INELASTIC CHANNEL TRACES IN ELASTIC SCATTERING CROSS SECTIONS IN THE $d + {}^{13}$C REACTION AT 14.5 MeV*

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Elastic and inelastic channels of the $d + {}^{13}$C nuclear reaction at $E(d) =$ 14.5 MeV are studied within the framework of the Coupled Channels method. Special attention is paid to the contribution of the inelastic channels to the elastic scattering channel. Preliminary results on the influence of the excited states 3.68 MeV and 7.54 MeV to the ground state in the target nucleus are shown. The transitions turned out to be having non-negligible contributions to the elastic scattering cross section.

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1. Introduction

The structure of the ^{13}C nucleus is of particular interest. Within the framework of the cluster model, the nucleus can be considered as three α particles and one neutron. Calculations within the framework of various theoretical models [1–4] and experimental works [5–8] show the uniqueness of the structure of the ^{13}C nucleus.

In particular, interest is put precisely in these three α-clusters, which can be formed by analogy with the Hoyle level in the ^{12}C nucleus at 7.65 MeV. In the previous work [6] from the series devoted to the structure of the ^{13}C nucleus, the structure of the excited states 3.089, 8.86, and 9.87 MeV was studied. It was shown that in the 3.089 MeV state, the nucleus predominantly has the $n + {}^{12}$C cluster structure, while in the other two states, the $\alpha + {}^{9}$Be cluster structure has a dominant contribution. The Hoyle state of

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the ^{12}C core in the ^{13}C nucleus studied was taken into account in the CC calculations. Its contribution to the 8.86 and 9.87 MeV states turned out to be insignificant as compared with the $\alpha + {}^{9}$Be excitation models.

Taking advantage of the Coupled Channel method, it is interesting to study the contribution of inelastic channels to elastic scattering in the $d + {}^{13}$C reaction at 14.5 MeV. Experimental data are used from Ref. [9]. At the moment, we consider only collectively excited states of the rotational band: 3.68 MeV and 7.55 MeV. In the next section, brief descriptions of the used method are given, and in the third section, preliminary results of the calculations are shown. At the end of the paper, the main conclusions of the study are presented.

2. Coupled Channels formalism

Here is a brief theoretical introduction to Coupled Channel formalism. More details can be found in Refs. [10, 11].

The total wave function Ψ of a $a + A$ nuclear reaction consisting of the channels $i = 1 \ldots N$ may have the form of

$$\Psi = \sum_{i=1}^{N} \phi_i(\xi_i)\chi_i(\boldsymbol{R}_i)\,, \tag{1}$$

where ξ are the internal coordinates for the i channel, $\boldsymbol{R}$ is the distance between colliding nuclei in the i^{th} channel, ϕ_i and χ_i are internal and relative motion wave functions in the i channel respectively. Multiplying Eq. (1) by the conjugated internal wave functions ϕ_i and integrating over their internal radii ξ_i, we can get the coupled equations in radial form as follows:

$$\left[E_i - T_{iL}\left(R_i\right) - U_i\left(R_i\right)\right]\chi_i\left(R_i\right) = \sum_{i'\lambda} i^{L-L'}\; V^{\lambda}_{ii'}(R_i)\;\chi_{i'}(R_i)\,, \tag{2}$$

where E_i is the channel energy, $T_{iL}(R_i)$ is the kinetic energy operator, U_i is the interaction potential including both the optical and Coulomb potentials, $V^{\lambda}_{ii'}(R_i)$ is the coupling potential used for the local coupling with the multipolarity λ.

Supposing the projectile a has no internal structure, in the inelastic channels, a target nucleus deformation δ_λ can be implemented through deforming the optical potential as

$$U(R) \equiv U(R) + \sum_{\lambda}\delta_\lambda Y_{\lambda 0}(\theta_R, 0)\,. \tag{3}$$

The deformation length δ_λ reflects the size of the λ-transition from the ground state to the excited state. Consequently, the coupling potential $V^{\lambda}_{ii'}(R_i)$ has the form of

$$V_{ii'}^{\lambda}(R_i) = \frac{1}{2}\int_{-1}^{1} \mathrm{d}u \, U\left(R^{\lambda}(R,u)\right) Y_{\lambda 0}(\theta_R, 0)\,, \qquad u \equiv \cos(\theta_R)\,, \tag{4}$$

where

$$R^{\lambda}(R,u) = R + \sqrt{\frac{2\lambda+1}{4\pi}} P_{\lambda}(u)\delta_{\lambda}\,, \tag{5}$$

and $Y_{\lambda\mu}(\theta_R, \phi_R)$ is the spherical harmonic, $P_{\lambda}(\cos(\theta))$ gives the Legendre polynomial.

3. Results and discussions

The differential cross sections for elastic scattering and inelastic channels have been obtained by means of the Fresco code [10]. The potential obtained in the work [6] was used in the CC calculations, while the deformation parameters were taken from Ref. [9]. The matrix elements for the transitions were calculated with a multipole equal to 2. The results of theoretical estimates for the differential cross section of elastic scattering of the $d + {}^{13}\mathrm{C}$ reaction and the contributions of inelastic channels are shown in Fig. 1. It

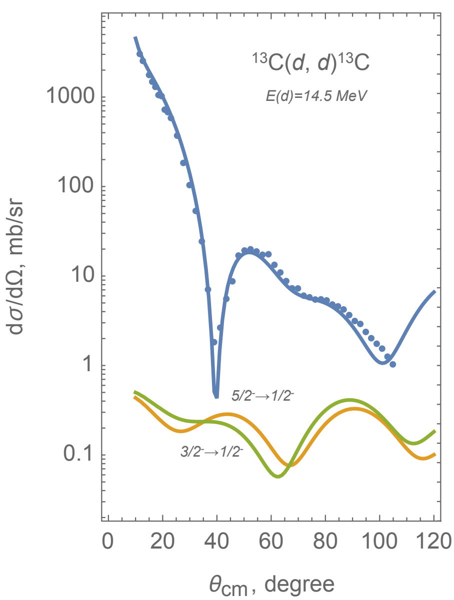

Fig. 1. (Color online) Elastic scattering differential cross-section data (circles) for the $d + {}^{13}\mathrm{C}$ reaction at $E(d) = 14.5$ MeV as compared with the CC calculations (blue/black), also contributions from the inelastic channels 3.68 MeV ($3/2^- \to 1/2^-$ orange/light gray), and 7.55 MeV (green/gray, $5/2^- \to 1/2^-$) are shown.

can be seen that quadrupole transitions show a nonzero contribution. The largest contribution is observed in the regions of angles 40 and 100 degrees. The spin reorientation effect is not observed, since the total momenta $\frac{1}{2}$, $\frac{1}{2}'$, and 2 do not meet the conditions of the triangle rule.

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