Scattering of 9.5-Mev Protons by Carbon and Oxygen

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The elastic and inelastic scattering of 9.5-Mev protons by C^{12} and O^{16} nuclei has been studied by means of photographic plates. The 4.43-Mev state of C^{12}, as well as the 6.05-, 6.13-, 6.9-, and 7.1-Mev states of O^{16} have been observed. The angular distribution of the protons elastically scattered by C^{12} and O^{16} has been determined and compared with Rutherford scattering. In the case of the protons inelastically scattered by C^{12}, the angular distribution shows symmetry around 90°.

EXPERIMENTS have been carried out using a beam of molecular hydrogen accelerated in the 60-inch Birmingham cyclotron; when passing through the aluminium window into the scattering camera the hydrogen molecules split and give rise to a beam of protons of an energy of 9.5-Mev. The scattering camera was the same as that described by Burrows, Powell, and Rotblat;[1] some minor modifications were made, mainly to make possible the absolute measurement of the beam intensity. Gaseous targets of hydrogen, helium, carbon, nitrogen, oxygen, fluorine, neon, and argon were used, and the scattered particles were recorded in photographic emulsions.

For the experiments on carbon the scattering chamber was filled with acetylene at pressures of 15–20 cm. The range distribution of the scattered particles showed (a) the group of elastically scattered protons, (b) the inelastically scattered protons corresponding to the 4.43-Mev state[2] of C^{12}, and (c) at angles less than 90°, the group of protons scattered by hydrogen. The differential cross section of p-p scattering was found to vary with angle in the same way as that described recently by Allred *et al.*,[3] but our values of the absolute differential cross sections are about 20 percent lower than theirs. A survey of values of the proton-proton scattering cross section at 90°, at various proton energies, published by a number of authors in recent

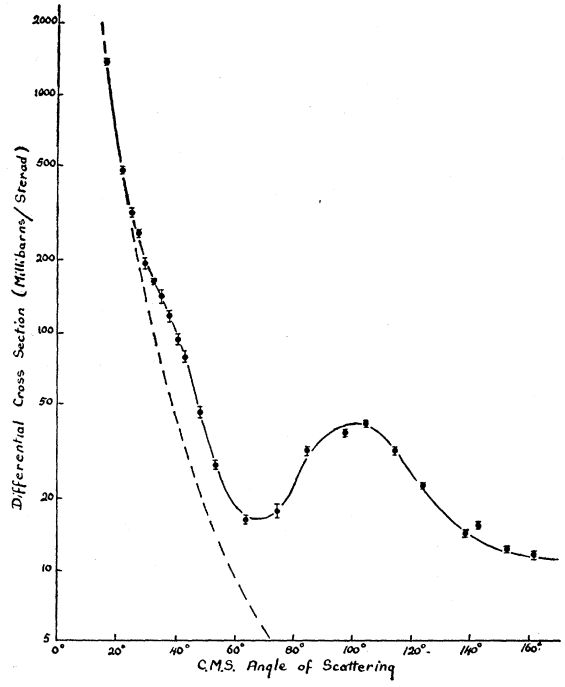

FIG. 1. Angular distribution in the center-of-mass system of protons elastically scattered by carbon. $\sigma(\phi)$ = c.m. differential cross section in millibarns per steradian.

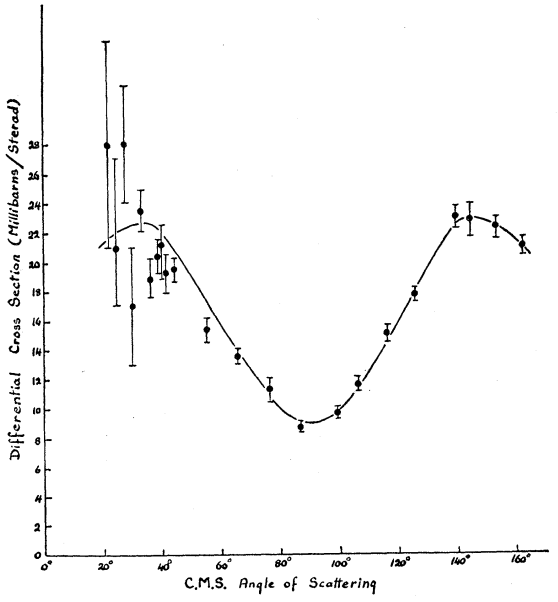

FIG. 2. Angular distribution in the center-of-mass system of protons inelastically scattered from carbon, leading to the 4.43-Mev state of C^{12}. $\sigma(\phi)$ is given in millibarns per steradian.

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[1] Burrows, Powell, and Rotblat, Proc. Roy. Soc. (London) **209**, 461 (1951).

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

[3] Allred, Armstrong, Bondelid, and Rosen, Phys. Rev. **88**, 433 (1952).

years, indicates that our values are probably too low, while Allred's values are probably too high. Possible sources of error in our beam integrating system are being investigated; for the time being we have to assume an uncertainty of the order of 8 percent in our absolute cross-section measurements; the relative error is much smaller, only of the order of 2 or 3 percent. Figure 1 shows the observed angular distribution of protons elastically scattered by C^{12}; the broken line gives the Rutherford scattering. Figure 2 shows the distribution observed for the protons inelastically scattered from carbon, with formation of the 4.43-Mev state of C^{12}. Unlike the findings of Gove and Stoddart,[4] who at 7.3-Mev observed an asymmetrical distribution, our curve seems to be symmetrical around 90°. Below 40° the measurements are difficult but the more reliable

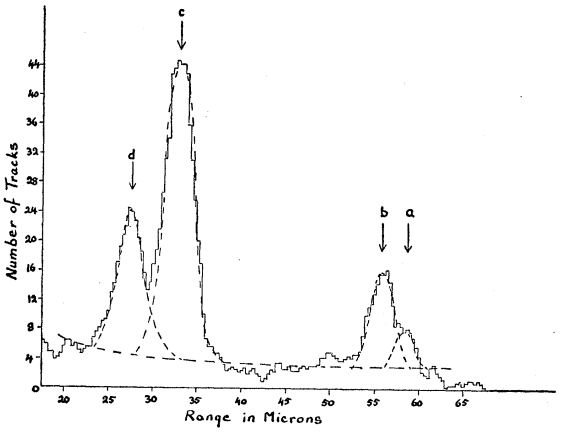

FIG. 3. Histogram of ranges of 9.5-Mev protons inelastically scattered from O^{16}, emitted at an angle of 85°; the four groups correspond to the excited states of O^{16} at (a) 6.05, (b) 6.13, (c) 6.9, and (d) 7.1-Mev.

results for angles greater than 40° show no sign of asymmetry.

In the experiments with oxygen the camera was filled with pure oxygen at pressures of 5–10 cm. In addition to the elastically scattered protons, we observed inelastically scattered protons leading to the four excited states of O^{16} at 6.05, 6.13, 6.9, and 7.1-Mev.[2] Figure 3 shows a histogram of tracks of the short-range

[4] H. E. Gove and H. F. Stoddart, Phys. Rev. 86, 572 (1952).

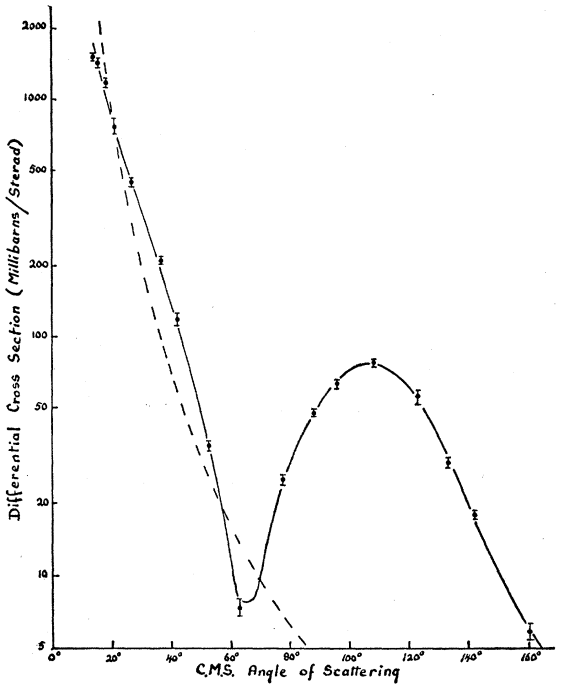

FIG. 4. Angular distribution in the center-of-mass system of protons elastically scattered by O^{16}. $\sigma(\phi)$ is given in millibarns per steradian.

protons observed at an angle of 85°. The tracks were measured to an accuracy of 0.4 micron and the distributions were smoothed out by averaging the tracks in five consecutive intervals of 0.4 micron each. Although the two lowest states, 6.05 and 6.13-Mev, are not completely resolved, their analysis into two groups can be easily carried out as indicated on the graph. Figure 4 gives the observed angular distribution of the protons elastically scattered by O^{16}, together with the Rutherford scattering curve. The observed angular distribution has a shape similar to that found in C^{12}, showing a minimum at around 65° and a maximum at about 110°, but the minimum is much more pronounced in O^{16} than in C^{12}.

Results obtained on the scattering of protons by the other elements, and the interpretation of these distributions, will be published later.