Interaction of 19-Mev Deuterons with Oxygen

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The charged particles emitted when oxygen is bombarded with 19-Mev deuterons have been studied by a photographic plate method. The angular distributions of the two groups of protons from the reaction $O^{16}(d,p)O^{17}$, O^{17} being formed in the ground and 0.88-Mev states, have been found to be in qualitative agreement with the predictions of the stripping theory. Similar measurements have been made for the elastically scattered deuterons and for the α particles from the reaction $O^{16}(d,\alpha)N^{14}$; the curve for the latter shows peaks at about 40°, 90°, and 140°, and is nearly symmetrical about 90°.

A STUDY has been made of the charged products of bombarding various light elements with 19-Mev deuterons from the Birmingham cyclotron. The particles were recorded in photographic plates, in the scattering camera described by Burrows, Powell, and Rotblat.[1] The camera has been modified by the introduction of improved shielding and stop systems to minimize neutron background, by the use of thicker emulsions which the particles enter slightly more steeply, so that tracks are less likely to leave the emulsion at either surface, and by the use of a Faraday cup which gives absolute values of the integrated beam current.

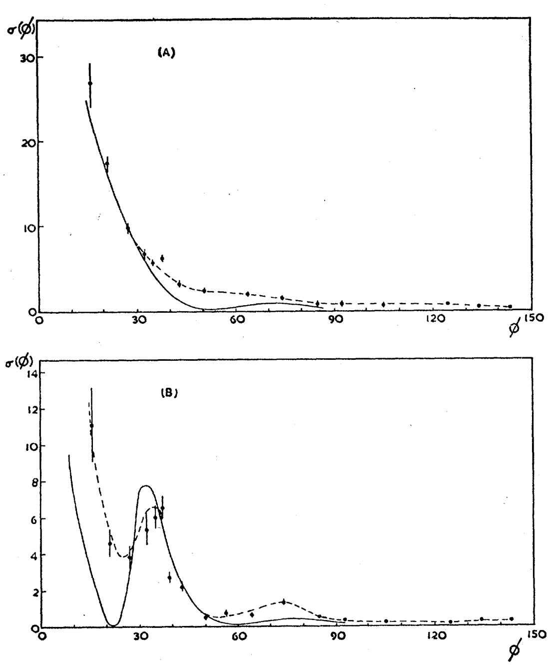

Fig. 1. Angular distributions in the center-of-mass system of protons from reaction $O^{16}(d,p)O^{17}$; (A) O^{17} formed in the ground state ($l=2$, $Q=1.92$ Mev); (B) O^{17} formed in the 0.88-Mev excited state ($l=0$, $Q=1.04$ Mev). $\sigma(\phi)$ is given in millibarns per steradian. The dashed lines are the experimental curves. The theoretical curves (solid lines) are obtained from Butler's theory, with $r_0=4.77\times10^{-13}$ cm.

The angular distributions of protons emitted in the reaction $O^{16}(d,p)O^{17}$, O^{17} being formed in the ground and 0.88-Mev excited states, are shown in Fig. 1, together with curves based on Butler's stripping theory.[2] According to this theory the angular distribution of protons from a (d,p) reaction depends characteristically on the angular momentum, l, transferred by the neutron to the nucleus which it enters. For the two groups observed, l must be 2 and 0 since the O^{17} levels have spin and parity $5/2+$ and $\frac{1}{2}+$, respectively.[3,4] It will be seen that there is qualitative agreement between the curves expected for these values of l and the experimental points; the agreement is not close, being in fact slightly worse than that observed at 8 Mev,[2,4] but indicates that the theory is correct in principle if not in detail at an energy of 19 Mev. The theory successfully predicts the observed differences in angle of corresponding peaks at 8 Mev and 19 Mev. We are much indebted to Mr. W. M. Fairbairn for calculating the theoretical curves.

The total cross sections for the formation of the ground and 0.88-Mev levels of O^{17} have been calculated from the angular distributions; the contributions from very small and very large angles, at which measurements were impossible, were estimated with the aid of the theoretical curves. The values obtained are 35.5 ± 3.5 and 22.7 ± 3.5 millibarns respectively, while those obtained at 8 Mev[4] were 125 ± 9 and 112 ± 11 millibarns.

Figure 2 shows the angular distribution of deuterons elastically scattered by oxygen, with the Rutherford scattering curve for comparison. Although we cannot be sure of our absolute cross sections to within less than about 8 percent[5] there is no doubt that the cross

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

[2] S. T. Butler, Proc. Roy. Soc. (London) **208**, 559 (1951).

[3] Geschwind, Gunther-Mohr, and Silvey, Phys. Rev. **85**, 474 (1952).

[4] Burrows, Gibson, and Rotblat, Proc. Roy. Soc. (London) **209**, 489 (1951).

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

section at 30° is at least 5 times less than the Rutherford value. The results may be compared with those obtained at 8 Mev.[4]

Groups of protons and deuterons are usually identified by their range, but α-particle tracks may be recognized at sight by their high grain density and low multiple scattering. Separate range distributions have been obtained for the α particles from the reaction $O^{16}(d,\alpha)N^{14}$; groups from the formation of N^{14} in its ground state and in the excited state at 3.9 Mev, as well as several incompletely resolved levels above 5 Mev, have been found.

In common with other workers, we find no sign of the 2.31-Mev level; this level is thought to have

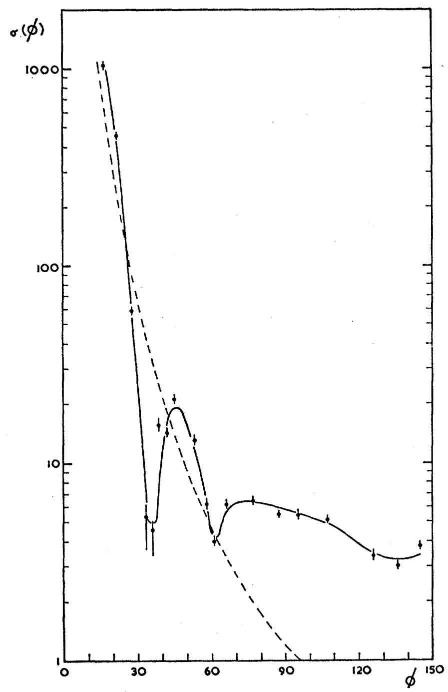

FIG. 2. Angular distribution in the center-of-mass system of deuterons elastically scattered from oxygen. $\sigma(\phi)$ is given in millibarns per steradian. The solid line is the experimental curve. The dashed line is the Rutherford scattering curve.

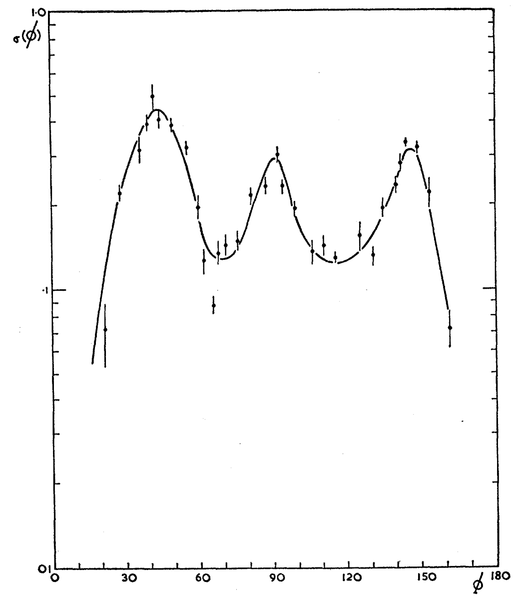

FIG. 3. Angular distribution in the center-of-mass system of α particles from reaction $O^{16}(d,\alpha)N^{14}$, N^{14} being formed in the ground state. $\sigma(\phi)$ is given in millibarns per steradian.

isotopic spin $T=1$, forming a triplet with the ground states of C^{14} and O^{14}; it would not then be formed by the interaction of a deuteron and an oxygen nucleus with emission of an α particle, since these three all have zero isotopic spin. Our measurements allow us to set an upper limit of 0.1 millibarn to the total cross section for the formation of this level, while the total cross section for the ground state is 2.6 ± 0.3 millibarns. In view of the fact that at 19 Mev the emitted α particles are not affected by the potential barrier, these figures support the view that the 2.31-Mev level is predominantly $T=1$.

The angular distribution of the ground state α particles is shown in Fig. 3. The curve is not unlike that obtained for the reaction $N^{14}(d,\alpha)C^{12}$ at 8 Mev,[6] but it is much more nearly symmetrical about 90°.

[6] W. M. Gibson and E. E. Thomas, Proc. Roy. Soc. (London) **210**, 543 (1951).