TABLE I. Elastic scattering of 9.73-Mev protons by helium.

$\theta_{c.m.}$	$d\sigma/d\Omega_{c.m.}$ (10^{-27} cm^2)
17°10′	512.6±7.2
25° 8′	374.9±4.5
30°56′	346.9±5.5
36°57′	305.0±3.6
37°16′	303.3±5.5
42°14′	281.2±3.1
49° 5′	236.9±3.1
55°40′	204.3±2.4
68°17′	132.5±1.6
72°27′	108.6±1.4
89°21′	57.0±1.6
104°23′	32.2±1.5
132°55′	24.5±0.7
154°15′	58.4±1.1

of aluminum absorber required to stop the scattered protons in the foil that separated the second and third counters was a measure of the proton energy. The incident proton beam was calculated to have an energy of 9.73±0.05 percent.

III. RESULTS

The uncertainties are estimated to be as follows: integrated charge, ±0.4 percent; solid-angle calculations, ±0.5 percent; pressure and temperature, ±0.3 percent; and proton energy, ±0.5 percent. Estimates were made of the loss in counts caused by multiple scattering in the helium; also, the pressure of the helium in the scattering chamber was changed over the range from 5 to 15 cm mercury and no corrections appear necessary. No corrections were made for scattering caused by contamination in the helium.

The differential cross section is plotted in Fig. 1 and tabulated in Table I. Some of the lower-energy data and the higher-energy data are shown on the same plot. It is observed that the measured cross section for 9.73-Mev protons scattered in the forward direction is lower but in good agreement with the 9.48-Mev data of Putnam. However, the cross section for protons scattered in the backward direction is approximately 75 percent of the value published by Putnam. Each of these deviations is in the direction which would be expected by extrapolation from lower and from higher energies,[12] but the deviation of the large-angle scattering is greater than the extrapolated value.

[12] Bruce Cork, Phys. Rev. 89, 78 (1953).

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Scattering of 9.5-Mev Protons by Nitrogen

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The elastic and inelastic scattering of 9.5-Mev protons by N^{14} nuclei has been studied by means of photographic emulsions. Groups of inelastically scattered protons have been observed due to the excited states of N^{14} at 2.3, 3.9, 4.9, and 5.1 Mev; the first of these was excited in a very low intensity. Angular distributions have been determined for the elastic group of protons as well as for the inelastic group corresponding to the 3.9-Mev state; the latter curve is symmetrical about 90°.

THE scattering of 9.5-Mev protons by various light elements has been studied with the beam of molecular hydrogen accelerated in the 60-in. Birmingham cyclotron; the scattering camera described by Burrows, Powell, and Rotblat[1] was used, after slight modification. Exposures were made with various gaseous targets; this note describes the preliminary results obtained with nitrogen.

The camera was filled with nitrogen at pressures of 19.9 cm and 14.8 cm. Ilford C2 emulsions, 200μ thick, were used to detect the scattered particles. The mean energy calculated from the ranges of elastically scattered protons was 9.45±0.01 Mev. Levels in N^{14} at 2.3, 3.9, 4.9, and 5.1 Mev have been observed as well as levels of higher excitation. The 2.3-Mev level was excited in surprisingly low intensity. Only after prolonged search over a large area of emulsion was it possible to detect the protons due to this level; we are able to set an upper limit of 7.0 millibarns for the total cross section for the inelastic scattering of protons from this state. The major contribution to this value comes from difficult measurements at forward angles, where the background of tracks due to elastically scattered protons penetrating the scattering gap wall is relatively high. At 45°, 65°, 115°, and 130°, where accurate measurements of the cross section were possible, we obtained values: 0.68±0.20, 0.26±0.08, 0.32±0.07,

[1] Burrows, Powell, and Rotblat, Proc. Roy. Soc. (London) **A209**, 461 (1951).

and 0.54±0.12 millibarns per steradian respectively. This level has previously been observed in the same reaction at other bombarding energies, as shown in Table I, which also gives comparable information for the 3.9-Mev state.

It appears that transitions to the 2.3-Mev level are becoming less probable as the proton energy increases. Moreover, the observed intensity relative to that of elastic scattering for 9.5-Mev protons, is not much greater than the upper limit set for the corresponding group in (d,d') scattering by Bockelman *et al.* at 7 Mev. This last experiment would at first sight appear to give excellent confirmation of the isotopic spin selection rules, but the present similar result, to which these rules do not apply, suggest that such observations must be interpreted with caution.

The angular distribution of the elastically scattered protons is shown in Fig. 1. It is more complicated than the corresponding distribution found for C^{12} and O^{16} by Burcham *et al.*[2] In addition to the statistical uncertainties shown, there is a possibility that the absolute values of the cross sections are about 5 percent too low.

The angular distribution observed for protons inelastically scattered from N^{14}, leading to the 3.9-Mev level is shown in Fig. 2. Measurements could not be made at angles less than 30° but the evidence from all higher angles is that the curve is symmetrical about 90° in the c.m. system. The result can be expressed as:

$$\sigma(\phi)=3.91P_0(\phi)+2.12P_2(\phi)+1.83P_4(\phi)+1.47P_6(\phi)-0.21P_8(\phi).$$

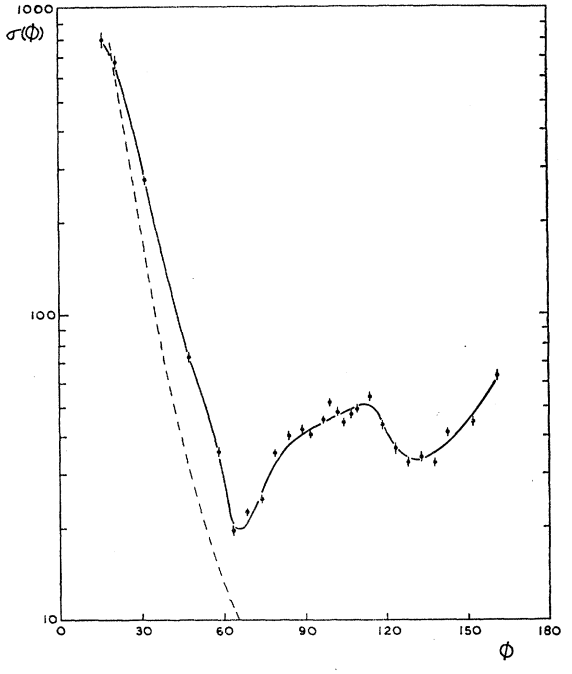

FIG. 1. Angular distribution in the center-of-mass system of protons elastically scattered by N^{14}. $\sigma(\phi)$ is given in millibarns per steradian. The dashed line is the Rutherford scattering curve.

[2] Burcham, Gibson, Hossain, and Rotblat, Phys. Rev. **92**, 1266 (1953).

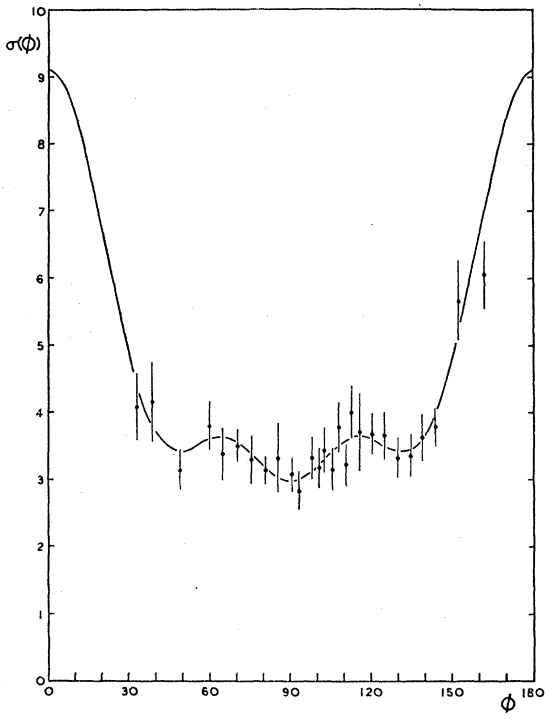

FIG. 2. Angular distribution in the center-of-mass system of protons inelastically scattered from nitrogen, leading to the 3.9-Mev state of N^{14}. $\sigma(\phi)$ is given in millibarns per steradian. The solid curve is the best fit in terms of even Legendre polynomials up to $P_8(\cos\phi)$.

TABLE I. The cross sections for the inelastic scattering of protons from the 2.3- and 3.9-Mev levels of N^{14}, relative to those for scattering from the ground state (g.s.).

Reference	E_p(Mev)	Angle	2.3/g.s.	3.9/g.s.
Bockelman *et al.*[a]	6.92	90°	5%	10%
Cowie *et al.*[b]	7.4	90°	5%	13%
Arthur *et al.*[c]	8.0	150°	2%	4%
Present work	9.5	90°	<1%	7%
		150°	<2%	12%
Fulbright and Bush[d]	15.0	···	not observed	

[a] Bockelman, Browne, Buechner, and Sperduto, Phys. Rev. **92**, 665 (1953).
[b] Cowie, Heydenburg, and Phillips, Phys. Rev. **87**, 304 (1952).
[c] Arthur, Allen, Bender, Hausman, and McDole, Phys. Rev. **88**, 1291 (1952).
[d] H. W. Fulbright and R. R. Bush, Phys. Rev. **74**, 1323 (1948).

One would expect a symmetrical distribution if only one level in the compound nucleus, O^{15}, of unique spin and parity were involved. But this is unlikely to be the case with the high excitation given by 9.5-Mev protons, and some other cause for symmetry must presumably be sought.