K_0, K_1, and K_2 at intervals of $\pi/12$ for the parameters in the range 0 to π. For each $K_0 = n\pi/12$, $(n=1, 2, \cdots, 12)$, the curves $f_1(n\pi/12, K_1, K_2) = R_1$, $f_2(n\pi/12, K_1, K_2) = R_2$ were then constructed and intersections of curves for the same K_0 were determined by Newton's method. The points of intersection determine the curve in (K_0, K_1, K_2) space on which the intersection of the three surfaces must lie, if, indeed, such an intersection exists at all. This point is determined as that point for which $f_3 = R_3$, and was found, again, by Newton's method. The values used were: $\theta_1 = 142° 26'$, $R_1 = 1.10$; $\theta_2 = 166° 33'$, $R_2 = 11.5$; $\theta_3 = 152° 23'$, $R_3 = 3.62$. From these values, the procedure described yielded a set of values $K_0 = 105°$, $K_1 = 150°$, and $K_2 = 94°$. The curve calculated from these values gives approximate agreement with the Riezler data.

As far as the Devons data are concerned, it will be seen that the low values for the scattering at low energies are consistent with any values of the orbital angular momentum with l less than or equal to three, and data at other angles are needed in order to settle the nature of this phenomenon. The experimental maximum at a higher energy has about the same property, but if the theoretical curve found above is prolonged to $\theta = 109° 28'$ (corresponding to 90° in the laboratory system), a very large discrepancy occurs. The question of whether this discrepancy is due to experimental error or to weaknesses in the theory can only be settled by the publication of more accurate data.

In conclusion, the writer wishes to express his thanks to Professor F. C. Hoyt and Professor Carl Eckart for suggestions in this work.

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The Distribution in Angle of Alpha-Particles from Lithium Bombarded with Protons

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The distribution in angle of alpha-particles from $Li^7 + H^1$ is found to be of the form $1 + A\cos^2\theta$. The variation of A with bombarding energy is characterized by a rapid increase in the range 250 to 325 kev presumably indicating resonance to a broad excited level of Be^8.

THE distribution in angle of α-particles from the $Li^7 + H^1 \rightarrow 2He^4$ reaction has been studied by Kirchner,[1] by Giarratana and Brennecke[2] and by Neuert,[3] all of whom report the distribution to be spherically symmetric. However, the data reported by these observers have in every case been taken at bombarding energies of 270 kev or less, and with relatively large statistical errors. We find that even at 100 kev there is a definite but small departure from spherical symmetry, while at energies of 350 kev the intensity in directions near that of the bombarding beam exceeds that in a direction at 90° to the beam by a factor of the order of 2. This is not surprising as it appears from other considerations that the reaction proceeds by p capture.[4]

Apparatus

The apparatus is shown in Fig. 1. A lithium target formed by evaporation from the furnace upon one of the surfaces of the hexagonal target support is bombarded by a beam of magnetically resolved protons or H_2^+ ions defined by the apertures. The two upper apertures are $\frac{1}{8}''$ circular holes, while the lowest is reduced to $3/64''$ in the plane of the paper. The target surface being tipped at an angle of 22.5° to the beam results in an approximately rectangular target spot about 3×3 mm. The sensitive volume

[1] F. Kirchner, Physik. Zeits. **34**, 785 (1933).
[2] J. Giarratana and C. G. Brennecke, Phys. Rev. **49**, 35 (1936).
[3] H. Neuert, Ann. d. Physik **36**, 437 (1939).
[4] M. Ostrofsky, G. Breit and D. P. Johnson, Phys. Rev. **49**, 22 (1936).

in front of any one of the eight collector plates can see this target spot through a $\frac{1}{8}''$ clear aperture made vacuum tight with 0.0015″ aluminum foil. The hole over which the foil is supported is $\frac{1}{4}''$ in diameter so that particles emerging through the $\frac{1}{8}''$ defining apertures do not strike the foil in the more steeply sloping region near its edge.

For counting, two independent linear amplifiers with associated scales-of-eight[5] and mechanical counters were used. The data obtained are the number of particles observed within a given time interval at any chosen window and the number observed in the same interval at the three forward windows. These three were connected in parallel to the input grid of one amplifier and the chosen window to the other, unless the latter was one of the forward three, in which case only two were in parallel and the total count on the three was obtained by adding the scores of the two counters. In any case the final result is the ratio of the number of particles counted at a given window to the number at

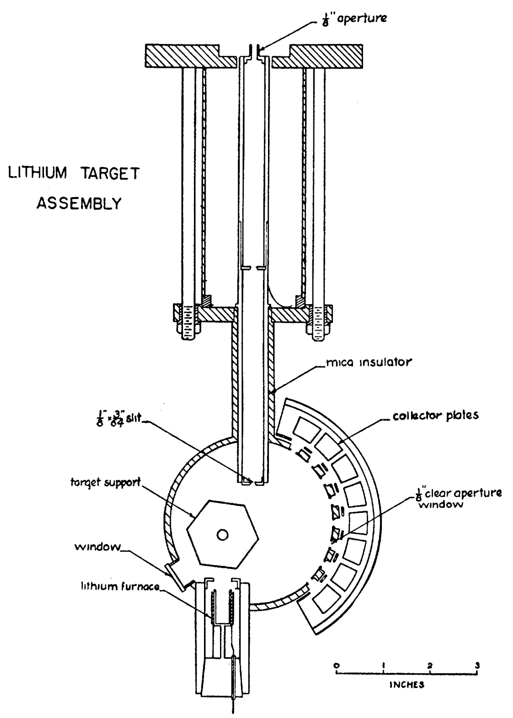

FIG. 1. Cross section of target chamber and defining apertures.

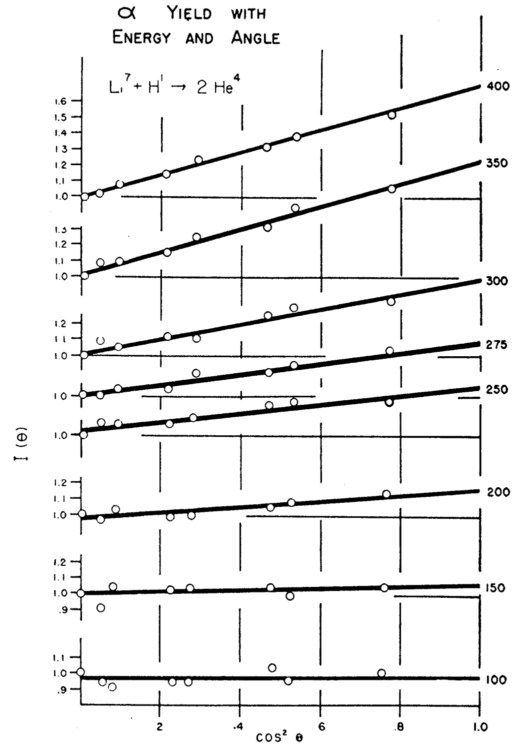

FIG. 2. Distribution in angle of alpha-particles from $Li^7+H^1 \rightarrow 2He^4$ for 8 bombarding energies from 100 to 400 kev. Relative numbers of alpha-particles per unit solid angle *vs.* square of cosine of angle between direction of emission and direction of bombarding beam in center of mass coordinate system.

the three forward windows. The latter number constitutes a measure of the number of disintegrations occurring in the interval in question. The use of such a monitoring arrangement eliminates obvious errors associated with measurement of bombarding current and the assumption of a yield proportional to the current.

Bombarding energies are taken from a magnet current *vs.* bombarding energy curve for which the 330-kev fluorine γ-ray resonance served as a fixed point, other points being interpolated by the usual procedure of bringing various m/e spots onto the target. This curve was checked using a resistance voltmeter. (450 10-megohm IRC resistors.)

Thickness of targets was estimated at from 2 to 40 kev stopping power, the thicker targets being used at low energies in order to secure increased yield. The estimate of target thickness was made by determining the yield from the

[5] H. Lifschutz and J. L. Lawson, Rev. Sci. Inst. **9**, 83 (1938).

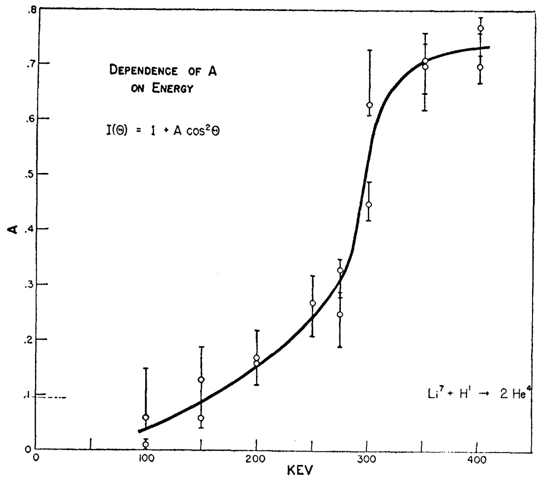

FIG. 3. The variation with bombarding energy of A in the expression $1+A\cos^2\theta$ which is found to represent the distribution in angle of the alpha-particles from $Li^7+H^1\rightarrow 2He^4$.

target in question at a particular bombarding energy, then the yield from a thick target both at this and at a somewhat lower energy so chosen that the decrease in thick target yield was approximately equal to the yield of the thin target. This gives only a rough value of target thickness, but probably good enough for the present purpose which is merely to make sure that the use of even thinner targets would not give sensibly different data. Targets were replaced after bombardment for less than half the time which experience showed to produce appreciable "fatigue."

RESULTS

The relative yields at various angles, transformed to the center of mass coordinate system, normalized to unity at 90°, and plotted against $\cos^2\theta$ are shown in Fig. 2 for several bombarding energies. The number of particles counted at any window is 3000 or more for the window in question and 10,000 or more on the monitor. Straight lines, $1+A\cos^2\theta$, have been drawn through these points by inspection and the values of A so determined are plotted against bombarding energy in Fig. 3. Vertical bars are estimated limits of error arrived at by drawing through the observed points of Fig. 2 straight lines of greatest and least admissible slope, admissibility being determined merely by the best judgment of the authors.

DISCUSSION

The appearance of Fig. 3 obviously suggests resonance to a rather broad excited state of Be^8.

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The Distribution in Angle of the Long Range Alpha-Particles from Fluorine Bombarded with Protons

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The distribution in angle of the long alpha-particles from the reaction $F^{19}+H^1\rightarrow O^{16}+He^4$ has been determined at bombarding energies of 330, 375 and 435 kev. This distribution shows a very strong fore and aft asymmetry which varies only slightly with the bombarding voltage. The distribution is well represented by the expression $1+0.66\cos\theta+0.25\cos^2\theta+0.41\cos^3\theta$.

THE present paper is concerned with the distribution in angle of the long range alpha-particles from fluorine bombarded with protons. The apparatus shown in Fig. 1 differs essentially from that described in the previous[1] paper only in the form of target support and in the dimensions of the defining apertures, which are as given in Fig. 1. Targets were prepared by electrolysis of hydrofluoric acid onto tantalum. Care was used to avoid boron contamination arising from the solution of Pyrex glass in the

[1] Young, Ellett and Plain, Phys. Rev. this issue.