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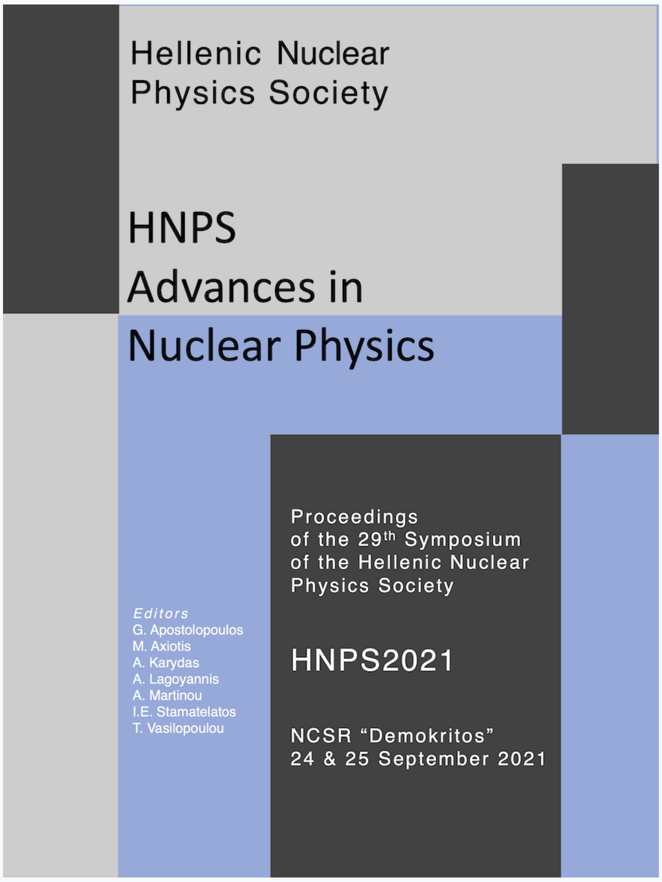

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Measurement of elastic backscattering differential cross sections for protons on ^{nat}O in the energy range E= 4- 6 MeV, suitable for EBS

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Abstract In this study we present the experimental cross sections of the $^{nat}O(p,p_0)$ elastic scattering, determined via the relative measurement technique, in the proton energy range E_{lab}=4- 6 MeV, at six backscattering detector angles between 120° and 170°, with a 10° step. The measurements were performed using the Van de Graaff Tandem 5.5 MV Accelerator of N.C.S.R. "Demokritos" in Athens, Greece and a high precision goniometer.

Keywords p- EBS, IBA, Oxygen

INTRODUCTION

Oxygen is a highly reactive non-metal and thus can easily form oxides with other elements and penetrate or diffuse deeply inside several matrices. Therefore, it is of paramount importance to acquire an accurate depth profiling in order to determine the exact concentration variations of oxygen in various samples, like superconductors or, e.g., in biological and geological materials. For this purpose, Ion Beam Analysis (IBA) methods have proven to be very effective, and more specifically, among them, the proton elastic backscattering technique (EBS), which is currently widely used for the detection of almost all light elements. For the accurate implementation of EBS, evaluated differential cross sections are required, provided by the online R-matrix SigmaCalc 2.0 calculator (http://sigmacalc.iate.obninsk.ru/). In the particular case of oxygen, the current evaluated data for protons cover the energy range between 100 and 4080 keV [4]. However, in order to investigate oxygen concentrations at larger depths, it is extremely important to go beyond this limit and this task is currently impeded by the relative lack of experimental [3] and, consequently, evaluated data for higher proton beam energies. Therefore, in this study we collected new experimental differential cross section data at six different angles in the energy range $E_{p,lab}$= 4-6 MeV, aiming at obtaining a new set of coherent measurements. These data will be used to expand the current evaluation beyond 4 MeV.

EXPERIMENTAL DETAILS

Protons were accelerated at lab energies $E_{p,lab}$=4-6 MeV in steps of 5-15 keV using the 5.5 MV Tandem Van De Graaff accelerator of N.C.S.R. ''Demokritos'' Athens, Greece. The minimum step of 5 keV was necessary in order to scan the narrow ressonances of the compound nucleus ^{17}F which was formed. The beam energy was determined using the Nuclear Magnetic Resonance (NMR) technique and was verified by the 991.89 keV resonance of the $^{27}Al(p,\gamma)$ reaction. The estimated ripple was 1.6 keV and the beam offset practically negligible (~0.04 keV).

The backscattered protons were detected using six SSB detectors, having a resolution ranging from 8.5-15.5 keV, mounted on a high precision goniometer at 120°-170°. The target used for these measurements was a self supporting thin foil consisting of three layers. The first one facing the beam

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was a thin layer of ^{197}Au evaporated on top of the main target, Na_2HPO_4 (oxygen enriched), for wear protection normalization purposes. The backing of the target consisted of ^{12}C. The target was fabricated at N.C.S.R. 'Demokritos'. In order to keep the counting rate relatively reasonable and the angular resolution less than 1°, the detectors were placed ~10 cm away from the target. Cylindrical tubes were placed in front of the detectors so as to reduce the background in the acquired spectra, resulting from colisions of protons with the walls of the goniometric chamber and the Faraday cup.

In addition, measurements for $E_{p,lab}$= 2000, 3200, 3900 keV at 140°, 150°, 160° and170° were performed to accurately describe the target stoichiometry. For this reason, evaluated differential cross section data will be used for all elements from Sigma Calc 2.0. The SIMNRA code [1] will be used to simulate the experimental spectrum from these measurements.

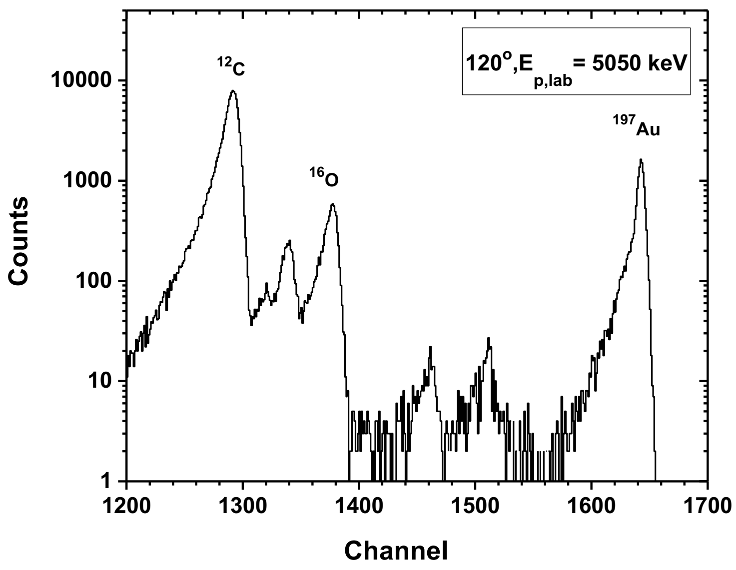

Fig. 1. *Experimental spectrum at $E_{p,lab}$= 5050 keV at 120°*

RESULTS AND DISCUSSION

The relative measurement technique was used to calculate the excitation functions of the elastic scattering of protons from oxygen. The differential cross sections were deduced relative to the elastic scattering of protons from ^{197}Au, which is purely Rutherford (including screening corrections) at the energies studied. Consequently, the following formula was implemented [2]:

$$\left(\frac{d\sigma}{d\Omega}\right)^{E,\theta}_{^{16}O} = \left(\frac{d\sigma}{d\Omega}\right)^{E',\theta}_{^{197}Au} \frac{Y_{^{16}O}}{Y_{Au}} \frac{N_{t,Au}}{N_{t,^{16}O}}$$

where θ corresponds to the scattering angle of protons, E represents the energy of protons at half of the target thickness, E′ the energy at the surface of the target following the accelerator calibration and Y_{natO} and Y_{Au} are the integrated yields of the experimental elastic peaks of ^{nat}O and ^{197}Au respectively. Finally, the fraction $N_{t,Au}/N_{t,natO}$ is the ratio of the total number of ^{197}Au and ^{nat}O atoms present in the target and is yet to be determined.

For the peak integration of the experimental spectra the Tv code was used and a linear background was assumed. A representative spectrum is shown in Fig.1. The determined excitation functions are shown in Fig. 2, where the effect of the resonance mechanism due to the excited states of the compound nucleus ^{17}F is evident, yielding complicated structures with strong maxima and minima that require further investigation in the framework of the R-matrix theory.

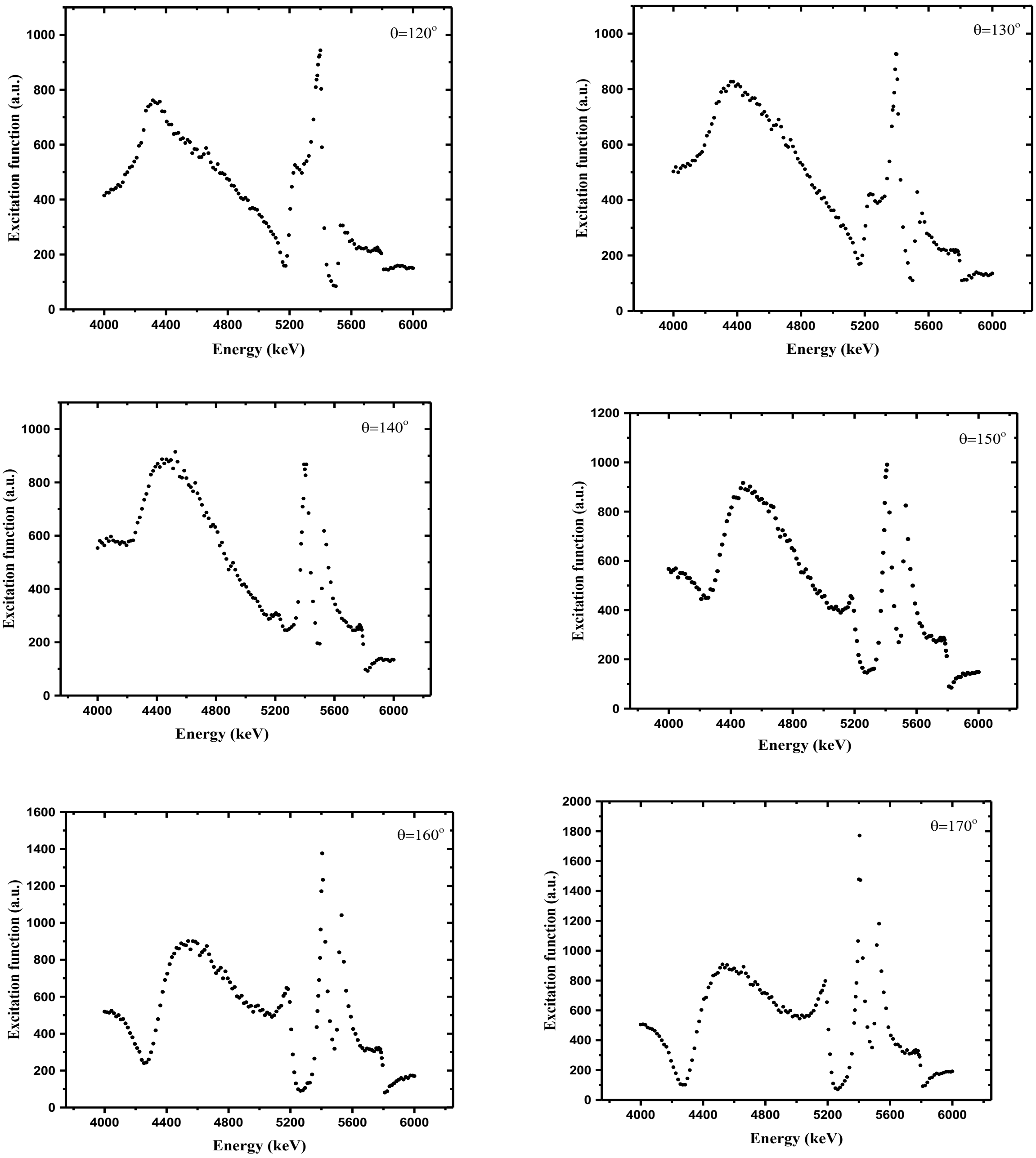

Fig. 2. *Excitation functions of the $^{16}O(p,p)$ elastic scattering for the angles 120°- 170°.*

CONCLUSIONS

The elastic backscattering of protons from oxygen has been studied for energies $E_{p,lab}$=4-6 MeV and at 120°-170° with a 10° step for the first time. In addition, the excitation function for each angle has been calculated, as shown in Fig.2. The target stoichiometry will be determined via the dedicated measurements and the SIMNRA code. As a result, the differential cross-section values of $^{nat}O(p,p_0)$ at six backscattering angles will be calculated, thus creating a coherent set of cross-section data. Finally, R-Matrix calculations for the theoretical reproduction of the data will be performed aiming at the expansion of the current evaluation for proton energies 4-6 MeV.

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