with liquid nitrogen were employed to detect the radiations. The beta-crystal was so thin (*ca* 20 mg/cm²) that its efficiency for gamma-rays was negligible. The coincidence circuit employed blocking oscillator pulse shaping and a 6BN6 mixing stage. Various lengths of terminated RG 65/U cable were used to introduce the delays.

A plot of the coincidence rate *versus* delay time is shown in Fig. 2. The dotted curve is that of Co^{60} and is typical of substances

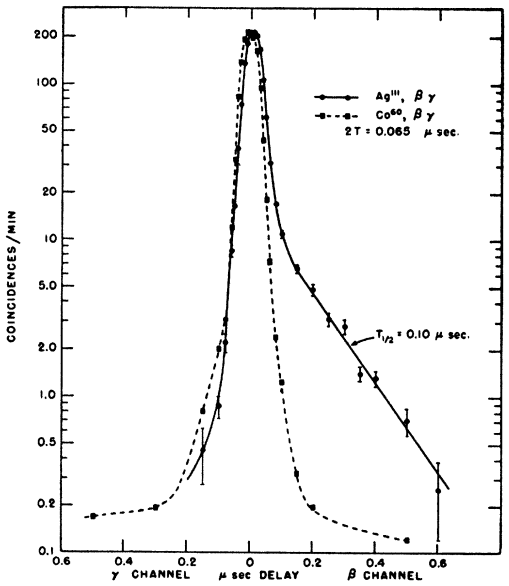

FIG. 2. Delayed coincidences in 7.5-day Ag^{111}.

showing no measurable gamma-delay. The solid curve is that observed with a purified source[4] of Ag^{111}. The main body of the transitions shows no delay greater than 0.02 μsec. A small fraction of the transitions are delayed with a half-life of 0.10±0.02 μsec. Since nearly equal counting efficiencies for the two gammas are expected, it may be calculated that the ratio of the undelayed to delayed transitions is about 6:1. This agrees well with the ratio of 8:1 for the 340-kev to 243-kev transitions found by Johansson.

The identification of the 243-kev level in Cd^{111} formed by beta-decay of Ag^{111} with the 0.09-μsec level observed in the *K*-capture decay of In^{111} and in the 48-min isomeric transition of Cd^{111*} thus appears to be justified.

[1] Stig Johansson, Phys. Rev. **79**, 896 (1950).
[2] M. Deutsch and D. T. Stevenson, Phys. Rev. **76**, 184(A) (1949).
[3] F. K. McGowan, ORNL-366, 34 (August 12, 1949) (unpublished).
[4] Obtained through the courtesy of the Isotopes Division of the Oak Ridge National Laboratory.

The Thermal Neutron Capture Cross Section of Co^{59}

L. YAFFE, R. C. HAWKINGS, W. F. MERRITT, AND J. H. CRAVEN
Atomic Energy Project, National Research Council of Canada, Chalk River, Ontario, Canada
(Received April 2, 1951)

A DISCREPANCY has existed in the values published for the thermal neutron capture cross section of Co^{59}. The activation method used by Seren, Friedlander, and Turkel[1] yielded a value of 21.7±4.3 barns. The "pile oscillator" or "danger coefficient" method gave values of 34.3±0.7 barns,[2] 34.2±3.4 barns,[3] and 38.2±3.0 barns.[4] This discrepancy suggested either an error in the pile activation determination or possibly a short-lived isomer of Co^{60} that had not been detected.

We have determined the activation cross section of Co^{59} for thermal neutrons, using the NRX heavy-water reactor. The thermal neutron cross section of Au—93 barns—was used as a standard.[2] The Au and Co were irradiated simultaneously in a position where the neutron distribution was known to be predominantly thermal. The contribution of epi-cadmium neutrons was determined by an irradiation under cadmium and small corrections were made for this (2.2 percent for Au and 0.2 percent for Co).

The Co metal (99.92 percent pure) was irradiated as a weighed disk 0.3 mm thick. A disk was cut out of a sheet of gold leaf of known weight and area, floated on water, and lifted onto an aluminum backing. The water was then evaporated, and the area of the disk, and hence its weight, was determined under a microscope.

After a measured irradiation period of about 20 hours the Co and Au samples were dissolved in *aqua regia* and made up to standard volumes. From these solutions known aliquots were withdrawn and activity measurements made several hours later. The absolute disintegration rates of these aliquots were measured by 4π proportional counting and by coincidence counting techniques. The relative values were confirmed by an end window counter.

Half-lives of 5.26 years[5] and 2.69 days[6] for Co^{60} and Au^{198}, respectively, were used in making corrections for decay and for lack of saturation of bombardment.

The thermal neutron capture cross section for Co^{59} leading to the formation of 5.26 year Co^{60} was found to be 34.2±1.4 barns. This result is the mean of 6 activations. A large proportion of the probable error is introduced by variations in the thickness of the gold leaf used. The cross section leading to the formation of the 10.7-minute isomer is 0.66 barns,[1] and thus only about 2 percent of the thermal neutron captures lead to the short-lived isomer. Of this, less than 10 percent[7] decays independently to Ni^{60}, leaving a maximum of only 0.2 percent not included in the ultimate production of 5.26 year Co^{60}. The cross section as measured can then be taken equal to the total absorption cross section of Co^{59}, with an error of less than 0.07 barns.

It will be noted that the activation cross section is now in excellent agreement with the results obtained by the "pile oscillator" method.

When this work was completed Dr. B. W. Sargent kindly drew our attention to an unpublished report by Jones, *et al.*,[8] which gives a value of 33 barns for Co^{59} obtained by the activation method. Agreement with our value is satisfactory.

[1] Seren, Friedlander, and Turkel, Phys. Rev. **72**, 888 (1947).
[2] Harris, Muehlhause, and Thomas, Phys. Rev. **79**, 11 (1950).
[3] H. S. Pomerance, private communication.
[4] F. C. W. Colmer and D. J. Littler, Proc. Phys. Soc. (London) **A63**, 1175 (1950).
[5] G. L. Brownell and C. J. Maletskoss, Phys. Rev. **80**, 1102 (1950).
[6] Nuclear Data, National Bureau of Standards Circular No. 499.
[7] Deutsch, Elliott, and Roberts, Phys. Rev. **68**, 193 (1945).
[8] Jones, Clark, and Overman, MonC 398 (unpublished).

The Excitation Functions for $B^{10}(d, \alpha)Be^8$

W. D. WHITEHEAD
*Bartol Research Foundation of the Franklin Institute, Swarthmore, Pennsylvania**
(Received March 29, 1951)

THE excitation functions for the ground-state group and the first excited state group for $B^{10}(d, \alpha)Be^8$ have been determined by bombarding thin targets (375 μg/cm²) of isotopically enriched boron (96 percent B^{10}) and of normal boron with deuterons from the Bartol van de graaff generator, and observing the reaction α-particles with an argon-filled proportional counter, biased to count the α's at the end of their range, at 90° to the incident beam. The isotopic assignment of groups was first made by observing the α-particle groups from the target of 96 percent B^{10} (Fig. 1) and from a normal boron target (Fig. 2) bombarded with 1.20-Mev deuterons and noting the change in intensity with change in isotopic ratio. As seen in the curves, groups 1, 2, and 3 are due to the B^{10} reaction, and group 4 is due to B^{11}. This confirms

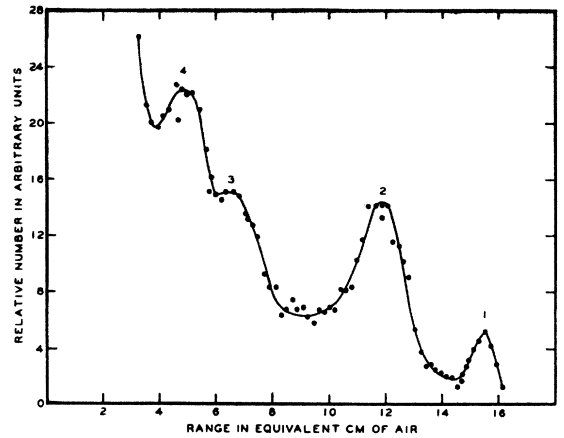

FIG. 1. Number of α-particles *vs* range in equivalent cm of air for B(d, α)Be with a target of 96 percent B^{10} and a bombarding energy of 1.20 Mev.

the work of Smith and Murrell[1] and shows that their tentative assignment of the group with a Q value of 4.90 Mev to the Li contamination is probably correct, for there is no evidence of a group between groups 2 and 3 on either curve.

The ranges of the α-particles were measured using aluminum absorbing foils and a movable proportional counter; the gross range changes were made with foils and the fine changes by moving the counter in air. The energy of the α-particles was determined from the range to the peak of the group, using the procedure of Holloway and Moore[2] for converting from the range to the peak to the mean range, and using the Brookhaven[3] range tables to determine the energy. The Q values determined from these energies are 17.92±0.15 Mev for the ground state, and 15.19±0.15 Mev for the first excited state which is thus 2.73±0.20 Mev above the ground state. Using the ground-state Q value from this reaction, the masses of B^{10} and d from Tollestrop *et al.*,[4] and the mass of the α-particle from Whaling and Li,[5] the mass of Be^8 is 8.00780±0.0016 MU and is unstable to α-emission by 0.110±0.150 Mev. Assuming that the width in range at half-maximum for the excited state is $(\sigma_x^2+\sigma_n^2)^{\frac{1}{2}}$, where σ_x is the experimental half-width due to range straggling and angular straggling, and σ_n is the spread in range due to the natural width of the level, the width of the first excited level in Be^8 is 0.95±0.20 Mev.

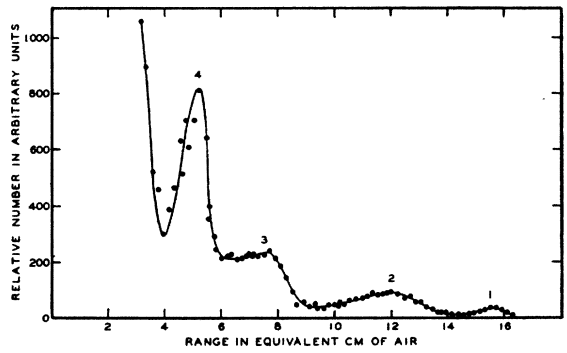

FIG. 2. Number of α-particles *vs* range in equivalent cm of air for B(d, α)Be with a target of normal boron (80 percent B^{11}) and a bombarding energy of 1.20 Mev.

The excitation functions were determined by measuring the peak heights as the bombarding energy was varied from 0.50 Mev to 1.60 Mev in 0.1-Mev intervals (Fig. 3). The ratio of the peak heights of the two groups is not equal to the ratio of the intensities; but the ratio of the areas under the peaks is, and at 1.20 Mev

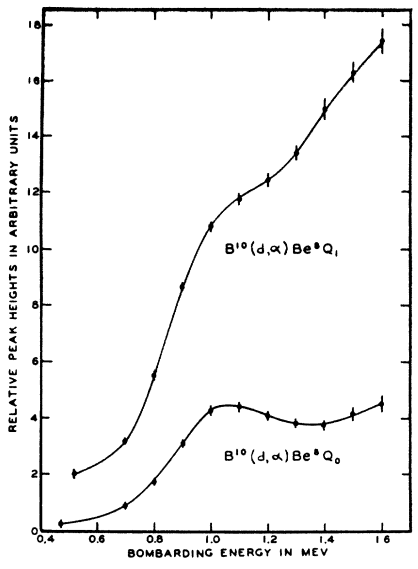

FIG. 3. Peak heights in arbitrary units *vs* bombarding energy for $B^{10}(d, \alpha)Be^8$ ground state and $B^{10}(d, \alpha)Be^8$ first excited state. The statistical errors are less than 2 percent.

is 7.1. The resonances in the excitation curves at 1.05-Mev bombarding energy give a level in C^{12} at 26.1 Mev. Since the ground-state group of α's and the protons from the ground state of $C^{12}(d, p)C^{13}$ have approximately the same range, and the first excited group of α's and the protons from the ground state group of $O^{16}(d, p)O^{17}$ have approximately the same range, at a bombarding energy of 1.05 Mev, the possibility that the resonance is due to piling up of the protons and alphas has to be considered. The protons are not counted directly because their maximum pulse height is 16 volts, and a bias of 30 volts was used in the discriminator; also, the number of counts per microcoulomb was independent of current as the current was changed by a factor of six, so that the piling up is negligible.

* Assisted by the joint program of the ONR and AEC.
[1] Smith and Murrell, Proc. Cambridge Phil. Soc. **35**, 298 (1939).
[2] M. G. Holloway and B. L. Moore, Phys. Rev. **58**, 847 (1940).
[3] H. A. Bethe, "The properties of atomic nuclei II," Brookhaven National Laboratory BNL-T-7 (unpublished).
[4] Tollestrop, Fowler, and Lauritsen, Phys. Rev. **78**, 372 (1950).
[5] W. Whaling and C. W. Li, Phys. Rev. **81**, 150 (1951).

Erratum: The Cathode Field in Diodes under Partial Space-Charge Conditions with Initial Velocities

[Phys. Rev. **81**, 274 (1951)]
A. O. BARUT
Department of Applied Physics, Swiss Federal Institute of Technology, Zurich, Switzerland
(Received March 28, 1951)

IN the formulas for $f(0)$ and for the saturation current I_{sa}, the letter ϑ should read $(2e)$, where e is the charge of the electron.

The Ratio of Proton and Electron Masses

FRIEDRICH LENZ
Düsseldorf, Germany
(Received April 5, 1951)

THE most exact value at present[1] for the ratio of proton to electron mass is 1836.12±0.05. It may be of interest to note that this number coincides with $6\pi^5=1836.12$.

[1] Sommer, Thomas, and Hipple, Phys. Rev. **80**, 487 (1950).