of broad resonances at high excitation energy in the ^{14}C and ^{15}C spectra [3] [4] [5].

Exact finite range coupled reaction channel calculations based on the parameter free Sao-Paulo double-folding optical potential accurately described the measured absolute cross section, for the first time without the need of any arbitrary scaling factor [6]. An interesting feature of the experimental angular distributions is that only the transition to the $^{14}\text{C}_{\text{g.s.}}$ presented an oscillating pattern characteristic of the expected $L = 0$ angular momentum transfer [6], whereas the other transitions, characterized by $L \neq 0$, did not show such pronounced oscillations. The phenomenon is typical of heavy-ion transfer reactions near the Coulomb barrier [7] and causes a lack of sensitivity for the $L > 0$ at this incident energy. However, there should be a threshold energy, reasonably above the Coulomb barrier, above which the oscillations in the angular distributions for $L \neq 0$ should also appear (good l -matching condition).

Recently, the same $^{12,13}\text{C}(^{18}\text{O},^{16}\text{O})^{14,15}\text{C}$ reactions have been studied at 275 MeV incident energy, by an ^{18}O cyclotron beam. The experiment was performed at INFN-LNS using the MAGNEX spectrometer. The aim of the experiment was to study the dynamical evolution of the structures observed in the region at high excitation energy in the spectra and to investigate the energy dependence of the good l -matching condition for two-neutron transfer reactions. In the present work, some preliminary results about the $^{12}\text{C}(^{18}\text{O},^{16}\text{O})^{14}\text{C}$ reaction are presented and compared with the previous study at 84 MeV incident energy.



2. The experiment

The $^{12}\text{C}(^{18}\text{O},^{16}\text{O})^{14}\text{C}$ reaction was measured at the INFN-LNS in Catania using an $^{18}\text{O}^{4+}$ beam at 275 MeV accelerated by the K800 Superconducting Cyclotron accelerator. A $63 \pm 3 \mu\text{g}/\text{cm}^2$ self-supporting ^{12}C was used. The ^{16}O ejectiles were momentum analyzed by the MAGNEX large acceptance spectrometer [8] and detected by its focal plane detector [9]. The spectrometer worked in the full acceptance mode (solid angle $\Omega \sim 50 \text{ msr}$ and momentum range $\Delta p/p \sim 24 \%$), thus the total covered angular range of $3^\circ < \theta_{lab} < 18^\circ$ in the laboratory reference frame was obtained by only two runs in which the spectrometer optical axis was located at $\theta_{lab}^{opt} = 7^\circ, 12^\circ$.

The identification of the ^{16}O ejectiles was performed by combining two techniques, as described in Ref. [10]. The first step consists in the identification of the atomic number (Z) of the ejectiles by the standard ΔE - E technique. An example of the ΔE - E bi-dimensional plot is shown in figure 1 (left panel) with a coarse graphical contour that includes the Oxygen ejectiles. For the mass identification, the correlation between the measurement of the horizontal position at the focal plane (X_{foc}) and the residual energy (E_{resid}) is exploited, in which the ions are distributed on different curves according to the ratio m/q^2 . Therefore, it is possible to clearly separate and select the $^{16}\text{O}^{8+}$ ejectiles, as shown in figure 1 (right panel). With this identification technique a mass resolution as high as 1/160 is reached [10].

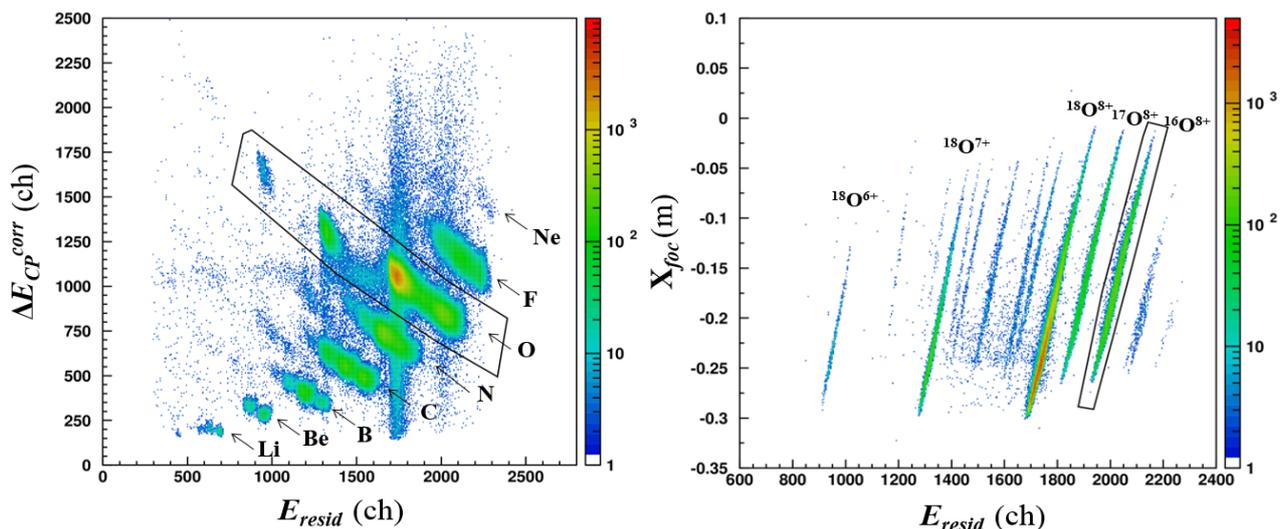


Figure 1. Example of the identification plots. (left panel) Typical energy loss ΔE_{PC}^{corr} vs E_{resid} matrix for the unselected ejectiles detected in the reaction $^{12}\text{C} + ^{18}\text{O}$ at 275 MeV incident energy at $\theta_{lab}^{opt} = 7^\circ$. The different ion species and a coarse graphical contour on the ^{16}O region are indicated. (right panel) Typical X_{foc} vs E_{resid} matrix plotted with the graphical condition indicated in the left panel. The different Oxygen isotopes and a graphical contour selecting the $^{16}\text{O}^{8+}$ ejectiles are indicated.

When dealing with large acceptance spectrometers, as MAGNEX, high order aberrations have to be compensated by hardware and/or software techniques. In the present case, a 10th order reconstruction of the scattering angle and momentum modulus was performed, based on the fully algebraic method implemented in MAGNEX [11] [12]. The excitation energies $E_x = Q_0 - Q$ (where is Q_0 the ground to ground-state Q -value) were then obtained by the application of the relativistic kinematic transformations. An overall energy resolution of about 600 keV (full width at half maximum) was obtained. This was mainly determined by the spectrometer finite energy resolution (1/100), the straggling introduced by the target and the momentum distribution of the beam, as discussed in Ref. [13].

3. Discussion

An example of the obtained energy spectrum for the ^{14}C residual nucleus is shown in figure 2. In such a spectrum it is possible to recognize some known states of ^{14}C , namely the ground state ($J^\pi = 0^+$), a peak at ~ 6.9 MeV corresponding to the superposition of the states at $E_x = 6.73$ (3^-) and 7.01 (2^+) MeV and the states at

$E_x = 8.32$ (2^+), 10.75 (4^+), 12.96 (3^-) MeV. These states are the same populated in the previous $^{12}\text{C}(^{18}\text{O},^{16}\text{O})^{14}\text{C}$ reaction explored at 84 MeV incident energy [4] [6], but there are some differences between the two spectra, as a result of the larger incident energy in the present case. First of all, in the region above the two-neutron emission threshold ($S_{2n} = 13.122$ MeV) a much larger background is observed as a result of the opening of dissipative channels at energies far above the Coulomb barrier. Another effect of the higher incident energy is to favor the population of high spin states. Indeed, in the present ^{14}C spectrum the 0^+ ground state is strongly suppressed and the most populated state is the 4^+ one at 10.75 MeV.

In the region at $E_x \sim 17$ MeV a large bump is observed, superimposed on the high background. This was observed also in the previous reaction $^{12}\text{C}(^{18}\text{O},^{16}\text{O})^{14}\text{C}$ studied at 84 MeV [4]. Work is in progress to explain the origin of such a bump, which could reveal the excitation of the Giant Pairing Vibration mode [14] in these experiments.

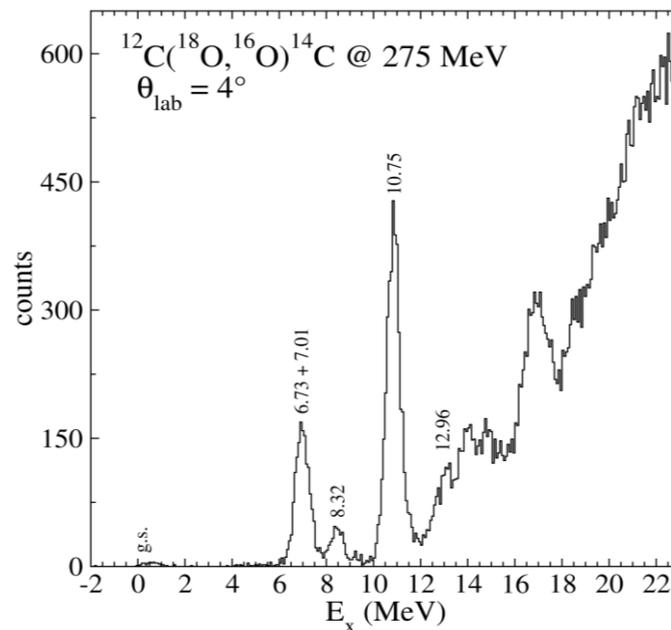


Figure 2. Excitation energy spectrum of the $^{12}\text{C}(^{18}\text{O},^{16}\text{O})^{14}\text{C}$ reaction at 275 MeV incident energy and $\theta_{lab} = 4^\circ$.

Acknowledgments

The work of one of us (D.C.) was supported by the Italian Ministry of Education, Universities and Research (MIUR) under the grant “LNS-Astrofisica Nucleare (fondi premiali)”.

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