NUCLEON CHARGE-EXCHANGE REACTIONS AT INTERMEDIATE ENERGIES IN THE ONE-MESON EXCHANGE PICTURE

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A method to describe the observables in the nucleon charge-exchange reactions on nuclei at intermediate energies with the explicit inclusion of the pion and rho-meson exchange and an excitation of the intermediate Δ (1232) isobar is proposed. The A(p,n)B reaction may be imagined as A(p,n)A+π reaction with the pion four-momentum equal to $(m_\pi, 0)$. This allows one to use the findings of the pion production/absorption theory in a combination with a standard distorted wave formalism for the description of the reaction observables. The corrections on the nuclear medium and short-range correlations are included. The calculations are compared with the experimental cross section of the ^{7}Li(p, n)^{7}Be reaction at $T_p = 200$ MeV and a satisfactory agreement is obtained.

Introduction

In the meson picture, it is well established by now that the long- and intermediate-range nucleon-nucleon (NN) forces are dominated by one-pion exchange. In addition to the one-pion exchange, there is a nearly model-independent understanding of the force as due to 2π exchange with Δ excitation down to a distance of about 1 fm [1]. However, the calculations of cross sections and other observables for nucleon charge-exchange reactions on nuclei at intermediate energies which explicitly use non-nucleon degrees of freedom, are very limited. One of such works is due to Krewald et al. [2]. In this comprehensive work, the authors use the Julich—Stony—Brook interaction for the calculation of magnetic excitations in various nuclei, the Gamow—Teller strength in charge-exchange reactions, medium effects on the bare two-nucleon potential, etc. The experimental NN scattering phase shifts and the deuteron properties are described reasonably well within a nonrelativistic model of NN interaction below the pion production threshold with virtual Δ isobars taken into account explicitly in the coupled channel formalism in [3]. The (n, p) reaction is used to study the possibility of formation of deeply bound pionic atom states in ^{208}Pb in the energy range of 400—1000 MeV [4]. These authors treat the n$\to$p transition to be caused by the one-pion plus one-rho meson exchange and the p-wave part of interaction is dominated by the Δ-pole term. Jain and Santra [5] and Jain [6] study the spin-isospin responses in nuclei and the formation of Δ isobar in the (^{3}He,t) reaction at the ^{3}He energy of 2 GeV and higher. For this purpose, they treat the elementary process pp$\to$n Δ^{++} in the framework of a one-boson exchange model. The triton spectra calculated in this approach including the direct and exchange diagrams agree well with experiment. In order to eliminate the seeming contradiction between a small value of the Landau—Migdal parameter for the delta-nucleon coupling, g'_Δ, following from the recent (p, n) spin experiments and a large value of g'_Δ required by the missing pion condensation and its precritical phenomenon, Toki and Tanihata [7] insist on the relativistic description of nuclei and reactions. Moreover, the relativistic approach gives the ratio of the spin longitudinal to transverse response functions less than 1, as required by the (p, n) experiments.

However, more numerous are the calculations of the cross sections and polarization observables for the nucleon charge-exchange reactions at intermediate energies, which use a certain type of the effective interactions as a transition potential. The most popular are the t-matrix [8] and various kinds of G-matrix (Paris, Bonn, M3Y, etc.) interactions. The status of the problem as of 1987 is described in [9]. The things have not changed much since that time.

There is another class of calculations [10—13]. These all in one way or another use a relativistic approach both to the continuum wave functions and the transition operator. The authors of works [10—12] start from the NN Lorentz invariant amplitude developed in [14] to obtain the macroscopic potentials for distorted wave functions in the relativistic impulse approximation (RIA) [10, 12] or relativistic distorted-wave Born approximation (RDWBA) [11]. In [11, 12], the continuum wave functions are obtained from the Dirac equation, and Clark et al. [10] used the coupled

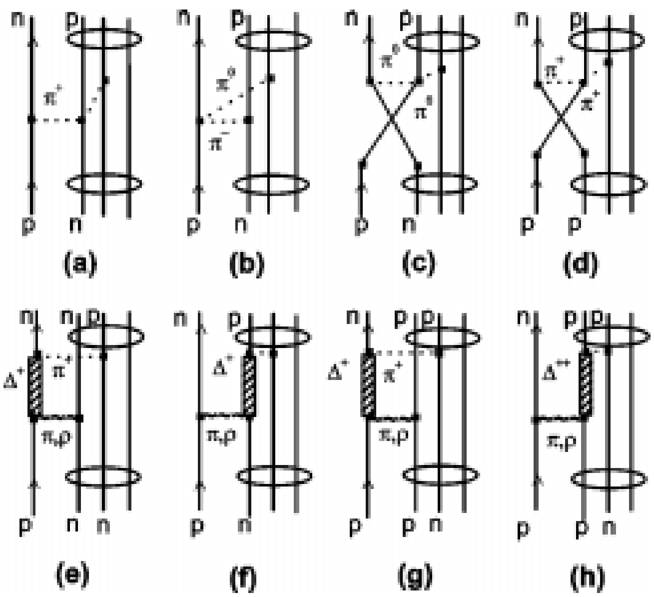

Fig. 1. Schematic representation of the contributions to the A(p,n)B reaction amplitude. Broken and wavy lines denote the meson propagation, shaded rectangles are the Δ (1232) isobars, and ovals denote the bound system

Lane—Dirac equations. Anderson et al. [13] used a phenomenological optical model potential for distorted waves within the distorted-wave impulse approximation (DWIA) and took the energy and density dependent G-matrix interaction of Nakayama and Love (see [9]) for the effective interaction. Coefficients of the sum in the on-shell NN t-matrix [14] are functions of energy and momentum transfer. In terms of the meson exchange model of NN interaction, the different coefficients can be identified as those corresponding to scalar, vector, tensor, pseudo-scalar, and axial-vector "meson" exchanges. The authors of work [11] generalize the scalar and vector amplitudes to include isospin.

Among a variety of works devoted to multi-step direct reactions, we note the recent work [15] analyzing the two-step process in the (p, p) and (p, n) reactions at intermediate energies.

In the present work, our goal is to study the possibility of the description of the (p, n) reaction observables at intermediate energies with explicit inclusion of the meson and Δ degrees of freedom.

1. Philosophy and Ingredients of the Approach

The nucleon charge exchange reaction A(p, n)B can be imagined as a reaction A(p, n)(π⊗A) with pion four-momentum $K_\mu = (m_\pi, 0)$. Then, for a description of the (p, n) reaction observables, one may use the findings of the pion production / absorption theory in a combination with the a well-known RDWBA formalism. In such an approach, the charge exchange process is viewed as follows. An incident proton interacting with an active target nucleon emits (absorbs) the off-shell meson which rescatters then on the target (incident) nucleon and is absorbed by another target nucleon. Here, it is assumed that the probability for a rescattered pion to land on the same nucleon is small [1].

With these assumptions, the reaction amplitude can be exhibited to the first order as a sum of diagrams depicted in Fig. 1. Here, diagrams (a)-(d) correspond to the s-wave rescattering and (e)-(h) are related to the p-wave rescattering. It is assumed that, at energies lower than 1 GeV, the p-wave interaction is dominated by the Δ(1232) isobar excitation and the other nucleon resonances do not contribute. The intermediate meson can be emitted from the projectile [diagrams (a), (f) and (h)] and from a target nucleon [diagrams (b), (e) and (g)]. Diagram (c) describes the process when one of the target nucleons having emitted a pion converts into the ejectile and the incident nucleon becomes bound in the residual nucleus. Diagrams (d), (g) and (h) account for the possibility when an active target nucleon is a proton. Lastly, in the p-wave amplitudes, we do not consider the so-called "pre-emission" diagrams (when the second pion is emitted at the first isobar vertex). It has been found in reactions of the pion production (p, p′π) [16] and (p, π) [17] that such diagrams only contribute a few percents relatively to the contribution of the "post-emission" process at incident energies of about 200 MeV.

Thus, for the evaluation of amplitudes, we need the propagators for intermediate pions, rho-mesons and Δ-isobars, coupling constants at the πNN, ρNN, πNΔ, and ρNΔ vertices, wave functions of incident and outgoing nucleons, wave functions of nucleons bound in the target and residual nucleus, and the wave function of a pion captured in one of the nucleon states of the residual nucleus. Now let us concentrate on these elements of the amplitude.

The full meson propagator is known to have the form

$$D(q^0, q) = \frac{D^0(q^0, q)}{1 - D(q^0, q)\Pi^0(q^0, q)}, \tag{1}$$

where the free propagator, D^0, is given by

$$D^0(q^0, q) = (q^{02} - q^2 - m^2 + i\varepsilon)^{-1} \tag{2}$$

with (q^0, q) the meson four-momentum (in our case, it is the momentum transfer) and its mass, m. Hereafter, we use the relativistic conventions adopted by Bjorken and Drell [18]. In Eq. (1), Π^0 is the self-energy of a pion. For a real pion, Π^0 is related to the optical potential through $\Pi^0 = 2\omega V_{\rm opt}$. The virtual pion propagating through the nuclear medium produces the particle-hole and Δ-hole excitations and these modifications are accounted for by including the self-energy in the pion propagator. In the calculation of the pion self-energy, we use expressions given in [16], where the nuclear density distribution is approximated by a Fermi gas. In addition we account for the 50% relativistic reduction in the Lindhard function for the pion self-energy as suggested in [7]. For the ρ-meson propagator, we employ (2). The Δ propagator is commonly given by

$$D_\Delta(\omega_\Delta, q_\Delta) =$$

$$[\omega_\Delta - T_\Delta - M_\Delta - V_\Delta(\omega_\Delta, q_\Delta) + i\Gamma_\Delta(s')/2]^{-1}, \qquad (3)$$

where $V_\Delta(\omega_\Delta, q_\Delta)$ represents the nuclear potential for Δ with energy ω_Δ and momentum q_Δ, T_Δ and M_Δ are the kinetic energy and mass of the isobar. The isobar width depends on energy and is given by

$$\Gamma_\Delta(s') = \frac{2}{3}\frac{1}{4\pi} f^2_{\pi {\rm N}\Delta} \frac{2M_\Delta}{\sqrt{s'} + M_\Delta} \frac{k^3_{\pi {\rm N}}}{m^2_\pi}, \qquad (4)$$

where $\sqrt{s'}$ is the c. m. energy of the πN system and $k_{\pi {\rm N}}$ is the c. m. momentum.

Similarly to the pion propagator modifications due to the nuclear medium, changes in the Δ isobar width are also expected. These may arise from two competing mechanisms. First, the Pauli effects in intermediate transitions inhibit the process $\Delta \to \pi$N as some of the nucleon states can be occupied. Such effects tend to decrease the isobar width in the medium relative to the free width $\Gamma_0 = 116$ MeV. The other contribution to the width arises from nuclear interactions which are called "spreading" transitions in terms of the Δ-hole model. The imaginary part of the "spreading potential" tends to increase the isobar width. So, there must be a large cancellation between the two effects. Furthermore, it is worth to note that, at the proton energies of about 200 MeV, the cross section of the (p, π) reaction is rather insensitive to the choice of $\Gamma_\Delta({\rm s}')$ (see e.g., [17]). For the coupling constants, we use the commonly adopted values [1]

$$f^2_{\pi {\rm NN}}/4\pi = 0.08, \quad f^2_{\pi {\rm N}\Delta}/4\pi = 0.37, \quad f^2_{\rho {\rm NN}}/4\pi = 4.86,$$

and $\quad f_{\rho {\rm N}\Delta}/f_{\rho {\rm NN}} = f_{\pi N\Delta}/f_{\pi {\rm NN}} = \sqrt{72/25}.$

Since the exchanged mesons in rescattering amplitudes are far off-shell, the off-shell continuation of the vertex functions must be taken into account. It is done by means of monopole form factors [1]

$$f_i(q^2) = f_i \frac{\Lambda_i^2 - m_i^2}{\Lambda_i^2 - q^{02} + q^2}, \qquad (5)$$

where i denotes the intermediate meson (π or ρ) and f_i are the correspondent on-shell values of coupling constants. The cut-off parameters are taken to be $\Lambda_\pi = 1200$ MeV and $\Lambda_\rho = 1500$ MeV.

To obtain the relativistic distorted wave functions for incident and outgoing nucleons, we follow the method of [19]. These authors obtained a Schrödinger-type equation by eliminating the small component of the Dirac spinor and a proper transformation. The large component of a nucleon wave function with the incident energy $T = E - M$ then obeys the equation

$$\left[p^2/2E + U_{\rm eff}(r) + V_{\rm C}(r) + U_{\rm s.o}\vec{\sigma}\vec{L}\right]\Psi(r) =$$

$$= (E^2 - M^2)/2E\Psi(r), \qquad (6)$$

where the Schrödinger equivalent potentials $U_{\rm eff}$ and $U_{\rm s.o}$ are the central and spin-orbit ones, respectively:

$$U_{\rm eff}(r) = U_V + \left[U_s(2M + U_s) - (U_V + V_{\rm C})^2\right]/2E,$$

$$U_{\rm s.o}(r) = \frac{1}{2ErD(r)}\frac{dD(r)}{dr},$$

$$D(r) = M + U_{\rm s}(r) + E - U_{\rm v}(r) - V_{\rm C}(r). \qquad (7)$$

Here, U_s, U_v, and $V_{\rm C}$ are the scalar, vector, and Coulomb potentials, respectively, and M is the nucleon mass. A small Darwin term is neglected. The bound-state wave functions (BSWF) of nucleons in the target and residual nucleus, needed for the calculation of the transition density, are obtained with the Woods—Saxon potential with a known binding energy. In order to obtain the BSWF for a trapped pion, we solve the Klein—Gordon equation numerically in the r-space with the pion-nucleus optical potential of the Ericson—Ericson type [1]. The optical potential parameters also are taken from [1].

We have two more ingredients for the evaluation of the πN T-matrix, namely, the s-wave and p-wave parts of the π-nucleon interaction. The popular choice of the s-wave part of interaction is a phenomenological Lagrangian [20]

$$\delta H^{(s)}_{\pi {\rm N}} = 4\pi\left[\frac{\lambda_1}{m_\pi}\bar{\Psi}\Phi\Phi\Psi + \frac{\lambda_2}{m^2_\pi}\bar{\Psi}\tau(\Phi \times \partial_l \Phi)\Psi\right], \qquad (8)$$

where Ψ, Φ are the nucleon and pion fields, respectively, τ is the Pauli isospin matrix, and λ_1, λ_2 are related to the isoscalar and isovector scattering lengths, respectively. The pion off-shellness is taken into account in [21] and the coupling strengths are

$$\lambda_1(q) = -\frac{1}{2}m_\pi\left[a_{sr} + a_\sigma\frac{m_\sigma^2}{m_\sigma^2 + \frac{3}{4}q^{02} - m_\pi^2 - q^2}\right],$$

$$\lambda_2(q) = \lambda_2\frac{m_\rho^2}{m_\rho^2 + \frac{3}{4}q^{02} - m_\pi^2 - q^2}, \qquad (9)$$

with $a_\sigma = 0,22m_\pi^{-1}$, $m_\sigma = 4,2m_\pi$ and $a_{sr} = -0,23m_\pi^{-1}$ to include short-range correlation effects, $m_\rho = 5,5m_\pi$, and $\lambda_2 = 0,046$.

The p-wave interaction comes from the π-and ρ-meson exchanges with intermediate Δ -isobar formation and is to be treated carefully. In the non-relativistic limit, the transition potential, V_p, corresponding to these exchanges is taken as

$$V_p(q^0,q) = \\ = \left[V_\pi(q^0,q)S^+q\sigma q + V_\rho(q^0,q)(S^+\times q)(\sigma\times q)\right]T^+\tau, \qquad (10)$$

or, in alternative form, as

$$V_p(q^0,q) = \left[V_{\rm c}(q^0,q)S^+\sigma + V_{\rm nc}(q^0,q)S_{12}(q)\right]T^+\tau, \qquad (11)$$

where $V_{\rm c}$ and $V_{\rm nc}$ correspond to the central and non-central parts of the interaction, $S_{12}(q) = 3S^+q\sigma q - S^+\sigma$ is the tensor operator, S and T are the transition spin and isospin operators, connecting spin-isospin 3/2- and 1/2-states and defined by means of $\left\langle 3/2\lambda_\Delta\middle|S_\lambda^+(T_\lambda^{+})\middle|1/2\lambda_N\right\rangle = \langle 3/2\lambda_\Delta|1\lambda 1/2\lambda_N\rangle$. If one treats the short-range part of the interaction too naively, the attractive parts of the one-pion exchange potential turn out to be so strong that a phase transition (pion condensate) can result, at least in the nuclear matter at a sufficiently high density [1]. Since this phase transition has not been observed, it is necessary to include the strong short-range repulsion which arises from the exchange of heavier mesons and other many-body effects. The major effect of short-range correlations is to suppress the relative wave function of two interacting nucleons at small distances $r = |r_1 - r_2|$. This can be made in different ways. The one is to use the parametrization of the correlation function (see, e.g., [2]) $\Omega(r) = 1 - j_0(m_c r)$, where $j_0(z)$ is the spherical Bessel function and m_c is the mass ω-meson which is mainly responsible for the short-range repulsion. Then the meson exchange part of the effective interaction $(V_\pi(q^0,q) + V_\rho(q^0,q))$ is replaced by

$$V_\pi(q^0,q) + V_\rho(q^0,q) - \left[V_\pi^c(q^0,q) + V_\rho^c(q^0,q)\right], \qquad (12)$$

$$V_{\pi,\rho}^c(q^0,q) = \frac{2\pi}{m_c^2}\int\frac{dk}{(2\pi)^3}\delta(|q-k| - m_c)V_{\pi,\rho}(q^0,q).$$

Another way [1, 4, 7] to handle the short-range correlations is to introduce the Landau—Migdal parameter, g'. Separating the interaction into spin-longitudinal, $V_l'(q)$, and spin-transverse, $V_t'(q)$, parts, we have

$$V_l'(q)q_iq_j + V_t'(q)(\delta_{i,j} - q_iq_j), \qquad (13)$$

with

$$V_l' = \frac{q^2}{q^{02} - q^2 - m_\pi^2}F_\pi^2(q) + g',$$

$$V_t' = \frac{q^2}{q^{02} - q^2 - m_\rho^2}F_\rho^2(q)C_\rho + g',$$

where F_π, F_ρ are the pion and ρ-meson form factors [see eq. (5)] and C_ρ is the ratio of the π and ρ coupling constants squared.

Finally, the differential cross section of the (p,n) reaction may be expessed as [18]

$$\frac{d\sigma}{d\omega} = \frac{p_n}{p_p s}\sum|T_{fi}|^2, \qquad (14)$$

where $p_n(p_p)$ is the momentum of the neutron (proton), s is the invariant energy squared in the incident channel, and the transition amplitude in the DWBA is given by

$$T_{fi} = \left(\chi_n^{(-)}, \left\langle\varphi_{A+\pi},\varphi_n\middle|\sum_i(V_s(i) + \right.\right. \\ \left.\left. + V_p(i)\middle|\varphi_A,\varphi_p\right\rangle, \chi_p^{(+)}\right), \qquad (15)$$

where $V_s(V_p)$ is the s-wave (p-wave) part of the effective interaction, φ_i are the spin-isospin functions of the correspondent particles, and $\chi^{(+)}(\chi^{(-)})$ is the distorted wave function in the incident (outgoing) channel. The sum in $V_s + V_p$ runs over the nucleons in the target nucleus.

2. Application to the ^{7}Li(p,n)^{7}Be Reaction at T_P=200 MeV and Discussion

The approach outlined above is applied to the (p,n) reaction on ^{7}Li at 200 MeV. This choice is motivated by the simplicity of the shell-model structure of the

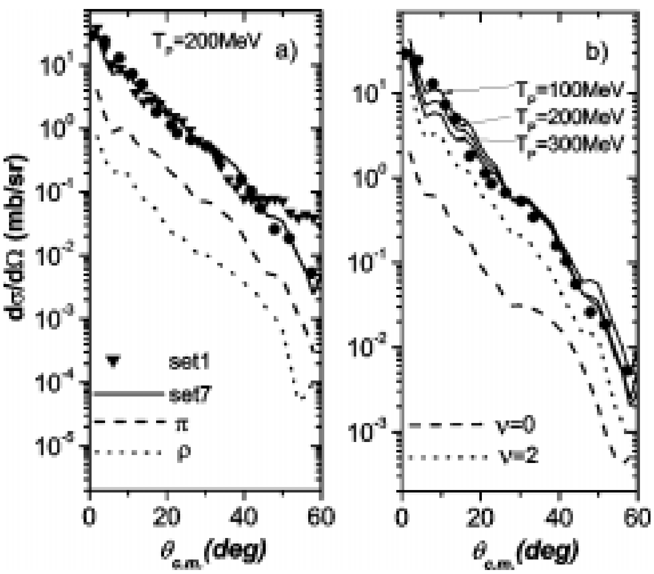

Fig. 2. Differential cross section for the ^{7}Li(p,n)^{7}Be(g.s.+0.43 MeV) reaction at 200 MeV. Solid points are experimental data from [22, 23]; *a* — solid curve and triangles denote the results of calculations with set *7* and set *1* of the OM parameters, respectively, taken from [24]. Dashed and dotted curves correspond to the contribution of either π- or ρ-meson exchange; *b* — solid curves are the results of calculations for proton energies indicated. Dashed and dotted curves correspond to the contribution of the central (ν=0) or tensor (ν=2) part of the effective interaction

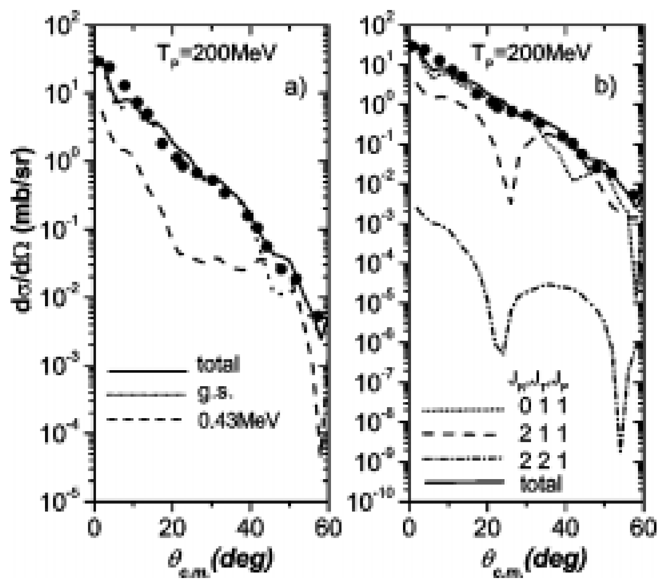

Fig. 3. Same as in Fig. 2, but: *a* — dotted and dashed curves correspond to the excitation of the ground state and first excited state (0.43 MeV) of ^{7}Be, respectively. Solid curve is their sum; *b* — decomposition of the calculated cross section (solid curve) into components corresponding to different sets of the relative total angular momenta J_R, J_T, J_P: 011 (dotted), 211 (dashed), and 221 (dot-dashed)

target and residual nuclei, which allows us to eliminate, to some extent, the nuclear structure effects and to concentrate on the reaction mechanism.

The present calculations are shown in Figs. 2,3 (solid curves) in comparison to the experimental data (solid dots). The experimental data are taken from [22] ($E_p = 60 \div 200$ MeV) and [23] ($E_p = 200 \div 400$ MeV). The optical model (OM) parameters are due to [24], where they are obtained from the fit to the elastic scattering of protons by ^{4}He and ^{16}O nuclei at 200 MeV. In Fig. 2,*a*, we show the results of calculations with two sets of OM parameters from [24], namely, set *7* ("deep" potential, solid curve) and set *1* ("shallow" potential, triangles). It can be seen that these two curves begin to differ at angles of about 40°. Because of the small reaction Q-value, we used the same OM potential for both the incoming and outgoing channels.

The striking constancy of the angular distribution of this reaction as a function of incident energy was the subject of discussion in [22, 23]. Indeed, the cross sections of this reaction measured in the energy region of 60—400 MeV almost exactly lie on a common curve. The authors of [22, 23] suggest that this reaction has a steadily decreasing contribution from the V_ι isospin part of interaction in this energy region which combines with the increasing $V_{\sigma\iota}$ contribution to make the ^{7}Li(p,n)^{7}Be(g.s.+0.43 MeV) cross section constant. But it is not the case for energies below 150 MeV. In the meson exchange treatment, this cross section constancy finds a natural explanation, namely, the approximate constancy of the pion energy transfer, the driving term in the meson propagators. For the bombarding proton kinetic energies of 100—300 MeV, this value is about 120 MeV for the projectile-emission diagrams (the difference between the c.m. energies of incident and outgoing nucleons) and a few MeV for the target-emission diagrams (the difference between binding energies of the particle-hole pair at the NN vertex). For the rescattered pion, the energy transfer varies from about 30 MeV to $m_\pi/2$ depending on the diagram. Our calculations for the three energies are shown in Fig. 2,*b* (solid lines). A slight difference between them is assumed to come from an energy dependence of the distorted wave functions. In Fig.2,*a*, we show the separate contribution of the pion exchange (dashed curve) and the rho exchange (dotted curve) to the reaction cross section. The dominance of the π -exchange is similar to that in the pion production reactions. The relative strength of the tensor part, ν =2, (dotted curve) of the interaction with respect to the central part, ν =0, (dashed curve) at the energy considered is seen in Fig.2,*b*. Again, the situation is the same as for for (p,π) reaction. It should be noted that, in our calculations, we used separately both methods to include the short-range repulsion, Eq.(12) with $m_c = 782$ MeV and Eq.(13) with $g' = 0.6$, and obtained practically the same result for the cross section in both cases.

Some of the nuclear structure effects on the cross section are depicted in Fig.3. In Fig.3,*a* we show a theoretical decomposition of the cross section for unresolved two states of ^{7}Be (the ground and 0.43-MeV first excited states) into separate contributions with equal weights. The result is consistent with the DWIA calculations [22] with the effective interaction as parametrized in [8].

In terms of the total angular momentum transferred to the projectile, target, and relative motion, J_P, J_T, and J_R, the cross section can be expressed as an incoherent sum of contributions corresponding to the possible sets of these quantum numbers. The momenta are defined as: $|J_a - J_b| \leq J_p \leq J_a + J_b$; $|J_A - J_B| \leq J_T \leq J_A + J_B$; $|J_P - J_T| \leq J_R \leq J_P + J_T$, where $J_a(J_b)$ and $J_A(J_B)$ are the spins of the projectile (ejectile) and the target (residual nucleus), respectively. In our case, they take the values $J_P = 0,1$; $J_T = 0,1,2,3$; $J_R = 0,1,2,3,4$ for the ground state of ^{7}Be and $J_P = 0,1$; $J_T = 0,1,2$; $J_R = 0,1,2,3$ for the 0.43-MeV state. Selection rules allow for the following sets of J_R, J_T, J_P: 000, 011, 211, 221, 231, and 431. It is seen from Fig.3,*b* that the most significant is the contribution with $J_R J_T J_P = 011$. The contribution with 000 is equal to zero identically and the contributions with 231 and 431 are negligibly small. It is worth to note that the cross section calculated with the harmonic oscillator wave functions for the BSWF in the transition matrix does not differ from that with the Woods—Saxon BSWF.

In conclusion, the approach proposed here allows one to describe satisfactorily the (p,n) cross sections at intermediate energies and does not depend on the particular choice of target nucleus or interaction. The dependence of the continuum wave functions on the OM parameters remains. We believe that this approach can be used to describe the cross sections and spin observables of the nucleon elastic and inelastic reactions.

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РЕАКЦІЇ ЗАРЯДОВОГО ОБМІНУ НУКЛОНІВ ПРИ ПРОМІЖНИХ ЕНЕРГІЯХ У ЗОБРАЖЕННІ ОДНОМЕЗОННОГО ОБМІНУ

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Р е з ю м е

Запропоновано метод описання спостережуваних величин у реакціях зарядового обміну нуклонів на ядрах при проміжних енергіях, який в явному вигляді містить обмін піоном і ρ-мезоном, а також збудження проміжної $\Delta(1232)$-ізобари. Реакцію A(p,n)B можна уявити як реакцію A(p,n)A+π з чотири-імпульсом, який дорівнює $(m_\pi, 0)$. Це дозволяє використати розробки теорії народження/поглинання піонів у комбінації зі стандартним формалізмом збурених хвиль для опису спостережуваних величин реакції. Включено поправки на ядерне середовище і короткодійні кореляції. Обчислення порівняно з експериментальним значенням перерізу реакції ^{7}Li(p,n)^{7}Be при $T_p = 200$ МеВ, досягнуто задовільне узгодження.