Letters to the Editor

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Angular Distributions of Protons from the Reaction $O^{16}(d, p)O^{17}$

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THE reaction $O^{16}(d, p)O^{17}$ gives a number of groups of protons, of which the two corresponding to the ground state and first excited state of O^{17} have Q-values of 1.925 Mev and 1.049 Mev (Buechner *et al.*[1]). The intensities of these two groups have been measured at seven angles by Heydenburg and Inglis,[2] using deuteron energies between 0.65 Mev and 3.05 Mev.

We have used the 8-Mev deuteron beam from the University of Liverpool cyclotron, and a scattering camera in which photographic plates record particles emitted from a gas target at all angles from 10° to 165°, to obtain detailed angular distributions for the charged particles emitted in a number of deuteron-induced reactions. A full account of the method and results will be published elsewhere, but because of their theoretical interest (Butler[3]), the angular distributions of the two groups of protons from the reaction $O^{16}(d, p)O^{17}$ are presented here.

Tracks of protons from the two groups were identified by their ranges in the photographic emulsion, and the number of protons in each group, found in a given area, was determined for a series of angles from 10° to 160°. Ordinarily, measurements were made at 5° intervals, but at the more critical angles the interval was reduced to 2.5° or even to 1.25°. Using these numbers and the geometry of the apparatus, we calculated the angular distributions of the two proton groups in the center-of-mass system. These are shown in Fig. 1, in which the ordinates are proportional to the cross sections per unit solid angle in the center-of-mass system, at a center-of-mass angle ϕ, and the abscissae are $\cos\phi$.

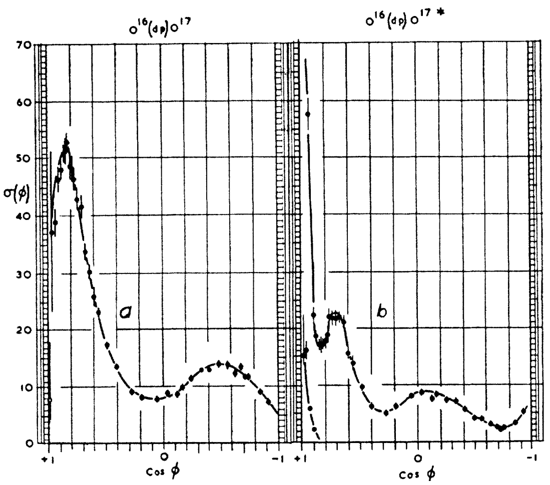

FIG. 1. $O^{16}(d, p)O^{17}$ angular distributions in the center-of-mass (c.m.) system: ϕ = c.m. angle, $\sigma(\phi)$ = c.m. differential cross section in arbitrary units. Curve a is for formation of O^{17} in the ground state, and curve b is for the 0.88-Mev excited state.

Figure 1a shows that when the O^{17} nucleus is formed in its ground state, there is a definite maximum in the intensity at $\cos\phi = 0.83$ ($\phi = 34°$). At higher angles, the intensity falls to a minimum at about 85°, rises to a smaller maximum at 120°, and falls again towards 180°. Below 34° the intensity falls, apparently tending to zero in the forward direction, although it is not excluded that it may rise again at very small angles; it is hoped that further experiments will show the behavior at angles too small to be studied with this apparatus.

In contrast to this, the intensity of protons from the formation of O^{17} in its excited state at 0.88 Mev (Fig. 1b) has a peak at $\cos\phi = 0.7$ ($\phi = 45°$) and a minimum at $\cos\phi = 0.84$ ($\phi = 33°$), rising steeply as the angle decreases from 33°.

The most interesting feature of these results is the difference in behavior of the two groups at angles below 50°. Butler[3] has shown that a stripping process, in which no compound nucleus is formed, can give one of several characteristic angular distributions, according to the spins and parities of the reacting nuclei. The observed results for small angles fit very well with the theoretical predictions, and it appears that (d, n) and (d, p) angular distributions may be of use in determining the spins and parities of ground and excited states in many nuclei.

[1] Buechner, Strait, Sperduto, and Malm, Phys. Rev. **76**, 1543 (1949).
[2] N. P. Heydenburg and D. R. Inglis, Phys. Rev. **73**, 230 (1948).
[3] S. T. Butler, Phys. Rev. **80**, 1095 (1950). Following letter.

On Angular Distributions from (d, p) and (d, n) Nuclear Reactions

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THE purpose of this note is to report the results of calculations which show how information regarding the spins and parities of nuclear energy levels can be obtained from angular distributions from nuclear reactions of the type $X(d, p/n)Y$ without the necessity of assuming properties of resonance levels of a compound nucleus. This work was commenced, at the suggestion of Professor Peierls, when experimental angular distributions for certain (d, p) reactions[1] were made available to him some time ago by Professor Rotblat. All exhibited a pronounced structure at small angles, and the work of Holt and Young[2] gives similar results. Such a structure must arise from contributions from high incident angular momenta of classical impact parameters larger than the nuclear radius. The obvious conclusion is that the reactions proceed, at least in part, by a stripping process in which one of the particles of the deuteron is absorbed into the nucleus, while the other merely carries off the balance of energy and momentum. Such a process is possible in the case of (d, p) and (d, n) reactions because of the low binding energy and large diameter of the deuteron.

I have calculated angular distributions resulting from such a stripping process by equating, at the nuclear surface, the exact wave function for a particle outside the nucleus to the interior wave function. After some simplification the resulting boundary equations can be solved in such a way that unknown properties of the nuclear wave functions affect the important parts of the distributions merely as a constant multiplying factor. The resulting curves show a pronounced maximum near the forward direction, the position of which is determined in each case by the spins and parities of the nuclear states involved. This is due to the fact that the requirements of conservation of angular momentum and of parity allow the nucleus to accept a particle (say a neutron) with only very limited values of angular momenta l_n, and the angular distribution depends very sensitively on these