Photographic Plate Spectrum of *d–d* Neutrons

Recently in this laboratory[1] a search was made for a low energy group of neutrons arising from the *d-d* reaction by an observation of helium recoils produced in a cloud chamber. No indication of such a group was found. The fact that the short recoils previously observed in methane[2] and in hydrogen[3] were of the range one would expect for deuterons formed by proton capture of the high energy *d–d* neutrons would explain the experimental facts, but the ratio of the probability of capture to the probability of collision for neutrons of 2.5 Mev energy in hydrogen is theoretically much too small to account for the relative intensities of the two groups on this basis.

In the present work we thought to test the idea of radiative capture of neutrons by using the technique of photographic plates,[4] in which a deuteron could be distinguished from a proton. Also, photographic plates, compared to heavier detecting equipment, give less scattering, and hence we could study the possibility that the low energy group previously reported was due to this cause.

Magnetically analyzed 700-kv deuterons, accelerated by the Rice pressure Van de Graaff generator, fell on a heavy paraffin target of about 20 kv thickness for one microampere-hour. Photographic plates were placed 12 cm from the target at 0° and at 90° to the bombarding beam. Following the technique which one of us (HTR) has previously used,[5] we have analyzed the two plates for proton recoils. Only those recoils within 12° of the forward direction were tabulated; a photomicrograph of a recoil proton track is shown in Fig. 1.

The range-number curve for each plate was converted to a range-energy curve, shown in Fig. 2, by calculating the stopping power of the photographic emulsion. With $Q=3.32$ Mev, one calculates the energy of the neutrons emitted at 90° to the 700-kv bombarding beam to be 2.67 Mev, while neutrons emitted at 0° have an energy of 3.82 Mev. These groups showed mean ranges of 73 and 138 microns, respectively. Hence the stopping power of the emulsion is 6.4 microns per cm of air in the first case, and 6.6 microns per cm of air in the second. Some α-tracks, caused by radioactive contamination of the emulsion, were also observed. These, however, show a much greater density and are thus easy to distinguish from the tracks produced by proton recoils.

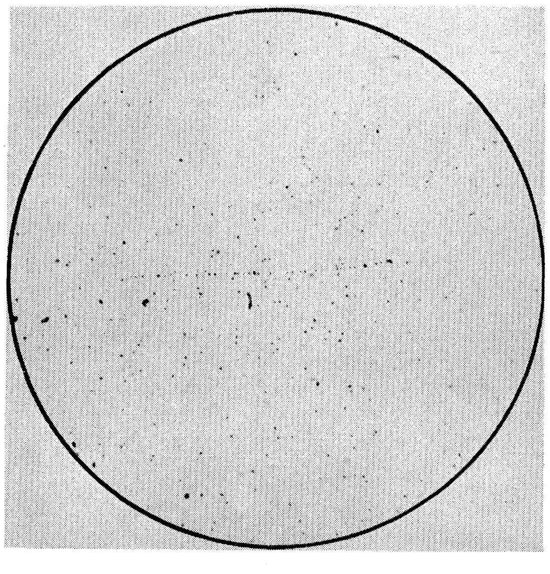

FIG. 1. A photomicrograph (750×) of a 78-micron proton recoil in a photographic emulsion. The proton in this case proceeded from left to right. Increased linear grain density and small angle deflection are characteristic of the termination of such tracks.

It will be observed that there is no evidence of a short range group of recoils in the data at 90°. This shows that radiative capture cross section is indeed very small, and also shows that there is no low energy group of neutrons from the *d–d* reaction. The data at 0° confirm these conclusions, since the weak group at 2.5 Mev is thought to have arisen from bombardment of deuterium contamination on a wall of the magnet box by the molecular beam. Since the molecular beam is deviated through only a small angle before striking the wall, neutrons from this source must be ejected at nearly 90° to the molecular beam in order to strike the photographic plates. The tail present beyond the maximum on the curve obtained from the plate at 90° to the bombarding beam is doubtless due to the scattering by the target holder of high energy neutrons ejected at smaller angles.

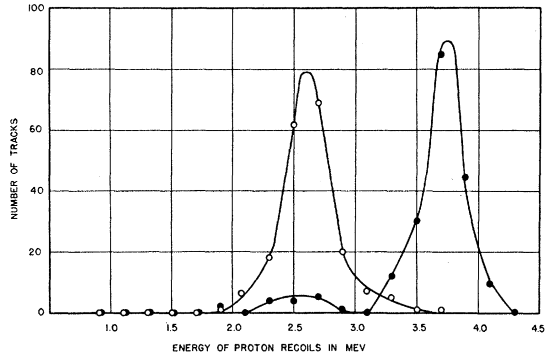

FIG. 2. The *d–d* neutron spectrum as observed in photographic plates placed at 90° (open circles) and at 0° (dots) to a 700-kv bombarding beam.

We therefore conclude that the radiative capture cross section is at least 100 times smaller than the scattering cross section for 2.5-Mev neutrons. We further conclude that there is only a single group of neutrons from the *d–d* reaction. The short range groups previously reported could have arisen through scattering or through contamination of the cloud chamber by some radioactive substance which could yield a radioactive gas.

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[1] E. Hudspeth and H. Dunlap, Phys. Rev. **57**, 971 (1940).

[2] T. W. Bonner, Phys. Rev. **52**, 685 (1937) and **53**, 711 (1938).

[3] E. Hudspeth and H. Dunlap, Phys. Rev. **55**, 587 (1939).

[4] Ilford Special Halftone plates, of 100 microns thickness, were used in this work.

[5] An account of this investigation (of the Li neutron spectrum) will be published soon and will include details of the particular technique employed.

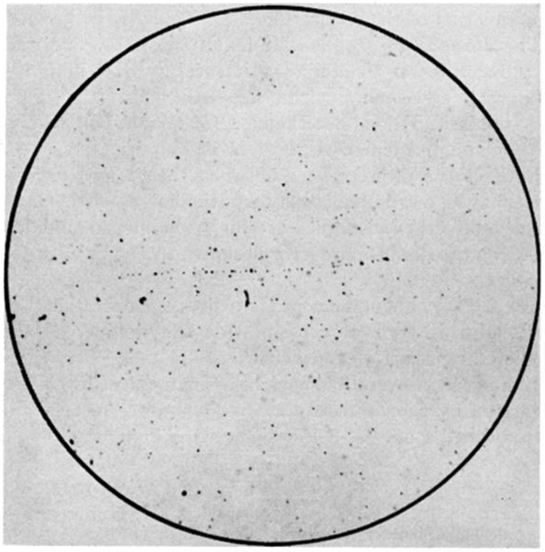

FIG. 1. A photomicrograph (750×) of a 78-micron proton recoil in a photographic emulsion. The proton in this case proceeded from left to right. Increased linear grain density and small angle deflection are characteristic of the termination of such tracks.