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Asymptotic normalization coefficients from the proton transfer $^{14}\mathrm{C}(^{3}\mathrm{He},d)^{15}\mathrm{N}$ reaction

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In this work, we analyzed the differential cross sections (DCS) of the $^{14}\mathrm{C}(^{3}\mathrm{He},d)^{15}\mathrm{N}$ proton transfer reaction using the Modified Distorted Wave Born Approximation (MDWBA) method. From this analysis, the squared values of the Asymptotic Normalization Coefficients (ANCs) for the ground and excited states of $^{15}\mathrm{N} \longrightarrow {}^{14}\mathrm{C}+p$ were extracted. In addition to providing new insights into the structure of the $^{15}\mathrm{N}$ nucleus, knowledge of the squared ANC for the $^{15}\mathrm{N} \longrightarrow {}^{14}\mathrm{C}+p$ configuration is essential for calculating the proton radiative capture cross section $^{14}\mathrm{C}(p,\gamma)^{15}\mathrm{N}$. This reaction competes with the neutron capture reaction $^{14}\mathrm{C}(n,\gamma)^{15}\mathrm{N}$, which is considered in inhomogeneous Big Bang models [1]. In this context, the competing $^{14}\mathrm{C}(p,\gamma)^{15}\mathrm{N}$ reaction influences the nucleosynthesis scenario and requires careful evaluation. This leads to a higher reaction rate for $^{14}\mathrm{C}(p,\gamma)^{15}\mathrm{N}$ at lower temperatures [2], significantly enhancing the role of this reaction in the synthesis of heavier elements in the low-energy region during various stages of the Universe's formation and evolution [3].

The experimental data were taken from [4]. The optical potential (OP) parameters used in the DCS calculations within the MDWBA framework are provided in [4-6]. To assess the peripherality of proton transfer, the geometric parameters of the Woods–Saxon (WS) potential for the bound state of the proton in the $^{15}\mathrm{N}$ nucleus were varied within the ranges 1.10<r0<1.40 fm and 0.5<a<0.8 fm. It showed that the transfers of a proton to the ground state as well as to 5.27 MeV (5/2+), 5.30 MeV (1/2+), 6.32 MeV (3/2-), 7.16 MeV (5/2+) and 7.30 MeV (3/2+) states of the 15N nucleus are practically peripheral, since the spread of the test function ρ(b) values does not exceed the experimental DCS errors. At the energies considered, all studied reactions were found to be peripheral in the region of the main diffraction maximum of the angular distribution of the emitted deuteron. The squared values of the ANCs were extracted by normalizing the calculated DCS to the experimental data using a χ2 minimization criterion, considering all measured angles within the region of the main maximum of the deuteron angular distribution. The complexity of this work lies in the fact that the first (5.27 MeV) and second (5.30 MeV) excited states of the $^{15}\mathrm{N}$ nucleus under study are located very close to each other. Therefore, in [4], the experimental differential cross-section values are reported jointly for both excited states We extracted the ANC values for both excited states separately, following the approach in [7]. For $^{3}\mathrm{He} \longrightarrow$ d+p binding, the value of the squared ANC was used equal to 4.28±0.50 fm^{-1} [8]. The values of the ANC squares were found to be 4.32±0.76 fm^{-1}, 12.52±2.17 fm^{-1}, 0.48±0.09 fm^{-1}, 0.032±0.007 fm^{-1} and 0.0068±0.0015 fm^{-1} for the states 5.27 MeV, 5.30 MeV, 6.32 MeV, 7.16 MeV and 7.30 MeV, respectively. These findings demonstrate that such reactions provide a reliable method for determining ANCs, even for tightly bound proton states.

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Primary authors: TULKINOV, Azizbek (National University of Uzbekistan named after Mirzo Ulugbek, Tashkent, Uzbekistan); RUZIEV, Elbek (Institute of Nuclear Physics, Tashkent, Uzbekistan)

Co-author: IKROMKHONOV, Erkinjon (Institute of Nuclear Physics, Tashkent, Uzbekistan)

Presenters: TULKINOV, Azizbek (National University of Uzbekistan named after Mirzo Ulugbek, Tashkent, Uzbekistan); RUZIEV, Elbek (Institute of Nuclear Physics, Tashkent, Uzbekistan)

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