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DETERMINATION OF THE ASYMPTOTIC NORMALIZATION COEFFICIENTS FOR ^{8}B+p→^{9}C FROM THE ^{8}Li(d,p)^{9}Li REACTION USING DISPERSION PERIPHERAL POLE MODEL

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Annotation: *The main purpose of this work is to determine of the values of the asymptotic normalization coefficients for ^{8}Li+n→^{9}Li and ^{8}B+p→^{9}C. For this purpose, the analysis of the measured differential cross section for the neutron transfer reactions ^{8}Li(d,p)^{9}Li reaction at energy E=7.8 MeV has been performed within the dispersion peripheral pole model. New values of the asymptotic normalization coefficients for ^{8}Li+n→^{9}Li and according to charge symmetry, ANC for ^{8}B+p→^{9}C have been obtained.*

Keywords: *Differential cross section, Dispersion peripheral pole model, asymptotic normalization constant, mirror systems; astrophysical S factor*

Introduction

The ^{7}Be(p,γ)^{8}B(p,γ)^{9}C(α,p)^{12}N(p,γ)^{13}O reaction chain is considered as one of the possible alternative paths to the 3α process for transforming the nuclei in the pp chains to the CNO nuclei in the peculiar astrophysical sites where the densities and temperatures are so high that the proton- and α- capture reactions become faster than the competing β-decays [1]. The ^{8}B(p,γ)^{9}C reaction may play an important role in the evolution of massive stars with very low metallicities [1]. The results of several microscopic and systematic calculations of this reaction are in large discrepancy [1-3]. It is very difficult to directly measure this reaction at astrophysical energies because of very small cross section.

Usually the differential cross sections (DCSs) of nucleon transfer reactions (NTR) are analyzed within the modified DWBA for determination of an asymptotic normalization coefficient (ANC) by normalization of the calculated DCS to the experimental data [4]. The modified DWBA [4] and the dispersion peripheral pole model (DPPM) [5] can be used for determination of ANCs from the analysis of the DCSs of the peripheral NTR. In both of these methods, the DCS is expressed in terms of the ANCs for the removed nucleon from the residual nuclei.

In this work has been analyzed within the peripheral-model approach. New values of the asymptotic normalization coefficient for ^{8}Li+n→^{9}Li with their uncertainties has been extracted. The analysis is performed within the framework of the DPPM [5] with correct taking into account the three-body Coulomb dynamics in the transfer pole mechanism and Coulomb-nuclear distorted effects in the exit and entrance channels.

The analysis of the reaction ^{8}Li(d,p)^{9}Li reaction within the DPPM

In Ref. [5] the Dispersion Peripheral Pole model of direct nuclear reaction A(x,y)B was proposed, in which based on the two assumptions: i) The main contribution to the amplitudes of the direct nuclear reaction is made by the partial amplitudes with large "peripheral" values of orbital momentum and of the relative motion of the particles in the initial and final channels. ii) The dominant contribution to the peripheral partial amplitudes is made by the singularity cos □ = □ of the amplitudes of the reaction in the cos □- plane closest to physical region $-1 \leq$ cos □ ≤ 1.

Asymptotic normalization coefficient for ^{8}Li+n→^{9}Li and ^{8}B+p→^{9}C

The calculations were performed in the framework of the simplified two-parameter peripheral model (PM) in which cut-off is carried out only in the orbital angular momentum of the entrance and exit channels. The differential cross section depends on a positive integer cut-off parameters L and L’. The nuclear vertex constants $(□^{□}_{0,1/2})^2(□^{9□□}_{1,\ 3/2})^2$ were determined by fitting the calculated differential cross section to the experimental one in the region of the main maximum of the angular distribution by minimizing the value of $□^{2}$.

Corrections of nuclear scattering were taken into account by replacing the pure pole partial amplitudes $□^{□}_{□□'}$ by the quantities

$$□_{□□'} = (□^{(□)}_{□}□^{(□)}_{□'})^{1/2}□^{□}_{□□'}$$

If we assume that the spectroscopic factors $□^{9□}_{1,3/2}$ and $□^{9□□}_{1,3/2}$ are equal for mirror pairs, based on the relationship of spectroscopic factor and ANC $□^{2}_{□,□_□} = □_{□,□_□}□^{2}_{□,□_□}$, the ANC for ^{8}B+p→^{9}C can also be derived with

$$(□^{9□}_{1,3/2})^2 = (□^{9□□}_{1,3/2})^2\ (□^{9□}_{1,3/2})^2\ /\ (□^{9□□}_{1,3/2})^2.$$

The ratio of the proton and neutron single particle ANCs was extracted to be $(□^{9□}_{1,3/2})^2\ /\ (□^{9□□}_{1,3/2})^2$ = 0.83 from the single particle wave functions calculated with optical potential models.

According to charge symmetry [9,10], the relation between the ANC for ^{8}Li+n→^{9}Li and ^{8}B+p→^{9}C has the form

$$(□^{9□}_{1,3/2})^2 = \left|\frac{□_{□}(□□_{□}□_{□})}{□_{□}□_{□}□_{□}(□□_{□}□_{□})}\right|^2 (□^{9□□}_{1,3/2})^2$$

where $□_{□}$ and $□_{□}$ are the regular Coulomb wave function and the Bessel function, respectively. $□_{□}$ and are the wave numbers of proton and neutron determined with their separation energies.

The value of □□ is changed from 2.5 to 5.0 in the calculations and the ratio of the ANCs for the mirror systems is nearly a constant (0.89).

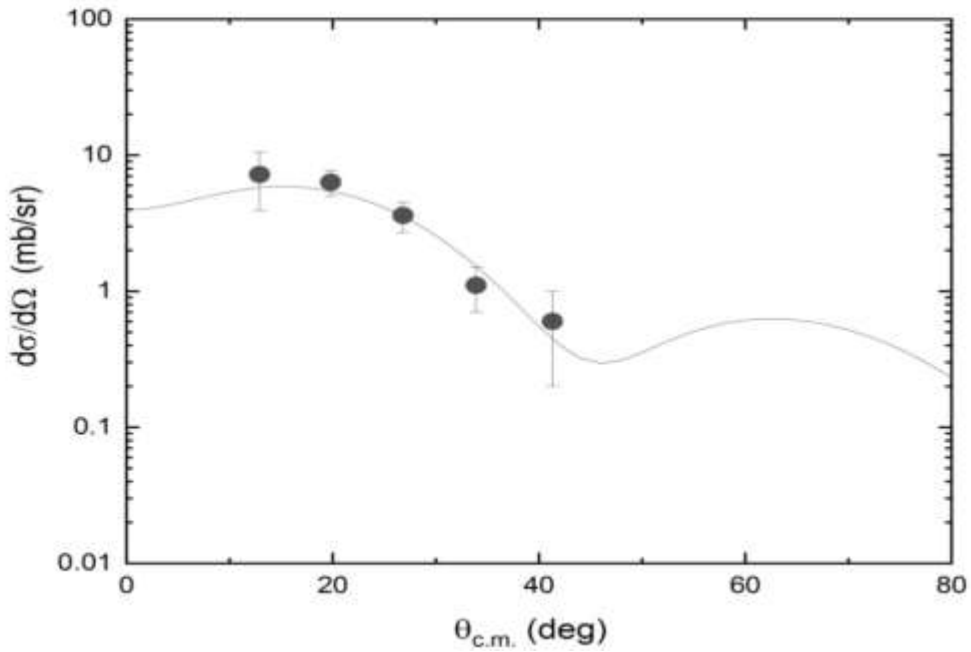

Figure 1. Angular distribution of the $^{8}Li(d,p)^{9}Li$ reaction at energy E=7.8 MeV. The experimental data are taken from [8] and the solid line is the calculated differential cross section within the DPPM.

Combining the results from above two calculations, the new extracted values of ANCs for $^{8}Li+n\rightarrow^{9}Li$ have been also used for determination of the ANCs for $^{8}B+p\rightarrow^{9}C$. The obtained values of ANCs for $^{8}B+p\rightarrow^{9}C$ are equal to $(□^{9□}_{1,\ 3/2})^2$=1.09 fm^{-1}. The obtained values of ANCs for $^{8}Li+n\rightarrow^{9}Li$ and $^{8}B+p\rightarrow^{9}C$ in the present work are in excellent agreement with the results. These deduced values of ANCs can be used for calculation of the astrophysical S factors of the radiative capture reactions $^{8}B(p,\gamma)^{9}C$.

Conclusion

The new values of the asymptotic normalization coefficients for $^{8}Li+n\rightarrow^{9}Li$ have been obtained from analysis of the measured differential cross section for the neutron transfer reactions $^{8}Li(d,p)^{9}Li$ reaction at energy E=7.8 MeV within the dispersion peripheral pole model approach. By using the mirror symmetry, the values of ANCs for $^{8}B+p\rightarrow^{9}C$ with their uncertainties have been determined.

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