THE REACTION OF DISLODGING OF NUCLEONES BY THE PROTONS FROM THE NUCLEUSES

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On the base of the quasi-classical approach the obtained expression for the amplitude of the quasi-elastic dislodging of nucleons by protons from the nucleuses is applied for the study of the membrane structure of light nucleuses. The results of concrete calculations of amplitude of *A(p,2p)B* process on ^{16}O and ^{12}C nucleuses are given for the comparison with the experimental data. The calculations have been carried out for the different outlet angles of the slow protons θ_1=61°, 64°, 67°, 73° at the fixed scattering angle of the quick proton θ_2=13.4°. The analysis of the results shows, that cross-sections of the scattering weakly depends on the angles of dislodging protons.

The quasi-elastic dislodging of nucleons by protons of intermediate energies from nuclears on the base of the quasi-classical approach, described in the ref. [1] is investigation.

Toward this end, the differential cross-section of reaction *A(p, NpP)B* is written in the form [2].

$$d\sigma = (2\pi)^4 \frac{m_p}{k} \mathbf{dp_2 dp_1} \delta(T_p - T_2 - T_1 - E_N - E_R) \frac{1}{2(2J_i+1)} \sum_{\substack{M_i M_f \\ \sigma_i \sigma_f}} \left|T_{if}\right|^2 . \quad (1)$$

Here T_p, T_2 and T_1 are energies of the corresponding incident, scattered and dislodging nucleons, E_N is the break energy of the weak connected nucleon.

$$E_R = \frac{P_R^2}{2M_{A-1}} \quad (2)$$

where E_R is the recoil energy of the daughter nucleus.

The matrix element of nucleus transition is presented in the form:

$$T_{if} = < J_f M_f \left| \int \mathbf{drdx_1} \overset{*}{\psi^{(-)}}(r) \psi^*(\mathbf{x_1}) V(\mathbf{r}\xi) \psi^{(+)}(\mathbf{r}) \psi(\mathbf{x_1}) \right| J_i M_i > . \quad (3)$$

The wave functions of the relative motion of the rescattered proton are obtained from the solution of the Shroedinger nonrelativistic equation [2].

The wave function of the dislodging nucleon (slow) has the form:

$$\psi(\mathbf{x_1}) = \int \varphi^*{}_{A-1}(\xi) \varphi_A(\mathbf{x_1}, \xi) d\xi . \quad (4)$$

The nucleus recoil energy is defined with the help of the momentum of recoil nucleus (P_r), which connected with missing mass (M_r) from the reaction, on the base of the law of conservation of energy:

$$M_R = [(M_A - m_p + T_p - T_2 - T_1)^2 - P_R^2]^{1/2} \quad (5)$$

The connection between nucleon divided energy (E_N) and daughter nucleus mass (M_{A-1}), which are known from experiment for missing mass is used by the following form:

$$E_N = M_R - M_{A-1} . \quad (6)$$

Thus, applying the quasi-classical theory on the proton scattering on the nucleuses, described in the ref [1], for the matrix element, we obtain:

$$T_{if} = -\frac{\hbar^2}{(2\pi)^2 \mu_0} \int \mathbf{drdx_1 dq'} e^{i[\mathbf{qr} + \Phi(\mathbf{r})]} e^{-\mathbf{ik_1 x_1}} e^{-\mathbf{iq'(r-x)}} \cdot \psi(\mathbf{x_1}) f_{NN}(\mathbf{q'}) < J_f M_f \left| \rho(\mathbf{x}\xi) \right| J_i M_i > . \quad (7)$$

After change of variables $u=r-x$ and using the expansion for the ill-wresting member $\Phi(r)$, we obtain:

$$T_{if} = -\frac{\hbar^2}{(2\pi)^2 \mu_0} \sum_{LM} \frac{1}{2L+1} \int e^{i[\mathbf{q}_{эф} - \mathbf{q'}]u} e^{-\mathbf{ik_1 x_1}} e^{i[\mathbf{qx} + \Phi(\mathbf{r})]} \times \times \psi(\mathbf{x_1}) f_{NN}(\mathbf{q'}) Y^*_{LM}(\hat{x}) \rho_L(\mathrm{x}) \mathbf{dudx\, dx_1 dq'} . \quad (8)$$

Here $\rho(x\xi)$ is expressed through radial transition nucleus density $\rho_L(x)$.

The expression for the nucleon-nucleonic amplitude $f_{NN}(q')$ is considered in the generic form [3].

Integrating the expression (8) on *du*, further on dq' and using the property of δ-function, for the cross-section we obtain:

$$\frac{d^3\sigma_{p,Np}}{d\Omega_1 d\Omega_2 dT_2} = \frac{(2\pi)^2}{k}\frac{m_p^4\hbar^2}{\mu_0^2}T_p^{1/2}(T_p - T_2 - E_N - E_R)^{1/2}\frac{2(J_f+1)}{2J_1+1}\sum\frac{1}{2L+1}\left|F_{LM}\right|^2. \quad (9)$$

At the quasi-elastic dislodging of nucleons, the recoil nucleuses have the hole in the casing, from which the proton is radiated, and the separation energy is equal to the energy of this single-particle state. The energy of dislodging nucleon has the value

$$T_1 = T_p - T_2 - E_N - E_R \quad (10)$$

And is defined with the help of the formula (2) and law of conservation of momentum

$$\mathbf{P_R} = \hbar\mathbf{k_i} - \hbar\mathbf{k_f} - \hbar\mathbf{k_1}. \quad (11)$$

The form factor of nucleus is

$$F_{LM}(\mathbf{q}) = \int e^{i[\mathbf{q}\mathrm{x}+\Phi(\mathbf{x})]} f_{NN}(\mathbf{q}_{\text{эф}}) Y_{LM}^*(\hat{x})\rho_L(\mathrm{x})\mathbf{dx}, \quad (12)$$

The mathematic calculation method is given in ref [1].

At the calculation (12) it is need to choose the coordinate system. Toward this end, it is supposed, that axis $OZ \uparrow\uparrow \mathbf{q}$, , where $q = \left|k_i - k_f\right| = 2k\sin\frac{\theta_2}{2} = 2k\alpha$ is recoil momentum to the nucleus, $\alpha = \sin\frac{\theta_2}{2}$ and axis $OX \perp \mathbf{q}$, where θ_2 is scattering angle of the incident particle,

$$\cos(\hat{\mathbf{q}}\hat{\mathbf{x}}_1)) = \mu, \quad \mathbf{x_1} = \{x_1\mu\varphi\},$$

$$\cos(\hat{\mathbf{x}}_1\hat{\mathbf{k}}_1) = -\mu\sin(\theta_1 - \frac{\theta_2}{2}) + \cos(\theta_1 - \frac{\theta_2}{2})\sqrt{1-\mu^2}\cos\varphi, ,$$

where θ_1 is the angle between incident and dislodging particles, which are familiar from the experiment.

Moreover, it is need to choose the function of nucleon density distribution in nucleuses. For the light nucleuses it is advisable to apply the symmetrized Fermi-densities, which well describe experimental cross-sections at the analysis of the elastic scattering of electrons and protons on light nucleuses [4,5].

The supposed approach allows to calculate the differential cross-sections on the dislodging of nucleons by protons with energy *Tp=1* GeV without free parameters. The results of the concrete calculations of reactions *A(p,2p)B* on nucleuses ^{16}O and ^{12}C in the comparison with the experimental data are given on the fig.1. and 2. The calculations, carried out for the outlet angle of slow protons θ_1=61° and at the fixed scattered angle of the quick proton θ_2=13.4°. The analysis of the results shows, that scattering cross-section weakly depends on the angles of the dislodging protons.

The nucleus ^{16}O can radiate the protons from the levels 1 $P_{3/2}$, 1 $P_{1/2}$, 1 $S_{1/2}$ and nucleus ^{12}C can radiate from levels 1 $P_{3/2}$ and 1 $S_{1/2}$, that's why the differential cross-section is calculated for each of this cases.

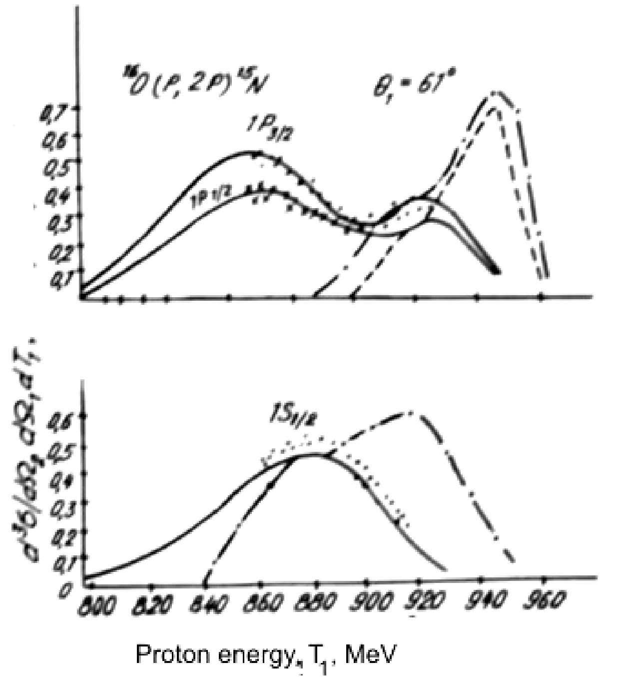

Fig. 1. The experimental (points) and theoretical differential cross-sections of the reactions of quasi-elastic dislodging of protons from the different nucleus membranes ^{16}O (touch dotted line). The cross-sections correspond to θ_1=61°, θ_2=13.4°. The continuous curve is results of the ref [6].

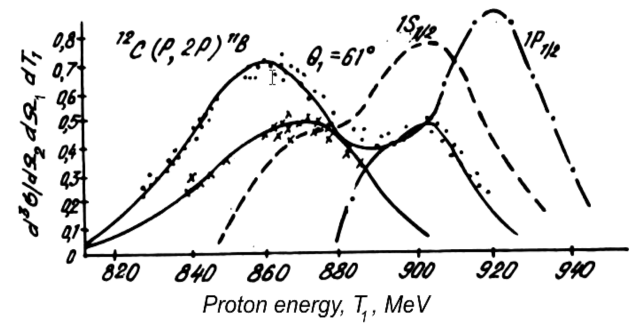

Fig. 2. The same, that on the fig.1., but for p-^{12}C.

In the experiment the slow protons were registered at energies T_1=(60÷105)MeV, the agreement of the theoretical cross-section with quick protons, measured on the registration was carrying out at these energy values of slow protons. As it is seen from fig.1., the theoretical curves, obtained in the present work on the dislodging of protons from the levels 1 $P_{3/2}$ and 1 $P_{1/2}$ in the difference from the experiment have only one maximum. This is the consequence of that in the process the absolute quasi-elastic dislodging of protons is considered, i.e. the residual nucleus doesn't react. The shift of the maximum to the side of the big energies probably connects with that the distortion doesn't take under consideration in the wave function of the dislodging proton.

For the comparison the theoretical curves, calculated in the wave-distorted momentum approximation, where the Hartri-Fock wave functions were used for the nuclear nucleons, are presented on the figures. Moreover, the authors of the work [6] also took under the consideration the excitation of the residual nucleus.

Thus, it is possible to conclude, that such calculations are comfortable for the practical use with the analytic wave functions of nucleus.

The theoretical analysis of dislodging reactions needs more detail consideration of the nuclear-force wave functions, in particular, more detail account of the excitation and distortion in the nucleus wave function.

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PROTONLARIN TƏSİRİLƏ NUKLONLARIN NÜVƏDƏN QOPARILMASI

Protonların təsirilə nüvədən nuklonların kvazielastiki qopma reaksiyasının amplitudunun analitik şəkli kvaziklassik yaxınlaşma əsasında tapılmışdır. A(p,2p)B reaksiyasının differensial kəsiyi ^{16}O və ^{12}C nüvələri üçün hesablanmış və alınan nəticələr təcrübə ilə müqayisə olunmuşdur. Hesablamalar sürətli protonların yalnız θ_2 =13.4^0 səpilmə bucağında, zəif protonların isə θ_1=61^0, 64^0, 67^0, 73^0 qopma bucaqları üçün aparılmışdır.

Nəticələrin analizi göstərmişdir ki, səpilmənin effektiv kəsiyi, qoparılan protonların uçuş bucağından asılılığı çox zəifdir.

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РЕАКЦИЯ ВЫБИВАНИЯ НУКЛОНОВ ИЗ ЯДЕР ПРОТОНАМИ

На основе квазиклассического подхода полученное выражение для амплитуды квазиупругого выбивания нуклонов из ядер протонами применено для изучения оболочечную структуру легких ядер. Результаты конкретных расчетов амплитуды процесса A(p,2p)B на ядрах ^{16}O и ^{12}C приведены в сопоставлении с экспериментальными данными. Расчеты выполнены для различных углов вылета медленных протонов (θ_1=61^0,64^0,67^0,73^0) при фиксированном угле рассеяния быстрого протона θ_2=13.4^0. Анализ результатов показал, что сечение рассеяния слабо зависит от углов выбитых протонов.

Received: 09.06.05