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MEASUREMENTS OF THE LEFT-RIGHT ASYMMETRY OF QUASI-ELASTIC 635 MeV POLARIZED PROTON SCATTERING ON ^{6}Li, ^{12}C AND ^{16}O NUCLEI

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Измерение лево-правой асимметрии квазиупругого рассеяния поляризованных протонов с энергией 635 МэВ ядрами ^{6}Li, ^{12}C и ^{16}O

С целью исследования зависимости асимметрии квазиупругого рассеяния от импульса остаточного ядра проведены измерения лево-правой асимметрии квазиупругого рассеяния поляризованных протонов с энергией 635 МэВ протонами s - и p-оболочек ядер ^{6}Li, ^{12}C и ^{16}O. Эксперимент выполнялся с помощью двух сопряженных телескопов из сцинтилляционных счётчиков, регистрирующих в определенном интервале энергий оба протона, возникающие в (p,2p) реакции. Наблюдена зависимость лево-правой асимметрии квазиупругого рассеяния поляризованных протонов от импульса остаточного ядра. Показано, что эта зависимость обусловлена двумя причинами: зависимостью асимметрии от энергии относительного движения падающего и ядерного нуклонов и влиянием эффективной поляризации нуклонов p-оболочки ядер ^{12}C и ^{16}O.

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Measurements of the Left-Right Asymmetry of Quasi-Elastic 635 MeV Polarized Proton Scattering on ^{16}Li, ^{12}C and ^{16}O Nuclei

The dependence has been observed of the left-right asymmetry of quasi-elastic 635±15 MeV polarized proton scattering by ^{16}Li,, ^{12}C and ^{16}O upon the momentum projection of residual nuclei.

This dependence has been shown to be due to two reasons: a) asymmetry dependence upon the relative motion energy of incident and nuclear nucleons, b) the effective polarization of the protons of ^{12}C and ^{16}O p-shells.

The investigation has been performed at the Laboratory of Nuclear Problems, JINR.

Communication of the Joint Institute for Nuclear Research. Dubna 1977

The asymmetry has been measured with two coincidence scintillation counter telescopes detecting both the protons from the (p, 2p) - reaction in the given energy range. Scattering geometry was chosen taking into account proton separation energy E_b from the nucleus so that the momentum q transferred to the residual nucleus should be equal to zero or directed along or against the proton beam. The values of the q_z momentum projection of the residual nucleus to the proton beam direction and scattering angles θ_{cm} c.m.s. of the incident and nuclear nucleons are presented in the Tables. The thickness of lithium, carbon (graphite) and oxygen (water) targets are 2.0, 6.8 and 4.0 g/cm^2, respectively. Polarized protons have energy of 635±15 MeV. Proton polarization is positive and amounts to 42.5%. For the ^{12}C nucleus with q_z = ±80 and ±160 MeV/c in the geometry corresponding to polarized proton scattering on nucleons of the p-shell (s-shell) contribution from scattering on nucleons of the s-shell (p-shell) is about one third of the total count.

When preliminary data had been obtained /1/ for the ^{6}Li nucleus a theoretical study appeared /2/ where on the basis of the calculations of the cross sections of polarized

quasi-elastic proton scattering by protons of the p-shell of the ^{16}O nucleus it has been shown that due to the common effect of spin-orbital binding of nuclear nucleons and nuclear absorption the quasi-elastic scattering occurs as on a polarized target. This effective polarization has opposite signs for the positive and negative values of q_z and depends upon the scattering angle. Since the ^6Li nucleus is not a proper target to observe effective polarization, the basic asymmetry measurements of the (p,2p)-reaction were made for the ^{12}C nucleus. The nucleons of the p-shell of this nucleus are mainly in the $p_{3/2}$ state.

Tables I, II, III present the data of asymmetry measurements for Li and C nuclei

Table I

^6Li

θ_{cm}	q_z (MeV/c)	e (%) p-shell E_b = 5 MeV	e (%) s-shell E_b = 21.5 MeV
57°	0	-	18.5±1.4
	80	20.9±1.5	22.8±1.7
	-80	13.7±1.3	11.7±2.0
46°	80	24.8±2.0	-
	-80	16.8±2.1	-

Table II

^{12}C

θ_{cm}	q_z (MeV/c)	e (%) p-shell E_b=15 MeV	e (%) s-shell E_b=35 MeV
57°	0	-	16.8±1.2
	80	17.8±0.9	18.2±1.3
	-80	15.5±0.8	11.5±1.5
	160	-	18.6±1.9
	-160	-	9.5±2.5

Table III

^{12}C

q_z (MeV/c)	e (%) θ_{cm} =46° p-shell	θ_{cm} =46° s-shell	θ_{cm} =75° p-shell	θ_{cm} =75° s-shell
80	19.7±1.0	20.6±1.5	13.9±1.4	11.9±1.5
-80	19.4±1.1	13.4±1.1	6.7±1.3	4.9±1.6

The Tables present statistical errors of measurements. As is seen from the Tables, there is as obvious asymmetry dependence upon

q_z for both nuclei. The data in the Figure for the s-shell of the ^{12}C nucleus at $\theta = 57°$ given for the total beam polarization are shown with respect to the energy of the relative motion of the colliding protons. The same Figure shows polarization data available in the literature arising in elastic unpolarized proton scattering on unpolarized protons at an angle $\theta_{cm} = 60°$.

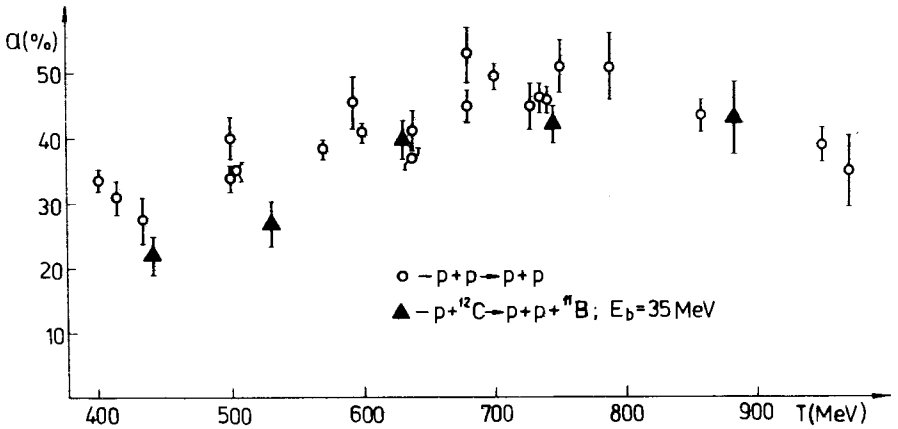

Figure. Asymmetry a versus energy with respect to proton motion with $\theta_{c.m.} = 57°$ for the totally polarized proton beam.

The Figure shows that both the dependences have a similar character and are close to each other. Since the effective polarizations for nucleons of the s-shell are equal to zero, it can be concluded that the asymmetry of the quasi-elastic scattering of polarized protons by protons of the s-shell depends upon the energy of the relative motion of colliding nucleons approximately in the same way as for elastic pp-scattering.

From Tables I and II it follows that in scattering on the nucleons of the p-shell of the ^{12}C nucleus at $\theta_{cm} = 57°$ and $46°$ the differences of the measured asymmetries

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

are considerably smaller than similar differences for the ^{12}C s-shell and for ^{6}Li s- and p-shells. This distinction Δ can be due to the effective polarization of the protons of ^{12}C p-shell which should lead to the decrease of asymmetry for $q_z = 80$ MeV/c and to the increase of asymmetry for $q_z = -80$ MeV/c compared to the proper values of s-shell protons. In order to explain the observed decrease of the difference Δ at $\theta = 57°$ it is sufficient to assume that the effective polarization of the ^{12}C nuclear p-shell protons is 15-20%. According to calculations [12] such effective polarization on carbon can be quite observable. The effective polarization of ^{6}Li nuclear p-shell protons should be considerably smaller, since the structure of this nucleus is mainly determined by the LS-coupling and the effect of nuclear absorption in it is considerably weaker than for the ^{12}C nucleus.

According to theory [2] with increasing the scattering angle in the interval up to 90° the absolute value of the effective polarization is reduced down to zero. Therefore, in passing from the angle $\theta_{cm} = 46°$ to

*This distinction has been first mentioned in ref. [3].

θ_{cm} = 57° and 75° a smaller distinction Δ should be observed for the nucleons of the p - and s -shell. It is seen from Tables II and III that for the ^{12}C nucleus just this picture takes place. Consequently, for the ^{12}C nucleus the effective polarization of p -shell nucleons at θ = 46° and 57° differs considerably from zero. But for p-shell nucleons of the ^{6}Li nucleus the effective polarization is close to zero for both the values of the scattering angle.

Table IV presents the data obtained for the ^{16}O nucleus at θ_{cm} = 46°.

Table IV
^{16}O

θ_{cm}	q_z (MeV/c)	e (%) $p_{1/2}$-sub-shell E_b = 12.4 MeV	e (%) $p_{3/2}$-sub-shell E_b = 19 MeV
46°	100	22.3±1.7	18.3±1.8
	-100	6.3±2.0	15.2±2.3

In view of their asymmetry dependence upon the total momentum of motion quantity of nuclear nucleons they agree well with the data for the ^{12}C nucleus. Since the effective polarizations for nuclear nucleons in the $p_{3/2}$- and $p_{1/2}$ states are opposite in sign, the asymmetry difference

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

is smaller when the basic contribution to scattering is made by nucleons of the $p_{3/2}$ sub-shell than in the case when the basic contribution to scattering is made by the nucleons of the $p_{1/2}$ -subshell. The probability that the distinction Δ for nucleons of the ^{12}C p- and s-shells at θ_{cm} = 57° and 46° and the distinction Δ for the ^{16}O $p_{1/2}$ - and $p_{3/2}$ -subshell nucleons is due to random deviations smaller than 10^{-4}. The data of Table IV are in agreement with recently published results [8] of the measurements of the cross sections of quasi-elastic scattering of 200 MeV polarized protons by the ^{16}O p -shell nucleons.

Thus, the whole amount of experimental data obtained makes it possible to conclude that observed in the experiment the dependence of the right-left asymmetry of quasi-elastic polarized proton scattering upon the momentum of the residual nucleus is due to two reasons:

a) asymmetry dependence upon energy of the relative motion of colliding nucleons, which is an analog of the proper dependence for free pp-scattering,

b) and effective proton polarization of ^{12}C and ^{16}O p-shells.

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