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Resonance strength measurement at astrophysical energies: The ^{17}O(p,α)^{14}N reaction studied via THM

M.L. Sergi[1], C. Spitaleri[1,2], M. La Cognata[1], L. Lamia[2],
R.G. Pizzone[1], G.G. Rapisarda[2] A. Mukhamedzhanov[3],
B. Irgaziev[4], X.D. Tang[5], M. Wischer[5], J. Mrazek [6], V. Kroha[6]

[1] INFN - Laboratori Nazionali del Sud, Catania, Italy
[2] Dipartimento di Fisica e Astronomia, Università di Catania, Catania, Italy
[3] Cyclotron Institute, Texas A&M University, College Station, TX 77843, USA
[4] GIK Institute of Engineering Sciences and Technology, Topi, Districti Swabi, K.P. Pakistan
[5] Nuclear Physics Institute of ASCR, Rez, Czech Republic

Abstract

In recent years, the Trojan Horse Method (THM) has been used to investigate the low-energy cross sections of proton-induced reactions on ^{17}O nuclei, overcoming extrapolation procedures and enhancement effects due to electron screening. We will report on the indirect study of the ^{17}O(p,α)^{14}N reaction via the Trojan Horse Method by applying the approach developed for extracting the resonance strength of narrow resonance in the ultralow energy region. The mean value of the strengths obtained in the two measurements was calculated and compared with the direct data available in literature.

1 Introduction

The ^{17}O+p reactions are of paramount importance for the nucleosynthesis in a number of stellar sites, including red giants (RG), asymptotic giant branch (AGB) stars, massive stars and classical novae [1]. At temperatures typical of the above mentioned astrophysical scenario, T=0.01-0.1 GK for RG, AGB [2] and massive stars and T=0.1-0.4 GK for classical nova explosion, the^{17}O(p,α)^{14}N reaction cross section is dominated by two resonances: one at about $E^{R}_{c.m.}$ =65 keV above the ^{18}F proton threshold energy, corresponding to the E_X=5.673 MeV level in ^{18}F, and another one at $E^{R}_{c.m.}$=183 keV (E_X=5.786 MeV). In the last few years, several measurements [3–7] of the $E^{R}_{c.m.}$=183 keV resonance both in the (p,γ) and (p,α) channels have drastically reduced the uncertainties on both ^{17}O(p,α)^{14}N and ^{17}O(p,γ)^{18}F rates in the context of explosive H burning, whereas only one direct measurement [8] of the $E^{R}_{c.m.}$=65 keV resonance was performed in the (p,α) channel. However, the screening of the nuclear Coulomb field by atomic electrons was not taken into account in [8].

In this paper, we report on the indirect measurement of the ^{17}O(p,α)^{14}N reaction at energies below 300 keV by means of the Trojan Horse Method (THM). In particular, by using the THM formalism developed for the resonant reaction, [9,10], both the 65 and 183 keV resonances were observed and the resonance strength of the 65 keV resonance has been deduced. Here, we apply the THM to measure the cross section of the ^{17}O(p,α)^{14}N reaction by selecting the QF contribution to the ^{2}H(^{17}O,^{14}Nα)n reaction. The proton is brought inside the nuclear field of ^{17}O, while the neutron acts as a spectator to the ^{17}O(p,α)^{14}N QF reaction. Deuteron was used as the Trojan Horse nucleus because of its $p-n$ structure and its relative low binding energy ($\sim$ 2.2 MeV) [9, 10].

2 The measurements and the results

The study of the ^{17}O(p,α)^{14}N via the THM application was made via two experiments: the first one at the Laboratori Nazionali del Sud (LNS) in Catania (Italy) and the second one at the Nuclear Science Laboratory (NSL) of the University of Notre Dame (USA). The experimental setup of the two experimental measurements, the data analysis and the results have been already described step by step in [10–12], here only the resulting 65 keV resonance strengths for the LNS and NSL experiments are reported. In particular, by using the formalism reported in [10], one gets the strength of the

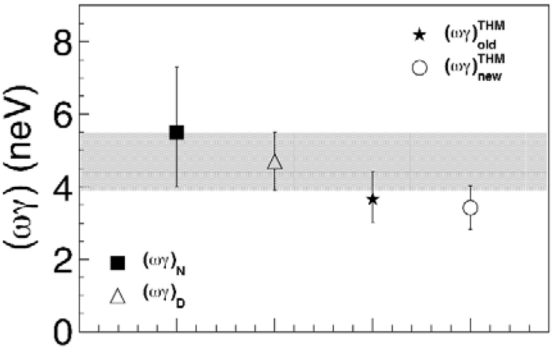

Figure 1: Comparison between the different values of the 65 keV resonance strength discussed in the text. The gray band represents the recommended range deduced by [3].

resonance at 65 keV for the LNS, $(\omega\gamma)_1^{THM} = (3.72 \pm 0.78) \times 10^{-9}$ eV, and for the NSL experiment, namely $(\omega\gamma)_1^{THM} = (3.16 \pm 0.68) \times 10^{-9}$ eV. The total error (~21% for the LNS experiment and ~22% for the NSL experiment) on the two $(\omega\gamma)_1^{THM}$ values is the sum in quadrature of the independent uncertainties (20.6% for LNS experiment and 21.4% for NSL experiment) due to the statistical error, the combinatorial background subtraction and peak value correlation (see Ref. [10]), and of the common uncertainty due to the normalization procedure (4.2% for both LNS and NSL experiments). For both LNS and NSL experiments, the normalization has been performed by scaling the strength of the 65 keV resonance, $(\omega\gamma)_1$, to the 183 keV one, $(\omega\gamma)_2$, which is well known from the literature. In more detail, the adopted value for the strength of the 183 keV resonance is $(\omega\gamma)_2 = (1.67 \pm 0.07) \times 10^{-3}$ eV, obtained by the weighted average of the four strength values reported in literature [3–5, 13]. Considering the upper and lower limits, the resulting weighted average $(\omega\gamma)_{new}^{THM} = (3.42 \pm 0.60) \times 10^{-9}$ eV is in good agreement with the strength given by NACRE, $(\omega\gamma)_N = (5.5^{+1.8}_{-1.5}) \times 10^{-9}$ eV [14] and with the direct value, $(\omega\gamma)_D = (4.7 \pm 0.8) \times 10^{-9}$ eV calculated by using the same Γ_p and Γ_α reported in [3, 13], namely $\Gamma_\alpha = 130$ eV [15] and $\Gamma_p = 19 \pm 3$ neV [16, 17]. The $(\omega\gamma)_{new}^{THM}$ value is, at the end, in agreement with the value $(\omega\gamma)_{old}^{THM} = (3.66^{+0.76}_{-0.64}) \times 10^{-9}$ eV measured in the previous THM analysis, that has been instead deduced considering the only three 183 keV resonance strength values reported in literature [3–5].

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