ANALYSIS OF THE MULTIPOLE TRANSITIONS IN THE REACTION $^{12}C(\gamma,3\alpha)$

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We obtained the relations for the amplitudes of the $E1\to{}^5P_1$, $M1\to{}^5D_1$, $E2\to{}^5D_2$-transitions at the two-cluster (α-$^8Be(2^+)$) photodisintegration of the ^{12}C nucleus from the analysis of the experimental data for $\Sigma(90°)$-asymmetry and the α-particle angular distributions in the reaction $^{12}C(\gamma,3\alpha)$ at energies of the linearly polarized photons 15.8-33.5 MeV.

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Interest to the investigation of the $^{12}C(\gamma,3\alpha)$ reaction is connected with the possibility of checking the α-cluster model for the ^{12}C nucleus and the two-particle mechanism of the photodisintegration with the production of the $^8Be(2^+)$ nucleus in the intermediate state [1]. The problems are the interpretation of the structure in the energy dependence of the total cross-section of the reaction in the photon energy region E_γ=10-38 MeV and the mechanism of the increased emission of the primary α-particles at an angle of 90° for some energy values imitating the forbidden E1-transition with $\Delta T=0$, where T is the isospin. The possibility of estimating the relations of the multipole contributions became possible due to the publication of the experimental data about the angular distributions [2] and the energy dependence of $\Sigma(90°)$-asymmetry of the output of α-particles for the energies of the linearly polarized photons 15.8-33.5 MeV [3].

To perform the analysis of the experimental data [2,3] we have made the multipole expansion of $\Sigma(90°)$ for two-particle photodisintegration of the ^{12}C nucleus with the production of the $^8Be(2^+)$ nucleus. In the approximation of the contribution of the $E1\to{}^5P_1$, $M1\to{}^5D_1$ and $E2\to{}^5D_2$-transitions we have obtained that $\Sigma(90°)=a/b$, where

$$a=0.45|E^1_{12}|^2+2.25|M^1_{22}|^2-2.69|E^2_{22}|^2+ +2.83\mathrm{Re}(M^1_{22}E^{2*}_{22}), \qquad (1)$$

$$b=3.15|E^1_{12}|^2+2.25|M^1_{22}|^2+4.47|E^2_{22}|^2+ +2.83\mathrm{Re}(M^1_{22}E^{2*}_{22}), \qquad (2)$$

E^J_{LS} and M^J_{LS} are the electric and magnetic multipole amplitudes; J, L, S are, respectively, the total momentum, the orbital momentum and the spin. In [2] using the method of the lowest squares the angle distributions of the primary α-particles was fit to the form of the series

$$d\sigma/d\Omega=\sum_{n=0}^{2} C_n\cos^n\theta. \qquad (3)$$

In this approximation the interpretation of the experimental data was limited to the decomposition

$$d\sigma/d\Omega=\sum_{n=0}^{2} A_n P_n(\theta), \qquad (4)$$

where $P_n(\theta)$ is Legendre polynomial.

In the approximation (3)

$$C_0=3.15|E^1_{12}|^2+2.25|M^1_{22}|^2+5.4|E^2_{22}|^2+ +2.83\mathrm{Re}(M^1_{22}E^{2*}_{22}), \qquad (5)$$

$$C_1=-7\mathrm{Re}(E^1_{12}M^{1*}_{22})+6.2\mathrm{Re}(E^1_{12}E^{2*}_{22}), \qquad (6)$$

$$C_2=-0.45|E^1_{12}|^2+2.25|M^1_{22}|^2-1.2|E^2_{22}|^2+ +8.85\mathrm{Re}(M^1_{22}E^{2*}_{22}). \qquad (7)$$

In contrast to C_1 in (3), it is possible to exclude from Eq. (1), (2), (5), (7) the interferential term $\mathrm{Re}(M^1_{12}E^{2*}_{22})$. Taking into account the interpolation between the experimental values for $C_{20}=C_2/C_0$ [2] and for $\Sigma(90^\circ)$ [3] at E_γ =15.8; 26; 28; 33.5 MeV we have obtained the following relations

$$|M^1_{22}|^2=0.23|E^1_{12}|^2+2.43|E^2_{22}|^2, \qquad (8)$$

$$|E^2_{22}|^2=0.15|E^1_{12}|^2+0.53|M^1_{22}|^2, \qquad (9)$$

$$|E^2_{22}|^2=1.1|E^1_{12}|^2+1.58|M^1_{22}|^2, \qquad (10)$$

$$|E^2_{22}|^2=0.26|E^1_{12}|^2+0.65|M^1_{22}|^2, \qquad (11)$$

$$|M^1_{22}|^2=0.70|E^1_{12}|^2+4.85|E^2_{22}|^2, \qquad (12)$$

$$|M^1_{22}|^2=-0.74|E^1_{12}|^2+0.51|E^2_{22}|^2, \qquad (13)$$

for E_γ=15.8 MeV, $\Sigma(90^\circ)$=0.26, C_{20}=0; $E_\gamma\approx$19-20 MeV, $\Sigma(90^\circ)$=0, C_{20}=-0.2; E_γ=26 MeV, $\Sigma(90^\circ)$=-0.36, C_{20}=-0.4; E_γ=27 MeV, $\Sigma(90^\circ)$=0, C_{20}=0; E_γ=33.5 MeV, $\Sigma(90^\circ)$=0.75, C_{20}=1.8; E_γ=33.5 MeV, $\Sigma(90^\circ)$=0.5, C_{20}=1.8 respectively. At E_γ=33.5 MeV, $\Sigma(90^\circ)<0.5$, C_{20}=1.8 a mathematical incorrect expression for the multipole amplitudes arises.

Thus we have demonstrated the principle possibility of getting in such an approach of the quantitative relations for the squares modulus of the amplitudes of the $E1\to{}^5P_1$, $M1\to{}^5D_1$ and $E2\to{}^5D_2$-transitions. From Eq. (9) - (11) for $19<E_\gamma<27$ MeV, where $\Sigma(90^\circ)<0$, it follows that $E2\to{}^5D_2$-transition dominates. From Eq. (12) for $28<E_\gamma<33.5$ MeV the $M1\to{}^5D_1$-transition dominates. For the latter case this also follows from the form of the α-angular distribution $dN/d\Omega$ [2].

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