Scattering of 9.5-Mev Protons by Neon and Argon

R. G. FREEMANTLE, *University of Birmingham, Birmingham, England*

D. J. PROWSE AND A. HOSSAIN, *University of Bristol, Bristol, England*

AND

J. ROTBLAT, *University of London, London, England*

(Received August 16, 1954)

The photographic emulsion technique was employed to study the scattering of 9.5-Mev protons by neon and argon. Energy levels of Ne^{20} at 1.58, 4.20, 4.95, and 5.62 Mev have been observed as well as of A^{40} at 1.48 Mev. Angular distributions have been determined for the protons elastically scattered by Ne^{20} and A^{40}, as well as for the inelastic groups from the 1.58-Mev level of Ne^{20} and the 1.48-Mev level of A^{40}.

THE experimental procedure in this work was similar to that described in the preceding paper. The chamber was filled with neon of normal composition at a pressure of 6.2 cm. A typical histogram of the tracks observed at an angle of 80° is shown in Fig. 1; it clearly shows the presence of a number of groups corresponding to excitation levels in Ne^{20}. From the ranges of the elastically scattered particles we obtain 9.51±0.01 Mev as the incident proton energy. The excitation energies obtained from measurements at a large number of angles are 1.58±0.01, 4.20±0.01, 4.95±0.02, and 5.62±0.02 Mev. The first two agree within experimental error with those given by Ajzenberg and Lauritsen,[1] while the two states at 4.95 and 5.62 Mev replace the quoted level at 5.4 Mev; it would appear that previous measurements, on the reaction $F^{19}(d,n)Ne^{20}$, had not resolved this doublet.[2] The possibility that one or both of these levels might be due to Ne^{22} rather than to Ne^{20} has been ruled out by the variation of range with angle.

Figure 2 shows the angular distribution of the protons elastically scattered by neon (Curve A). It bears a marked similarity to both the carbon and oxygen curves obtained at the same energy.[3] The angular distribution of the protons arising from the 1.58-Mev level is shown in Fig. 3; it fits the equation:

$$\sigma(\phi)=14.0P_0(\phi)-10.4P_2(\phi)+3.2P_4(\phi).$$

There is a slight tendency to asymmetry at about 60° which may just be significant. This distribution may be compared with that obtained by Burcham *et al.*[3] for protons inelastically scattered from carbon, leading to

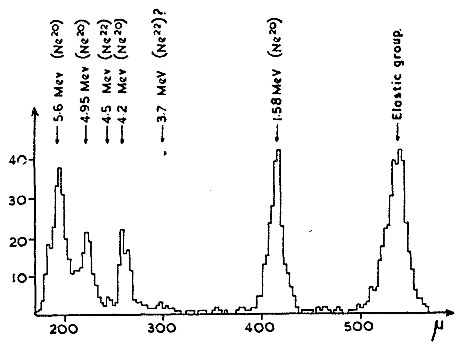

FIG. 1. Histogram of the tracks found at an angle of 80° (lab) in the neon experiment. A few tracks due to levels in Ne^{22} are visible but are not sufficient in number to enable accurate excitation energies to be given. All ranges should be reduced by 125 microns.

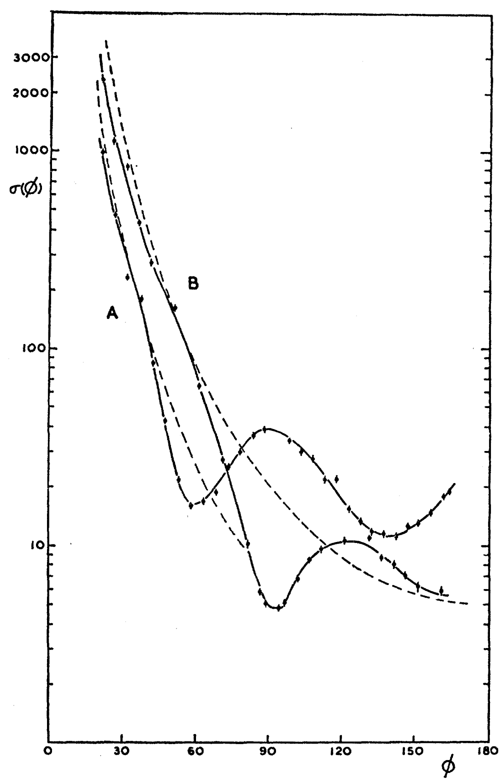

FIG. 2. Angular distributions of protons elastically scattered from (*A*) neon and (*B*) argon. $\sigma(\phi)$ is given in millibarns per steradian. The dashed lines are the curves to be expected from Rutherford scattering only.

[1] F. Ajzenberg and T. Lauritsen, Revs. Modern Phys. **24**, 321 (1952).

[2] T. W. Bonner, Proc. Roy. Soc. (London) **174**, 339 (1940).

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

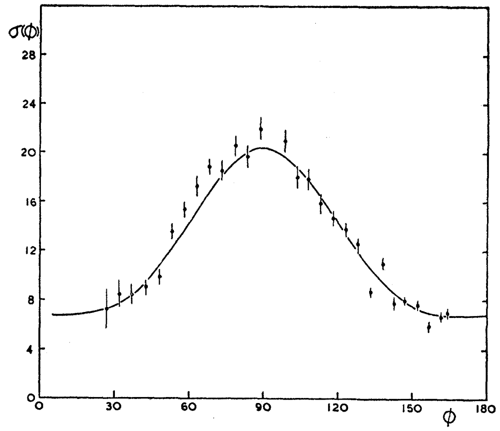

FIG. 3. Angular distribution of protons inelastically scattered from 1.58-Mev level of Ne^{20}. The solid line is the best fit in terms of even Legendre polynomials up to $P_4(\cos\phi)$. $\sigma(\phi)$ is given in millibarns per steradian.

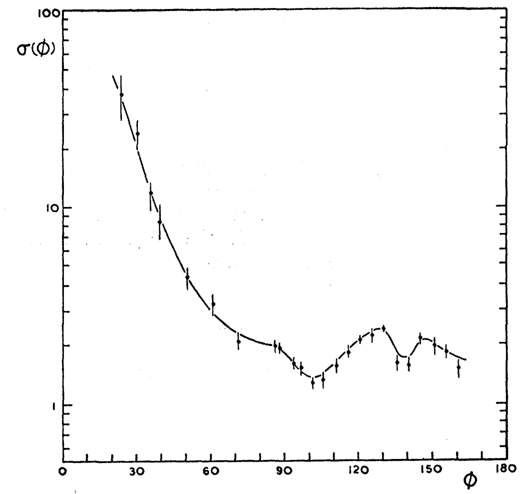

FIG. 4. Angular distribution of protons inelastically scattered from the 1.48-Mev level of A^{40}. $\sigma(\phi)$ is given in millibarns per steradian.

the excited state at 4.4 Mev. We have fitted a series of Legendre polynomials to this carbon distribution and obtained:

$$\sigma(\phi)=15.9P_0(\phi)+10.1P_2(\phi)-6.0P_4(\phi).$$

The constant terms in these two expressions are similar, but the coefficients of $P_2(\phi)$ while numerically indistinguishable from each other are of opposite sign. Since the spins and parities of the first excited states of C^{12} and Ne^{20} are both[4,5] 2^+ and those of the ground states 0^+, the difference between the angular distributions must be due to some other property of these states.

In the experiment with argon (at a gas pressure of 9.5 cm) we found in addition to the elastic group, one due to a level at 1.48±0.02 Mev. This is probably identical with that reported by Heitler, May, and Powell[6] at 1.46 Mev. Further investigations of the other energy levels are being made.

The angular distribution of the elastically scattered protons is shown in Fig. 2 (Curve B). The nuclear effect is much less marked in this curve than in those obtained from nitrogen or neon. At 90° the cross-section is 4 times less than that of Rutherford scattering. The general shape is similar to the other curves obtained, but the minimum has moved up to 95° and the maximum up to 125°. The angular distribution of the protons leaving A^{40} in its excited state at 1.48 Mev is shown in Fig. 4; in contrast to those obtained for carbon, nitrogen, and neon it is not symmetrical. It bears a generic resemblance to the curve obtained by Davis[7] for the inelastic scattering of 7.1-Mev protons from Be^9.

[4] Kraus, French, Fowler, and Lauritsen, Phys. Rev. **89**, 299 (1953).
[5] J. Seed, Phil. Mag. **44**, 921 (1953).
[6] Heitler, May and Powell, Proc. Roy. Soc. (London) **190**, 180 (1947).
[7] K. E. Davis, Phys. Rev. **88**, 1433 (1952).