Ground-State Q Values for the $Si^{30}(p,\alpha)Al^{27}$ and $O^{16}(p,\alpha)N^{13}$ Reactions*

R. E. WHITE† AND W. W. BUECHNER
Department of Physics and Laboratory for Nuclear Science, Massachusetts Institute of Technology, Cambridge, Massachusetts
(Received December 4, 1959)

Alpha-particle groups observed during the magnetic analysis of charged particles produced in the bombardment of silicon-dioxide targets with 8- and 8.59-Mev protons have been identified as arising from the reactions $Si^{30}(p,\alpha)Al^{27}$ and $O^{16}(p,\alpha)N^{13}$. The corresponding Q values are -2.366 ± 0.010 Mev and -5.206 ± 0.010 Mev, respectively.

A STUDY of the charged particles produced when thin films of natural silicon dioxide are bombarded with 8- and 8.59-Mev protons has revealed a number of alpha-particle groups among the elastically and inelastically scattered protons. From a comparison of measurements made at different energies and angles, it has been possible to establish the reactions that gave rise to these groups.

Silicon targets, prepared by evaporating purified silicon dioxide onto thin Formvar films, were exposed to beams of protons of 8- and 8.59-Mev energy from the MIT-ONR Van de Graaff accelerator. Charged-particle reaction products were analyzed with a broad-range magnetic spectrograph.[1] The results used to identify the alpha-particle groups mentioned above will now be discussed.

$Si^{30}(p,\alpha)Al^{27}$

Alpha particles that could have arisen from this reaction proceeding to the ground state of Al^{27} were observed in five different measurements; however, in only three of these was the intensity sufficient to allow an accurate Q value to be calculated. The experimental conditions for these three measurements, and the resulting Q values, are given in Table I.

Incident proton energies were calculated from the observed energies of protons elastically scattered from Si^{28}. Mass values used to calculate Q were taken from tables compiled by Wapstra.[2]

The Q value calculated from the 50-degree data is seen to be lower than the 90-degree and 130-degree values. This is attributed to a difference in the experimental conditions which arises between measurements at angles less than 90 and greater than 90 degrees. For angles greater than 90 degrees, the incident and emergent particles both enter and leave the same face of the target, while at small angles the target has to be traversed. Since the alpha particles lose more energy in passing through the target than do the elastically scattered protons used to determine the incident energy, the (p,α) reaction Q values calculated from small-angle measurements tend to be lowered. Rather than average the results, it seems better therefore to use only Q values determined at large angles unless the target thickness and constitution are accurately known.

Any deposition of material on the target during exposure will also lower the measured Q values but now for all angles of observation. The most likely material to be deposited is carbon, and an examination of the structure of the group of protons elastically scattered at 90 degrees from carbon in the Formvar target backing revealed some evidence that such deposition had occurred. To reach the target backing, incident protons have to pass through the silicon-dioxide film, thereby losing energy, so that the elastically scattered protons from carbon should have an energy corresponding to a slightly lower input energy than those scattered from silicon. This was found to be so, the difference being 5 kev.

However, the carbon elastic peak showed some fine structure which could be interpreted as resulting from the presence of a small group of higher energy protons superimposed on the main group. If this small group, which constituted a few percent of the total scattered intensity, arises from elastic scattering in a thin carbon film deposited on the illuminated silicon-dioxide face, energy of the protons in this group should give an input energy slightly higher than that calculated from the silicon elastic group. This small carbon group corresponded to an input energy only 0.1 kev or less greater than that for the silicon elastic group so that the deposited film was very thin. Assuming this gives a reliable measure of the carbon film thickness, the effect on the $Si^{30}(p,\alpha)Al^{27}$ Q value would be to lower the 90- and 130-degree results by 0.8 kev and the 90-degree $O^{16}(p,\alpha)N^{13}$ value, discussed below, by 1.6 kev. In view of the much

TABLE I. $Si^{30}(p,\alpha)Al^{27}$ data.

Incident proton energy (Mev)	Angle to incident beam	Alpha-particle energy (Mev)	Calculated Q value (Mev)
8.007 ± 0.007	50°	5.178 ± 0.008	-2.376 ± 0.010
8.588 ± 0.007	90°	5.138 ± 0.008	-2.365 ± 0.010
8.584 ± 0.007	130°	4.609 ± 0.008	-2.367 ± 0.010

* This work was supported in part through funds provided by the U. S. Atomic Energy Commission, by the Office of Naval Research, and by the Air Force Office of Scientific Research.
† Now at A.E.R.E., Harwell Berkshire, England.
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[2] A. H. Wapstra, *Handbuch der Physik*, edited by S. Flügge (Springer-Verlag, Berlin, 1958), Vol. 38, Part 1, p. 7.

TABLE II. $O^{16}(p,\alpha)N^{13}$ data.

Incident proton energy (Mev)	Angle to incident beam	Alpha-particle energy (Mev)	Calculated Q value (Mev)
8.001±0.007	30°	2.580±0.007	−5.219±0.009
8.000±0.007	50°	2.295±0.008	−5.226±0.010
8.589±0.007	90°	2.076±0.008	−5.208±0.010

larger uncertainties which arise in these measurements, this effect has been neglected.

From these results, the Q value for the $Si^{30}(p,\alpha)Al^{27}$ reaction, including relativistic corrections which increase the Q value by 2 kev, is −2.366±0.010 Mev. Using the mass values quoted by Wapstra, a value of −2.378 ±0.020 Mev is predicted. Further, from the known Q values of the $Si^{30}(d,\alpha)Al^{28}$ and $Al^{27}(d,p)Al^{28}$ reactions,[3] the Q value for the $Si^{30}(p,\alpha)Al^{27}$ reaction should be −2.378±0.014 Mev.

$O^{16}(p,\alpha)N^{13}$

Alpha-particle groups which could be attributed to this reaction leaving N^{13} in the ground state have been found with sufficient intensity to allow a Q value calculation in three measurements. These are described in Table II.

The 30-degree Q value is slightly more accurate than the other two since the alpha-particle group was very intense in this measurement and allowed a more accurate determination of its energy than in the 50-degree and 90-degree cases.

For the reasons given above, the Q value for this reaction will be taken only from the 90-degree result. The spread in the Q values in Table II is thought to result from increased energy loss effects arising because of the considerably lower alpha-particle energies involved here. The Q value for this reaction, including relativistic corrections, is then −5.206±0.010 Mev. The value predicted from the masses is −5.207±0.005 Mev, while from the known Q values for the reactions $O^{16}(d,\alpha)N^{14}$, $C^{13}(p,n)N^{13}$, $C^{13}(d,p)C^{14}$, $N^{14}(n,p)C^{14}$,[3,4] the $O^{16}(p,\alpha)N^{13}$ Q value is expected to be −5.207±0.005 Mev.

One alpha-particle group observed at 30 degrees with an energy of 3.568 Mev has yet to be identified, and it is hoped that further measurements to be carried out in the near future will accomplish this.

In all these measurements, the energy of polonium alpha particles has been used as a standard, the adopted value being 5.2988 Mev. More recent measurements yield a value of 5.3042±0.0016 Mev.[5] Allowing for this change, the Q values measured here become −2.364 ±0.010 Mev and −5.201±0.010 Mev, respectively.

We would like to acknowledge the very careful work of the Laboratory's counting group in locating these generally weak groups and the generous cooperation of the entire laboratory staff.

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