POLARIZATION OF PROTONS IN THE He³ (d, p) He⁴ REACTION

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The angular dependence of the polarization of protons from the He³ (d, p) He⁴ reaction is measured for ~ 2-MeV deuterons. Proton polarization was measured at angles 35, 44, 60, 75 and 90° in the laboratory system and was found to be respectively 2.7 ± 2.0, 5.4 ± 3.2, 7.6 ± 33.6, 5.8 ± 3.5 and 4.1 ± 3.4%. A helium polarimeter was employed for measuring the proton polarization.

THE He³(d, p) He⁴ reaction was investigated many times (see [1-4]). It has been established that a broad resonance exists at deuteron energy E_d = 450 keV, connected with the s-deuterons. The resonance is well described by the Breit-Wigner theory for the isolated level. This is evidence of an appreciable contribution made to the reaction by deuterons with momentum $l > 0$, which should lead to proton polarization.

It is of interest to ascertain the degree of polarization of the protons produced in this important reaction. A diagram of the experiment is shown in the figure. A deuteron beam of specified energy from an electrostatic accelerator entered a chamber with He³ gas through a nickel foil partition 1. The gas target was a cylinder 30 mm long. On the side surface of the cylinder there is a window covered with a thin mica foil 2. The reaction products were fed to the analyzer through this window and collimating diaphragms.

A helium polarimeter, previously described (see [5]), was used to measure the polarization. The protons scattered by the helium were registered with telescopes of proportional counters and photomultipliers. The helium pressure in the sensitive volume of the polarimeter was 5 atm. Particular attention was paid to correct setting of the polarimeter relative to the deuteron beam. By looking along the axis O'O it was possible to see a clearly outlined deuteron track in the chamber with He³ through the collimating diaphragms and the slots 3 and 4, which were covered with thin mica foil. The diameter of the glowing track amounted to 3 mm. This track made it possible to set the polarimeter visually with sufficient accuracy.

In order to exclude systematic errors due to the geometry, the analyzer was turned during the time of observation through 180° about the OO' axis.
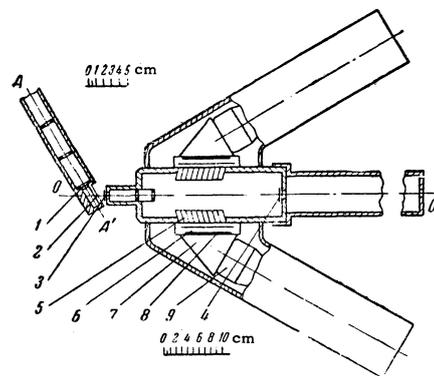
Experimental setup: 1 — nickel foil, 2, 3, 4 — mica foils, 5 — collimator, 6 — proportional counter, 7 — light pipe, 8 — CsI crystal, 9 — photomultiplier (the upper and lower scales pertain to the left and right halves of the apparatus, respectively.)

The resolution time of the coincidence circuits was chosen the same for the right and left sides of the polarimeter and amounted to 4 microseconds. It was verified many times during the course of the measurements, and the coincidence circuits were shifted periodically to serve the right-hand or the left-hand telescope.

As is well known, the degree of polarization of particles with spin 1/2 is determined by measuring the azimuthal asymmetry of the protons R, elastically scattered by the helium, using the well known formula

E_d, MeV (behind nickel foil)	Pressure of He³, atm	Scattering angle θ, deg (l.s.)	P_{an}, %	P_1, %
0.77	2.0	90	65	0±2.0
1.88	1.6	35	67	2.7±2.0
1.87	2.0	44	67	5.4±3.2
1.86	1.8	60	67	7.6±3.6
1.91	1.8	75	67	5.8±3.5
1.88	2.0	90	67	4.1±3.4

$$R = \frac{1 + P_1 P_{an}}{1 - P_1 P_{an}}.$$

Here R is the ratio of the number of protons scattered to the left to the number of protons scattered to the right, as viewed in the beam direction; P_1 is the polarization of the protons from the reaction and is considered positive in the direction of the normal to the scattering plane

$$[k_d \times k_p] / | [k_d \times k_p] |$$

(the vectors k_d and k_p define the directions of the incident deuterons and the protons emerging from the reaction), P_{an} is calculated from the geometry of the polarimeter and the $p - He^4$ elastic scattering phases. In our case the scattering was in the angle interval 55—81° in the laboratory system of coordinates. The initial data and the results of the measurements are represented in the table. In calculating the measurement errors account was taken in the calculations of the statistical errors only.

As noted earlier, at a deuteron energy of 450 keV there is excited the 3/2$^+$ level of Li^5, due to the interaction between the deuterons and the He^3 nuclei in the s state. Consequently, the protons produced as a result of the reaction are not polarized at this energy, and this resonance can be used to determine the geometrical corrections of the analyzer. It is seen from the table that there is actually no polarization in the region of the resonance. The measurements have shown that the geometrical asymmetry amounted to less than 1 per cent and was consequently disregarded. With increasing energy, a "left-right" asymmetry appears, and at a deuteron energy in the 2-MeV region, a noticeable polarization is observed. The table shows the dependence of the polarization on the proton emission angle. We see that it increases first, reaching a maximum at 60°, and then decreases.

It is interesting to compare the obtained results with those of Levintov et al[6], who measured the neutron polarization in the T(d, n) He^4 reaction at a deuteron energy 1.8 MeV. The neutron polarization turned out to be larger than that of the protons, but its angular dependence was the same for these two mirror reactions.

The anisotropy of the angular distribution of the protons increases with increasing energy, so that an increase in polarization is expected.

We are presently carrying out measurements at higher deuteron energy.

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