Proton Groups from the Reaction $O^{18}(d,p)O^{19}$

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Separated targets of O^{18} on thick and thin backings have been used in a search for proton groups from the reaction $O^{18}(d,p)O^{19}$. Three proton groups due to this reaction were found. Their energies were measured with a double focusing magnetic spectrometer which in this case was calibrated with known particle group energies from $B^{10}(d,p)B^{11}$ and $N^{14}(d,p)N^{15}$. The Q values of $O^{18}(d,p)O^{19}$ are $Q_1=1730\pm8$ kev, $Q_2=1636\pm8$ kev, and $Q_3=262\pm6$ kev.

INTRODUCTION

In an earlier paper[1] we reported two particle groups from $O^{18}(d,p)O^{19}$. It was not possible, however, to make a systematic search for particle groups over a large energy region, because the target backings were thick and a proton background from *d*-D protons masked large regions. In the present paper the proton spectra from deuteron bombardment of O^{18} targets are reported for the energy region 1.6–4.1 Mev, at the observation angle 61.0°, and for 0.7–3.9 Mev at the angle 134.7°. This work was performed by means of a target technique using thin foil backings.

We have found altogether three proton groups belonging to $O^{18}(d,p)O^{19}$. We cannot definitely say that we have found the ground-state transition, because one narrow energy region is masked, at both angles, by the unavoidable parasite proton group from carbon-12.

APPARATUS AND TARGET TECHNIQUE

The targets were produced by magnetic separation in the 1.6-meter isotope separator of the Nobel Institute.[2] The targets were prepared in two different ways. For one type, water was used that had been

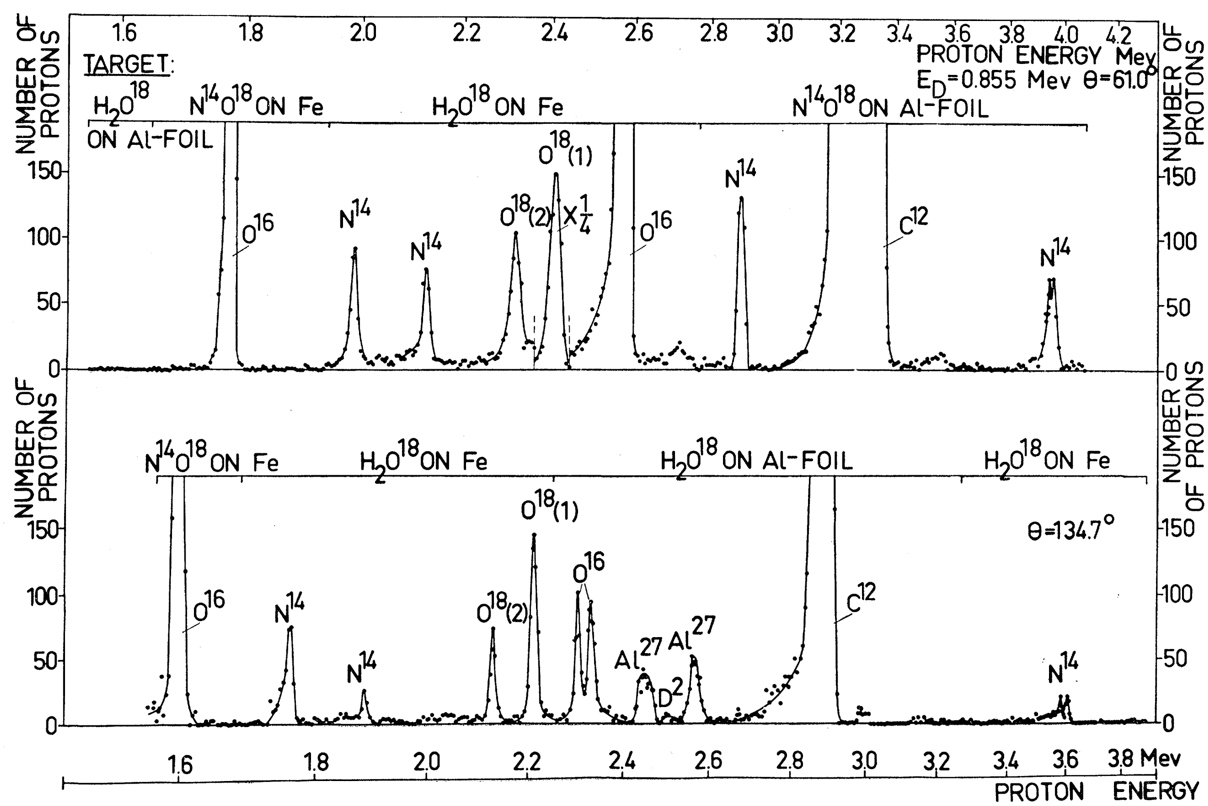

Fig. 1. The proton spectra from deuteron bombardment of O^{18} targets. The upper curve was obtained at the observation angle 61.0°, the lower curve at the angle 134.7°. The deuteron bombarding energy was 855 kev. The targets and target backings used at different energy regions are marked in the figure.

[1] K. Ahnlund and C. Mileikowsky, Arkiv. Fysik. (to be published).
[2] Bergström, Thulin, Svartholm, and Siegbahn, Arkiv. Fysik. 1, 281 (1950).

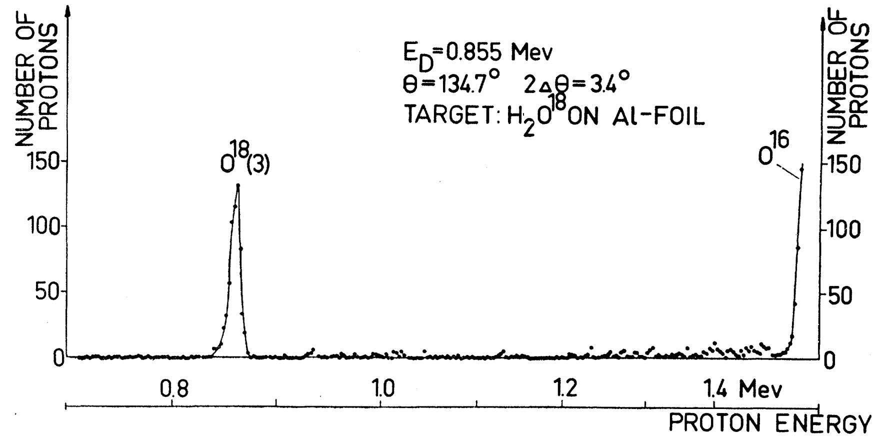

FIG. 2. Low-energy part of the proton spectrum at 134.7°. Deuteron bombardment energy 855 kev.

enriched in oxygen-18 at A.E.R.E., Harwell, and the H_2O^{18}-beam of mass number 20 was collected. The second type was produced from a sample of oxygen and nitrogen, presented to our laboratory by Professor K. Clusius, Zürich. In this case the $N^{14}O^{18}$ beam was collected.

The beams were collected on thick plates of steel or on thin foils of aluminum. The foils were about 20 kev thick for a single passage of deuterons of 850 kev.

The deuteron bombardment was performed with the stabilized Cockcroft-Walton accelerator at the Nobel Institute.[3] The primary beam passes an analyzing magnet and its energy is also calibrated by means of this magnet. The energy calibration of deuterons of 850 kev ultimately depends on the well-known proton resonance in F^{19} at proton energy 873.5 kev. The link from proton to deuteron calibration is obtained by scattering protons and deuterons against aluminum and beryllium[4] into the particle spectrometer, which is held at a given magnetic field.

In the present case, however, the absolute deuteron energy calibration is not very critical. This is because the energies of the proton groups from $O^{18}(d,p)O^{19}$ are compared with the close-lying proton groups of known energies from the reactions $B^{10}(d,p)B^{11}$ and $N^{14}(d,p)N^{15}$.[5,6] The final measurement of a Q value is performed in such a way that both the calibration group and the particle group to be measured fall on the photographic plate close together in the same magnetic field.

The particle spectrometer[7] is double focusing (40-cm radius) and stands on a rotating table so that it can accept the secondary particles at any angle to the primary beam from zero up to 135°. The incident beam path is screened over the important parts of its length by iron tubing. By this arrangement any significant displacement of the beam spot caused by the stray field from the spectrometer is avoided also at un-

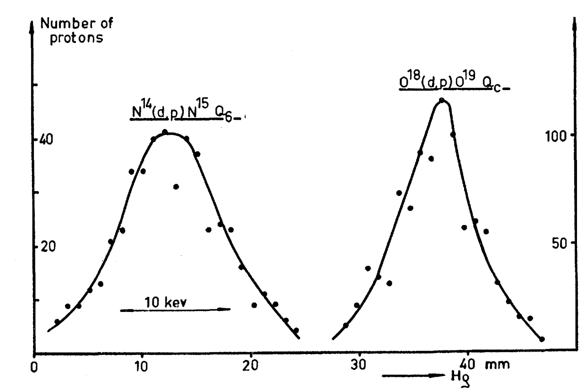

FIG. 3. The proton spectrum from $O^{18}(d,p)O^{19}$ and $N^{14}(d,p)N^{15}$ at a deuteron bombarding energy of 855 kev in the region of Q_3. The calibration peak of $N^{14}(d,p)N^{15}$ is due to Q_6=300 kev. The observation angle is 134.7°. Target backing: Al foils.

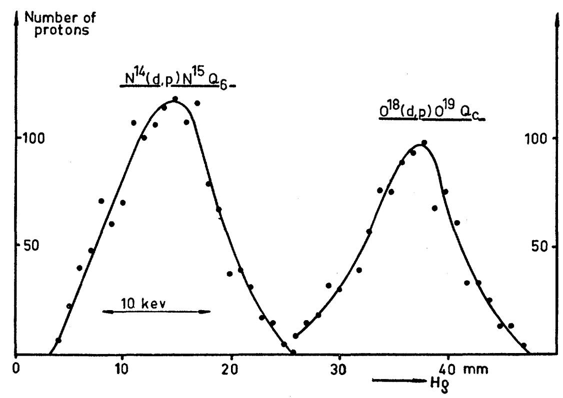

FIG. 4. The proton spectrum from $O^{18}(d,p)O^{19}$ and $N^{14}(d,p)N^{15}$ at a deuteron bombarding energy of 855 kev in the region of Q_3. The calibration peak of $N^{14}(d,p)N^{15}$ is due to Q_6=300 kev. The observation angle is 134.7°. Target backing: Al foils. The N^{14} targets are different in Figs. 3 and 4.

[3] C. Mileikowsky and R. T. Pauli, Arkiv. Fysik. **4**, 287 (1952).
[4] C. Mileikowsky, Arkiv. Fysik. **7**, 117 (1953).
[5] van Patter, Buechner, and Sperduto, Phys. Rev. **82**, 248 (1951).
[6] R. Malm and W. W. Buechner, Phys. Rev. **80**, 771 (1950).
[7] C. Mileikowsky, Arkiv. Fysik. **4**, 337 (1952).

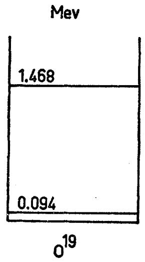

FIG. 5. Level scheme of O^{19}.

favorable angles. The protons were registered photographically with Ilford nuclear track plates.

Instrumental line widths, dispersion, measurement of angles, and arrangements for target exchange and plate exchange in vacuum have all been described elsewhere.[8–10]

RESULTS

The proton spectra at spectrometer angles 61.0° and 134.7° are shown in Figs. 1 and 2. For 61.0° the energy region is from 1.55 Mev to 4.10 Mev and for 134.7° the energy region is from 0.70 Mev to 3.90 Mev. Three of the proton peaks are the result of the reaction $O^{18}(d,p)O^{19}$. They are absent in runs on target backings which were not hit by the separator beam. Also, their energy change with spectrometer angle corresponds to target mass number 18. The other proton peaks correspond to different parasite reactions. Many of them are transitions in $N^{14}(d,p)N^{15}$, two are from $O^{16}(d,p)O^{17}$, and one is from $C^{12}(d,p)C^{13}$. The carbon peak is so strong and broad at both angles that no search for other groups can be successful within this region of about 100 kev, at least not with the bombarding energies available to us.

During bombardment, deuterons stick in the target, giving rise to d-D protons, which are very disturbing over a large energy region, if the target backing is thick. We have therefore used thin foil backings of aluminum in the energy region 2.8–4.1 Mev at the angle 61.0°, and in the region 2.25–3.25 Mev at the angle 134.7°, Fig. 1. We still get the d-D protons, now, however, in the form of a definite and rather small peak, as seen in the lower part of Fig. 1. In the region 0.7–1.5 Mev (Fig. 2) foil backings were also used to reduce the strong background of scattered deuterons. This was more successful at the angle 134.7° than at 61.0°.

TABLE I. Partial errors, referred to Q, in kev.

	For Q_1 and Q_2	For Q_3
Q of calibration reaction	± 5.6	± 4.0
Bombarding deuteron energy	± 1.8	± 0.8
Angle measurement	± 0.5	± 0.1
Reading of proton peaks	± 3.6	± 3.5
Dispersion in plate	± 3.2	± 1.5
Total probable error	± 7.6	± 5.6

The Q values obtained for $O^{18}(d,p)O^{19}$ are

$$Q_1 = 1730 \pm 8 \text{ kev},$$
$$Q_2 = 1636 \pm 8 \text{ kev},$$
$$Q_3 = 262 \pm 6 \text{ kev}.$$

The first two of these were obtained with $B^{10}(d,p)B^{11}$, $Q_6 = 1937$ kev, as a calibration of the spectrometer. This group is known to ± 6 kev and falls conveniently between the two $O^{18}(d,p)O^{19}$ groups. An evaporated natural boron target was used.

A group of $N^{14}(d,p)N^{15}$, $Q = 300$ kev, served to calibrate the spectrometer in the case of the third Q value. Two spectra taken in different runs on different targets are shown in Figs. 3 and 4. Each spectrum contains the calibration peak and the $O^{18}(d,p)$ peak to be measured.

The total probable errors are calculated from the partial errors, referred to Q, listed in Table I. The partial errors for reading of proton peaks given in this table also include uncertainties in layers on targets.

If we assume that Q_1 corresponds to the ground-state transition of $O^{18}(d,p)O^{19}$—which is not necessarily true—we obtain the level scheme in Fig. 5 for O^{19}. There is one low excited state at 94 kev, and one state at 1468 kev. With this assumption, and using the masses 18.004848, 2.014735, and 1.008142 amu for O^{18}, D^2 and H^1, we obtain the following mass for O^{19}:

$$19.009583 \pm 0.000025 \text{ amu}.$$

During this work we also registered the β activity of the O^{19} nuclei formed. The half-life was found to be 31 ± 4 sec.

ACKNOWLEDGMENTS

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[8] C. Mileikowsky, Arkiv. Fysik. **7**, 33 (1953).
[9] C. Mileikowsky, Arkiv. Fysik. **7**, 89 (1953).
[10] R. T. Pauli, Arkiv. Fysik. (to be published).