POLARIZATION OF PROTONS FROM STRIPPING REACTIONS ON LIGHT AND MEDIUM NUCLEI

M. V. PASECHNIK, L. S. SALTYKOV, and D. I. TAMBOVTSEV

Submitted to JETP editor March 3, 1962

J. Exptl. Theoret. Phys. (U.S.S.R.) **43**, 1575-1578 (November, 1962)

Experimental results are presented from a study of the polarization effect in stripping reactions in the region of light and medium weight nuclei. The deuteron energy was 13.8 MeV. For Be^9, B^{10}, and Ca^{40} target nuclei, we found the dependence of the proton polarization over the angular range 10—70°. For Si^{28} and the two nickel isotopes Ni^{58} and Ni^{60}, the polarization was measured at small angles.

THE study of the polarization of protons from deuteron stripping reactions is an important and very effective means of studying the mechanism of such reactions.

Proton polarization may be caused by any of the following interactions: 1) spin-orbit interaction of the neutron in the bound state in the final nucleus; the proton polarization occurs because of the correlation of the proton and neutron spins in the bound state of the deuteron; 2) spin-orbit interaction of the deuteron with the target nucleus and of the proton with the residual nucleus; 3) spin-orbit interaction of a proton which is in an outer shell of the target nucleus; a polarization effect appears if this proton is exchanged with the proton in the deuteron.

We have made measurements of the proton polarization for some light and medium nuclei, since there are at present very few experiments from which one could establish the behavior of the effect as a function of angle and mass number.

The deuterons were accelerated to 13.8 MeV in the cyclotron of the Physics Institute of the Academy of Sciences, Ukrainian S.S.R. Since we were studying protons from deuteron stripping reactions, the polarization was measured for angles $\theta \leq 70°$. A detailed description of the apparatus and the measurement procedure has been given by Tambovtsev.[1] In all, we measured 33 points.

For target nuclei, we chose Be^9, B^{10}, Si^{28}, Ca^{40}, Ni^{58}, and Ni^{60}. The results are shown in Figs. 1—4 and the table. In the figures, for illustrative purposes, we show the angular distributions of the protons without separation into spin states. For all the nuclei except Si^{28}, the results are for the ground state of the final nucleus.

The yields after scattering from He^4, which served as the analyzer, were such that in a 2—4 hr run we could get 1000—2000 counts in the region of the principal maximum and 200—400 counts outside it. This gave a statistical error of 3—4% at small angles and 8—9% at large angles. In addi-

Target nucleus	θ_{lab}	l	j	R^*	L^*	$(P \pm \Delta P)$%
Si^{28}_0	10	0	1/2	539	514	$+5 \pm 7$
$Si^{28}_{1.28}$	20	2	3/2	1007	1000	-0.7 ± 5
	30	2	3/2	570	600	-14 ± 7
Ni^{60}	10	1	3/2	458	308	$+39 \pm 7$

*R and L are the numbers of "right" and "left" counts.

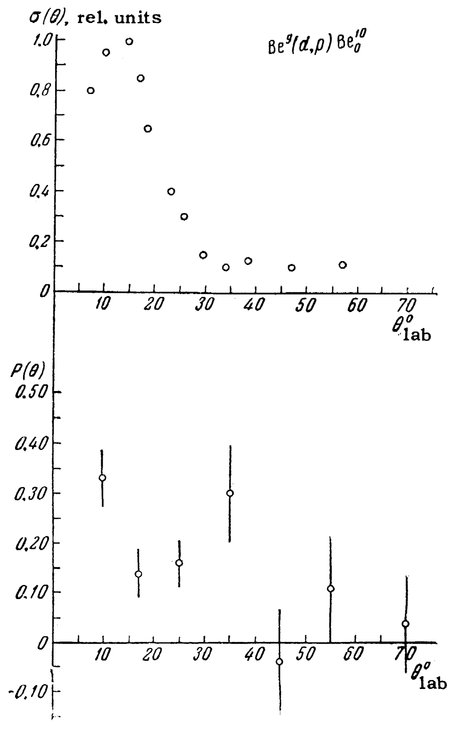

FIG. 1

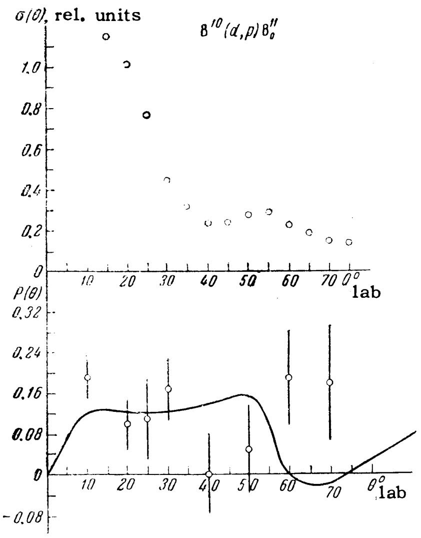

FIG. 2

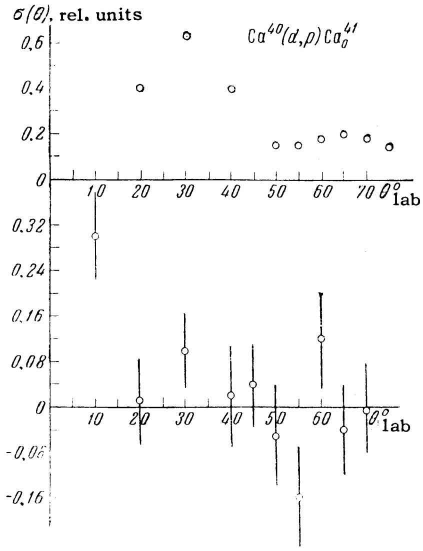

FIG. 3

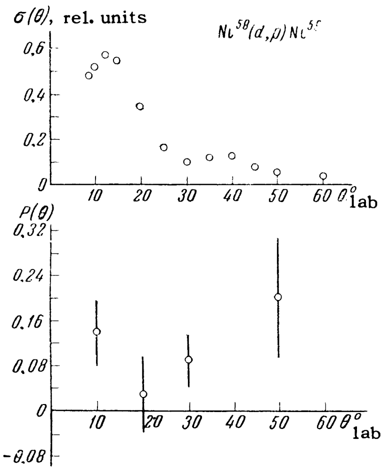

FIG. 4

tion to this, in the small angle region there was an additional error due to the background, which for the case of a beryllium target amounted to 30% of the effect. This increased the error by a factor of ~ 1.3. Finally a shift of the proton beam away from the center of the helium chamber could give a considerable contribution to the error, which could not be eliminated. The maximum error due to this effect was 2% at small angles and 4% at large angles. The error quoted with the results does not include the uncertainty associated with insufficient energy resolution, i.e., with a somewhat unsatisfactory selection of the proton "peak." This applies to the results at 10°, in particular for Ca^{40} and Si^{28}, and also to the measurements with Ni.

Because of low absolute value of the polarization of the protons from the Ca^{40} reaction and the large statistical error due to the low yield of this reaction, the measurements for this case were made at 5° intervals, even though the angular resolution of the apparatus was 7°.

The values of polarizations of protons for Be^9 and B^{10} at small angles are almost identical with those found earlier [3] with much lower energy deuterons. The weak energy dependence of the polarization at small angles has already been pointed out. [4,5] Such a behavior of the effect is unexpected, since theory predicts that it should be determined by the energy dependence of the reaction amplitude, which we know is extremely sensitive to the deuteron energy. The large percentage errors of the measurements limit us in any comparison of the observed angular dependence of the polarization with theoretical calculations. Besides, such a comparison would require difficult computations which could not be done without fast digital computers.

The qualitative conclusions which can be drawn from Figs. 1—4 are the following.

The sign of the polarization at small angles is related to the angular momentum of the captured neutron, namely: $P = \pm |P|$, when $j = l \pm 1/2$. This rule was predicted by the theory on the assumption that the polarization is caused by the first source listed at the beginning of the paper. The absolute value of the polarization should not exceed $1/6$ and, according to the theory, should generally be considerably less than this value.

It appeared, however, that in many cases it reached the theoretical limiting values 15—16%. This may mean that the deuteron wave is "distorted" much more than a proton wave, or that there is a sizable contribution to the proton polarization from the second and third mechanisms listed; for these the upper limits of $|P|$ are, respectively, $l/(l+1)$ (for $j = l + 1/2$) and 1.

The general character of the angular distributions of the proton polarization are similar for all the nuclei studied. There is an increase of the polarization at small angles ($< 15°$) and a minimum in the region of the principal maximum of the cross section. In the region where the cross section falls off, there is a slight rise and then a sharp drop with a possible change of sign. At large angles the polarization again reaches values close to those observed near the maximum of the cross section.

There is a characteristic connection between the position of the maximum of the polarization and the minimum of the cross section. The solid curve in Fig. 2 shows the computed[6] curve for $E_d = 8$ MeV.

We see that if we shift the maximum toward smaller angles by an amount corresponding to the shift of the cross section minimum due to the increase in deuteron energy from 8 to 14 MeV, we get good agreement with the theory.

Thus the "distorted wave theories" in their general features apparently give a correct description of the polarization of the protons, but further studies are needed to examine this mechanism in detail.

[1] D. I. Tambovtsev, Ukr. J. Phys. **7**, 245 (1962).

[2] N. I. Zaika and O. F. Nemets, Ukr. J. Phys. **4**, 519 (1959). Zaika, Nemets, and Prokopenko, JETP **38**, 287 (1960), Soviet Phys. JETP **11**, 208 (1960).

[3] R. G. Allas and F. B. Shull, Bull. Am. Phys. Soc. II, **6**, 24 (1961). Hird, Cookson, and Bokhari, Proc. Phys. Soc. (London) **72**, 489 (1958). I. C. Hensel and W. C. Parkinson, Phys. Rev. **110**, 128 (1958). B. Hird and A. Strzalkowski, Proc. Phys. Soc. (London) **75**, 868 (1960).

[4] R. G. Allas and F. B. Shull, Phys. Rev. **116**, 996 (1959).

[5] Bokhari, Cookson, Hird, and Weesakul, Proc. Phys. Soc. (London) **72**, 88 (1958).

[6] W. Tobocman, Phys. Rev. **115**, 98 (1959).

Translated by M. Hamermesh
272