Observation of a dependence of the left-right asymmetry of quasielastic scattering of polarized protons by ^{12}C and ^{16}O nuclei on the momentum of the residual nucleus

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It was observed that the left-right asymmetry of quasielastic polarized 635±15 MeV protons by ^{12}C and ^{16}O nuclei depends on the momentum of the residual nucleus. It is shown that this dependence has two causes, the dependence of the asymmetry of the energy of the relative motion of the incident and nuclear nucleons and the influence of the effective polarization of the target nucleons.

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The measurements were performed in complanar geometry with the aid of two scintillation-counter telescopes connected for coincidence and registering both protons from the $(p,2p)$ reaction in specified energy interval. The scattering geometry was chosen with allowance for the binding energy E_c of the proton in the nucleus in such a way that the momentum q of the residual nucleus be equal to zero or be directed parallel or antiparallel to the proton beam. For the ^{12}C nucleus, in a geometry corresponding to scattering of polarized protons by p-shell (s-shell) protons at projections $q_z=\pm 80$ and ± 160 MeV/c of the residual-nucleus momentum on the proton-beam direction, the contribution from the scattering by the s-shell (p-shell) nucleons is approximately one-third. The proton polarization in the beam is 42.5%; the polarization vector is directed upward relative to the scattering plane. The measurement results are listed in Tables I and II.

TABLE I. ^{12}C

θ_{cms}	q_z MeV/c	e, %	
		p-shell E_c = 15.0 MeV	s-shell E_c = 35.0 MeV
57°	0	—	16.8 ± 1.2
	80	17.8 ± 0.9	18.2 ± 1.3
	− 80	1.5 ± 0.8	11.5 ± 1.5
	160	–	18.6 ± 1.9
	−160	–	9.5 ± 2.5
46°	80	19.7 ± 1.0	20.6 ± 1.5
	− 80	19.4 ± 1.1	13.4 ± 1.1

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TABLE II. ^{16}O

θ_{cms}	q_z MeV/c	e, %	
		$p_{3/2}$-subshells E_c = 19.0 MeV	$p_{1/2}$-subshells E_c = 12.4 MeV
46°	80	18.3 ± 1.8	22.3 ± 1.7
	− 80	15.5 ± 2.3	6.3 ± 2.0

θ_{cms} denotes the scattering angle in the cms of the colliding nucleons.

The measurement data for the s shell of ^{12}C at $\theta_{cms} = 57°$, referred to the total polarization of the incident protons, are shown in Fig. 1 as a function of the energy T of the relative motion of the colliding nucleons.

Figure 1 shows also the published data on the polarization produced in elastic scattering of unpolarized protons at an angle $\theta_{cms} = 60°$.

It follows from the presented experimental data that the measured asymmetry has a clearly pronounced dependence on the projection q_z of the momentum of the residual nucleus. The form of the dependence changes on going from the s shell to the p shell of the ^{12}C nucleus and on going from the $p_{3/2}$ subshell to the $p_{1/2}$ subshell of ^{16}O. This complicated dependence, however, can be understood by comparing the results with the corresponding data for free pp scattering, and recognizing that quasielastic scattering of polarized protons by protons of the p shells of ^{12}C and ^{16}O should lead to effective polarization of the target nucleons.[1] According to[1] the effective polarization for ^{16}O can reach values close to unity. In scattering of polarized protons by s-shell nucleons, the effective polarization is zero.

As seen from Fig. 1, the plots for the quasielastic and elastic scattering are of the same form and are close to each other. Therefore in the case of scattering of polarized protons by s-shell nucleons of the ^{12}C nucleus the dependence of the asymmetry on the projection q_z is caused by its dependence on the energy

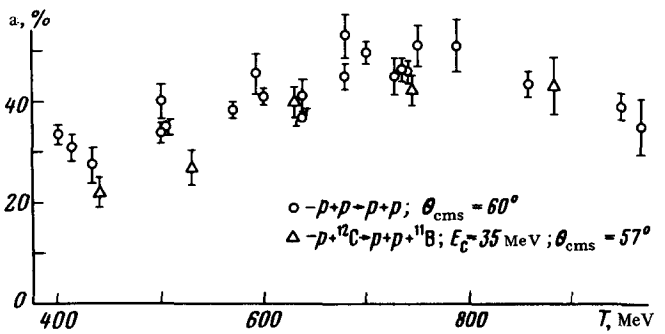

FIG. 1. Dependence of the asymmetry on the energy of the relative motion of the protons.

of the relative motion of the colliding nucleons, which is the analog of the corresponding dependence for free pp scattering.

For the p-shell protons of ^{12}C, which are predominantly in the $p_{3/2}$ state, the onset of effective polarization under the conditions of our experiment should lead to a decrease in the difference

$$\Delta = e(q_z = 80 \text{ MeV}/c) - e(q_z = -80 \text{ MeV}/c)$$

in comparison with the corresponding difference for the s-shell protons, i.e., it should lead to the observed difference of the differences Δ for p- and s-shell nucleons. This difference was noted by us for the first time in[2], and later in[3].

An estimate has shown that to explain the difference between the differences Δ for the p- and s-shell nucleons of ^{12}C at $\theta_{cms} = 57°$ a relatively small effective polarization, with absolute value 15—20%, is sufficient.

The asymmetry measurements on the p shell of ^{16}O agree well with the carbon data as to the character of the dependence of the asymmetry on the total orbital angular momentum of the nuclear nucleon. Since the effective polarizations for the protons of the $p_{3/2}$ and $p_{1/2}$ subshells are of opposite sign, the asymmetry difference

$$\Delta = e(q_z = 100 \text{ MeV}/c) - e(q_z = -100 \text{ MeV}/c)$$

is smaller when the main contribution to the scattering is made by the protons of the $p_{3/2}$ subshell than by the protons of the $p_{1/2}$ subshell. This agreement means that an effective polarization of the p-shell nucleons of ^{12}C and ^{16}O does indeed take place.

The probability that the difference between the asymmetry differences for scattering by protons of the p and s shells of ^{12}C, and the corresponding difference for scattering by protons of the $p_{3/2}$ and $p_{1/2}$ of the ^{16}O subshells can be attributed to purely random deviations is less than 10^{-4}.

Our data for oxygen are in qualitative agreement with recently published results[4] of the measurements of the cross sections of quasielastic scattering of 200-MeV polarized protons by ^{16}O p-shell protons.

Thus, the dependence of the left-right asymmetry of quasielastic scattering of polarized protons by ^{12}C and ^{16}O nuclei on the projection q_z, which was observed in our experiment, can be qualitatively explained as being due to two factors: 1) the dependence of the asymmetry on the energy of the relative motion of the colliding nucleon, which is the analog of the corresponding dependence for free pp scattering; 2) the influence of the effective polarization of the p-shell nucleons of ^{12}C and ^{16}O.

Measurements of the left-right asymmetry were performed by us also for the ^6Li nucleus.[5,2,3] The differences Δ for scattering by p and s-shell protons were found to be equal for this nucleus, within the limits of errors, thus indicating a low effective polarization of the p-shell nucleons.

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