CALCULATION OF THE CROSS SECTION OF THE REACTION $p + A \to \pi^+ (A + 1)$ IN THE SINGLE-PARTICLE MODEL

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We consider here reactions of the type $p + A \to \pi^+ + (A + 1)$, where A and (A + 1) are bound nuclei. In these reactions, the momentum transferred to the nucleus is large on a nuclear scale ($\sim 3\ F^{-1}$), so that the high-momentum components of the nuclear wave functions can be investigated.

Experimental data on the differential cross sections at 0° on the nuclei ^{12}C, ^{13}C, and ^{14}N at a proton kinetic energy 600 MeV were obtained in [1]. The cross sections of the reactions proceeding to the ground state of the product nucleus are listed in the table. In [2] they considered the two reaction mechanisms represented by diagrams I and II (Fig. 1).

1. Single-nucleon model. In this model, the incident proton emits a positive pion and is captured on the I $P_{1/2}$ shell. The entire momentum transferred to the nucleus is taken up by one nucleon. The nucleus is considered in the pure shell model.

2. Two-nucleon model. It is assumed that the pion is produced in the reaction $p + p \to \pi^+ + d$ (the cross section of this reaction is known from experiment), and the deuteron in the final state is bound in the nucleus. The presence of the deuteron in the wave function of the product nucleus denotes that p-n correlations are taken into account in this model.

Product nucleus	Differential cross sections at 0°, μb/sr					Saxon-Woods potential parameters		
	Experiment	Oscillator			Saxon-Woods			
		I	II	III		MeV	F	F
^{13}C	0.75 ± 0.30	0.0102	0.020	0.63	0.60	37.2	0.6	1.25
					1.84	37.0	0.5	1.25
^{14}C					0.83	42.0	0.6	1.25
	0.37 ± 0.12	0.0103	–	–	2.26	42.0	0.5	1.25
^{15}C	0.39 ± 0.14	0.0105	–	–	0.94	44.0	0.6	1.25
					2.29	43.9	0.5	1.25

The mechanism shown in diagram III was proposed in [3]. The pion is emitted by a nucleon from the target nucleus and is re-scattered by the incident proton via a (3, 3) resonance.

In all the indicated calculations, the wave function of the bound states were taken to be harmonic-oscillator functions with parameters $\alpha = 0.631\ F^{-1}$ and $\alpha' = 0.61\ F^{-1}$ for the initial and final nuclei, respectively. The parameters were chosen from experiments on the scattering of electrons by nuclei [4]. The calculation results are listed in the table. We see that in all the models the calculation

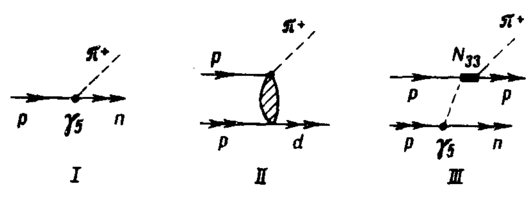

Fig. 1. The lines with two arrows denote bound states.

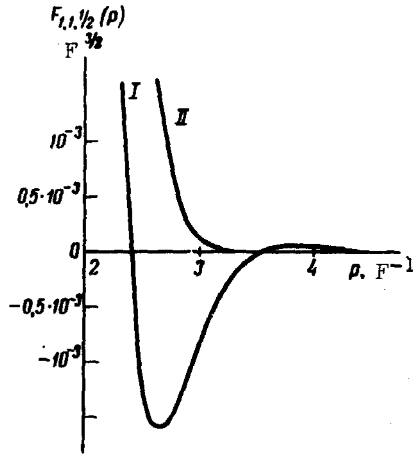

Fig.2

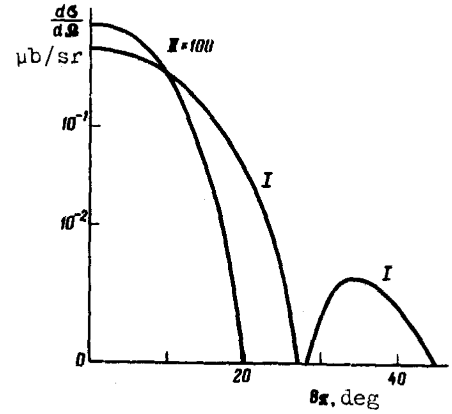

Fig. 3

Fig. 2. The function $F_{1,1,1/2}(p)$ for the ^{13}C nucleus: I - Saxon-Woods potential with parameters V_0 = 37.2 MeV, a = 0.6 F, r_0 = 1.25 F, and λ = 9; II - harmonic-oscillator potential with parameter α = 0.631 F^{-1}.

Fig. 3. Angular distribution of the reaction $p + {}^{12}C \to \pi^+ + {}^{13}C$ at a proton energy 600 MeV: I - Saxon-Woods potential with parameters V_0 = 37.2 MeV, a = 0.6 F, r_0 = 1.25 F, and λ = 9; II - harmonic-oscillator potential with parameter α = 0.631 F^{-1}.

differs significantly from the experimental data. The purpose of the present paper is to show that one of the possible causes of such a discrepancy is the incorrect behavior of the harmonic-oscillator function at large momenta transferred to the nucleus.

Let us consider the process shown in diagram I. The wave functions of the incident proton and π^+ meson, just as in [1], are chosen to be plane waves. The pion-nucleon interaction is described by a nonrelativistic pseudoscalar Hamiltonian

$$H_{\text{int}} = \frac{\hbar f}{m_\pi c}(\vec{\sigma}\nabla)(\vec{\tau}\vec{\phi}) - \frac{m_\pi}{m_p}(\vec{\tau}\vec{\phi})(\vec{\sigma}\vec{\nabla}); \quad \frac{f^2}{4\pi\hbar c} = 0.083 \tag{1}$$

Then the differential cross section in the l.s. can be written in the form

$$\frac{d\sigma}{d\Omega} = \frac{\hbar f^2 p_\pi}{2m_\pi^2 c^2 V_i}\left[p_\pi + \frac{m_\pi}{m_p}p_i\right]^2 \left|F_{1,1,1/2}(g)\right|^2, \text{where } g = \frac{M_A}{M_{A+1}}|p_i - p_\pi| \tag{2}$$

Here V_i and $\vec{p}_i$ are the velocity and momentum of the incident proton; g is the momentum of the neutron in the final state (with correction for recoil) and $|F_{1,1,1/2}(g)|^2$ is the momentum distribution of the I $P_{1/2}$ level of the final nucleus:

$$|F_{1,1,1/2}(g)|^2 = \frac{2}{\pi}\left|\int_0^\infty j_1(gr)R_{1,1,1/2}(r)r^2dr\right|^2. \tag{3}$$

The radial wave function $R_{1,1,1/2}(r)$ was calculated by solving the Schrödinger equation with a Saxon-Woods potential:

$$V(r) = -\frac{V_0}{1+\exp\left(\frac{r-R}{a}\right)} - \lambda V_0\left(\frac{\hbar}{m_p c}\right)^2 \frac{1}{r}\frac{d}{dr}\left[1+\exp\frac{(r-R)}{a}\right]^{-1}(\mathbf{l}\,\mathbf{s});$$

$$R = r_0 A^{1/3}.$$

The parameters were chosen from data on the elastic scattering of electrons and on the energy of detachment of the neutron from the product nucleus [5]. The results are listed in the table and are close to the experimental values.

In Fig. 2, the function $F_{1,1,1/2}(p)$ for ^{13}C is compared with the corresponding harmonic-oscillator function.

In spite of the fact that the radial wave functions differ negligibly within the limits of the nuclear radius, the momentum distribution at large momenta (≥ 2 F^{-1}) are entirely different in magnitude and in form (they practically coincide at small momenta). The function $F_{1,1,1/2}(p)$ in the Saxon-Woods potential at large momenta experiences oscillations that are possibly connected with reflections from the "sharp" boundary of the potential.

Figure 3 shows the angular distribution of the reaction $p + {}^{12}C \to \pi^+ + {}^{13}C$ at a proton energy 600 MeV. A characteristic feature is the presence of minima which are missing (at the considered proton energy) from the angular distribution obtained when p-n correlations are taken into account.

The present results show that the available experimental data can be described within the framework of the single-particle model of the nucleus. Therefore the contribution of the p-n correlations to the reactions in question is possibly smaller than that obtained in [2], and for their study it is necessary to have more detailed and exact experimental data.

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CONCERNING ONE MECHANISM OF THE PHOTOCONDUCTIVITY OF DISORDERED SEMICONDUCTORS

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As already noted by R. Kuyper and one of us, the hopping conductivity σ can be due to energy exchange between the carriers and any other elementary

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