SPECTROSCOPY OF ^{13}B VIA THE (^{18}O,^{16}O) TWO NEUTRON TRANSFER REACTION*

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The $N = 8$ neutron-rich nucleus ^{13}B has been investigated via the (^{18}O,^{16}O) two neutron transfer reaction at 85 MeV. Several excited states are populated in the final nucleus. A comparison with the ^{12}C(^{18}O,^{16}O)^{14}C two neutron transfer reaction at the same incident energy seems to confirm the rapid shell evolution recently observed in the $N = 8$ systems.

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1. Introduction

The rapid evolution of the shell structure in neutron-rich nuclei with the neutron number $N = 8$ has attracted an increasing attention in recent years. The shell closure is pronounced in the semimagic nucleus ^{14}C, with a large energy gap (~ 6 MeV) between the p and sd shells. On the other hand, the even–even nucleus ^{12}Be shows the presence of intruder sd-shell configurations already in its ground state [1]. The $N = 8$ nucleus ^{13}B is, therefore, expected to be on the borderline between these two opposite regimes. Recent results have demonstrated such peculiarity, showing that the ^{13}B isotope exhibits both low lying proton and neutron intruder states indicating a reduced shell gap between p and sd shells [2, 3].

In order to get information on ^{13}B excited states and find other experimental evidence about the evolution of the shell structure in this system, we present the preliminary results concerning the two-neutron transfer

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reaction (^{18}O,^{16}O) on ^{11}B target. Transfer reactions were carried out in the past mainly via (t, p) reactions [4, 5]. Nowadays heavy ion reactions (such as (^{18}O,^{16}O)) are preferred for different reasons. First and foremost the reaction mechanism can be generally described in a semi-classical way, thus providing a more clearly defined spectroscopy of both the target and the projectile [6]. Moreover, under appropriate kinematical conditions (Brink's matching rules [7]), transfer reactions between heavy ions at energies above the Coulomb barrier have a large cross-section and the angular distributions are sensitive to the details of the final populated states [6]. Finally, in the ^{18}O nucleus there is a preformed neutron pair which moves in an *sd*-orbital. If the same orbital is available in the target nucleus, such as the ^{11}B in our case, there is an enhancement in the probability of the direct transfer of the neutron pair.

2. Experimental set-up and data reduction

The experiment was performed at the Catania LNS-INFN laboratory using a 85 MeV energy ^{18}O Tandem beam impinging on a 78 μg/cm^2 thick ^{11}B target. The ejectiles were momentum analysed by the MAGNEX magnetic spectrometer [8] and detected by the Focal Plane Detector (FPD) [9, 10]. Two different angular settings were chosen, with the spectrometer optical axis located at 12° and 18° with respect to the beam direction. Due to the large angular acceptance of MAGNEX (–0.090 rad, +0.110 rad horizontally, ±0.125 rad vertically in the spectrometer reference frame), these settings cover a whole angular range of about $7° < \theta_{\rm lab} < 24°$ in the laboratory reference frame. The magnetic fields were set in order to accept the oxygen ions with charge between 6^+ and 8^+ at the maximum kinetic energy. The FPD is a gas-filled hybrid detector with a wall of 60 Si detectors at the back, which measures the horizontal and vertical coordinates and angles of each incident particle, the energy loss in the gas region and the residual energy released in the silicon detectors wall (see Ref. [11] for details). These parameters are used for the particle identification. In particular, the Z identification is obtained by the well known $\Delta E - E$ technique while the mass discrimination is based on the equation which describes the motion of a charged particle inside a magnetic field ($B\rho = p/q$). High order algorithms of trajectory reconstruction, developed for large acceptance spectrometers, give the kinetic energy and the scattering angle in the laboratory frame starting from the final phase space parameters measured at the FPD (x, y, θ, ϕ) for each identified particle [12]. Finally, the kinetic energy is transformed in Q-value or equivalently in excitation energy $E_x = Q - Q_0$, where Q_0 represents the ground state to ground state Q-value.

3. Preliminary results

A ^{13}B excitation energy spectrum is shown in Fig. 1. Several known excited states, which are the same observed in the (t, p) reactions [4, 5], are populated. The data refer to the angular setting with central angle 12°. The yields of the different oxygen ions detected in the reaction were estimated by the integration of the measured energy spectra. Transfer yields were then extracted by selecting the counts corresponding to the population of bound and resonant states of the residual nucleus, after subtracting a continuous background (solid/red line in Fig. 1 for the ^{16}O case). A total of 1.3×10^4 ^{17}O ions ($1n$-transfer) and 1.80×10^4 ^{16}O ions ($2n$-transfer) were identified, respectively.

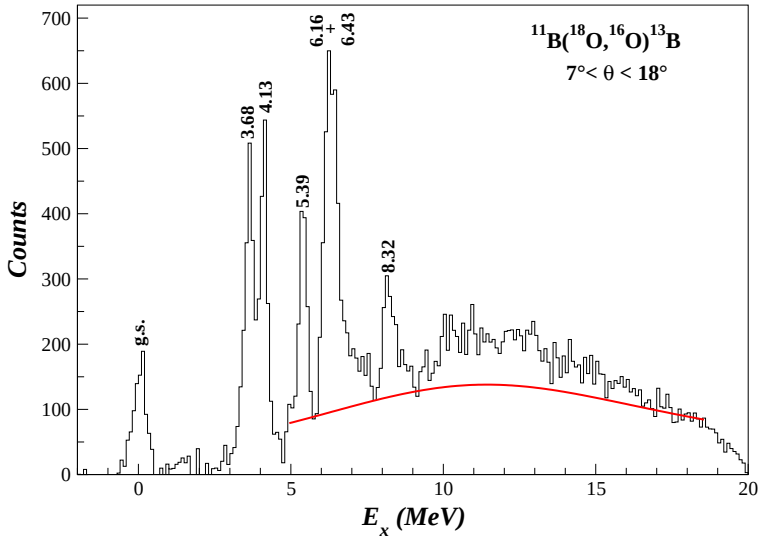

Fig. 1. Energy spectrum of the detected ^{16}O ejectiles. Several known excited states of ^{13}B are populated. The data are integrated over the angular range $7^\circ < \theta_{\rm lab} < 18^\circ$. The modelled three-body continuum adopted to evaluate the transfer yields is represented by the solid/red line.

The small difference between these two values is an evidence of the selectivity of the reaction studied. The striking result is that the two neutron transfer process appears as probable as the one neutron transfer. This enhancement of the ^{16}O yields is a clear evidence that the direct transfer of the neutron pair has a relevant contribution in the reaction mechanism. In fact, if this process was just a second order process, it would be expected a transition amplitude given by the product of two independent terms and consequently the experimental yields for ^{16}O should be much lower than the

measured ones. The spectrum shown in Fig. 1 is another evidence of the selectivity of the (^{18}O,^{16}O) reaction. Indeed, states excited in the one nucleon transfer reactions are scarcely populated, as for example the 4.8 MeV state which has been recently identified as a proton intruder state [2]. Finally, a qualitative comparison with the ^{14}C excitation energy spectrum populated via the (^{18}O,^{16}O) at 85 MeV is reported in Fig. 2. The excited levels schemes are similar in both cases. Since all the ^{14}C excited states populated in the reaction are known to be *sd*-shell states, we can guess that the present reaction proceeds through the excitation of analog *sd*-shell states in ^{13}B, just shifted of about 3.5 MeV with respect to the ^{14}C ones. Therefore, this very preliminary result can be considered as another evidence of the lowering of the *p*–*sd* shell gap corresponding to a fading of the $N = 8$ shell closure.

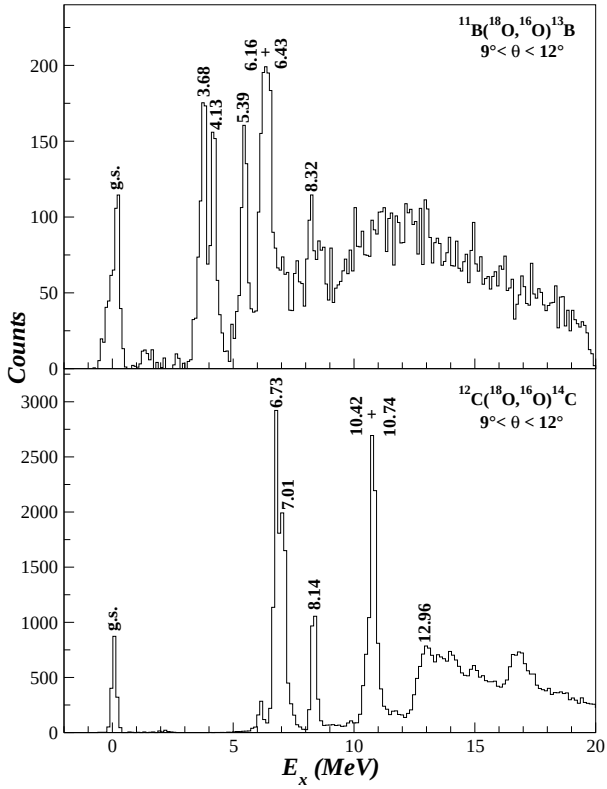

Fig. 2. Qualitative comparison with the ^{14}C excitation energy spectrum populated via the (^{18}O,^{16}O) at 85 MeV. The excited levels schemes are similar in both cases.

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