Search for Gamma-Rays from the Deuteron-Deuteron Reaction

The discovery by Bonner[1] of a second group of neutrons from the reaction

$$H^2+H^2 \rightarrow He^3+n^1 \quad (1)$$

has suggested the possibility that He^3 may be formed in an excited state about 2 Mev above the ground state. The difficulty of reconciling such a state with present nuclear theory has been emphasized by Share[2] and Schiff.[3] If such a state exists we should expect to observe gamma-rays due to the transition of He^3 to its normal state. Evidence for a gamma-ray has been given by Kallmann and Kuhn,[4] who used coincidence counters to investigate the reaction. We have made a search for this gamma-ray by means of a cloud chamber.

The cloud chamber was placed about 25 cm from a heavy phosphoric acid target bombarded by 0.5 Mev deuterons. A lead collimator was placed between the target and the cloud chamber and both were provided with thin aluminum windows. A sheet of carbon 0.15 cm thick extended across the center of the chamber as a source of Compton electrons. A magnetic field of 715 gauss was used to determine the electron energies. Many recoil electrons were observed, but most of these appeared to be due to the gamma-rays from slow neutron capture and from the inelastic scattering of fast neutrons in the material around the chamber. In order to determine whether any gamma-rays came directly from the target, the following experiment was performed. On alternate expansions the hole in the lead collimator was filled with a lead block 4 cm thick. This would have decreased the intensity of a gamma-ray from the target by a factor ten. Actually no difference in the numbers of electrons between 1 and 2 Mev energy was observed in the two cases.

In order to determine the ratio of the number of gamma-rays to the number of neutrons from the reaction, the target holder was placed directly within the cloud chamber and surrounded by a foil of Cellophane 0.1 mm thick. From the number of proton tracks coming from this foil the neutron intensity could be estimated using the known cross section for neutron-proton scattering. The gamma-ray intensity was determined simultaneously by counting the Compton electrons produced in a sheet of carbon in the center of the chamber. Since the time of sensitivity of the cloud chamber for electron tracks is smaller than the time of sensitivity for proton tracks, a correction factor was necessary. An estimate of this ratio was found by placing in the chamber a natural radioactive source which emitted a known ratio of beta-rays and alpha-particles. From the ratio of Compton electrons to protons obtained in this way it was calculated that there is not more than one gamma-ray for every 200 neutrons. This figure agrees with the estimate of Kallmann and Kuhn;[4] the intensity of Bonner's second neutron group[1] is, however, one-tenth of the 2.6 Mev group.

During the course of this investigation many protons were observed which penetrated a carbon sheet 0.15 cm thick, and consequently had an energy greater than 15 Mev. Since these were present when the chamber was separated from the target by 4 cm of lead, they must be due to neutrons, possibly from the secondary reaction

$$H^3+H^2 \rightarrow He^4+n^1+17.6 \text{ Mev} \quad (2)$$

due to recoiling H^3 nuclei from the reaction

$$H^2+H^2 \rightarrow H^3+H^1. \quad (3)$$

We understand that energetic protons from the analogous reaction of He^3 with H^2 have been reported by Oliphant.[5] The ratio of the number of these very energetic recoil protons to those of the 2.6 Mev group was of the order of one to one thousand; consequently reaction (2) must be an exceedingly probable one.

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[1] Bonner, Phys. Rev. **53**, 711 (1938); also Baldinger, Huber and Staub, Helv. Phys. Acta **11**, 245 (1938).
[2] Share, Phys. Rev. **53**, 875 (1938).
[3] Schiff, Phys. Rev. **54**, 92 (1938).
[4] Kallmann and Kuhn, Naturwiss. **26**, 106 (1938).
[5] Unpublished; private communication from Professor H. A. Bethe.

Observation of H^1 and H^3 Ranges from the Disintegration of Deuterium by Deuterons

Recent cloud chamber experiments[1] on the energy spectrum of recoil protons produced by neutrons from the reaction

$$H^2+H^2 \rightarrow He^3+n^1$$

have shown the presence of a low energy group of neutrons, and indicate the existence of an excitation level in He^3 at 1.89 Mev. Ionization chamber studies[2] have led to this same conclusion. In view of this excitation level in He^3 it seems reasonable to expect a similar level in H^3. Consequently we have looked for a short range group of protons from the reaction

$$H^2+H^2 \rightarrow H^3+H^1.$$

We used apparatus previously described.[3] The protons were observed in a cloud chamber filled with air and alcohol vapor. They were allowed to pass into the chamber through an aluminum foil which had a stopping power of approximately 0.5 cm. A slit system defined the direction

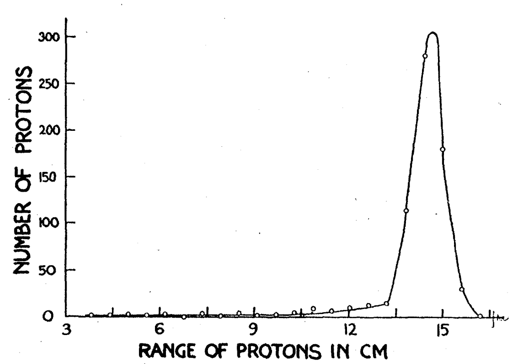

Fig. 1. Range distribution of protons from the disintegration of deuterium by deuterons.