Scattering Cross Section of Protons for 900-Kev Neutrons

A number of experimental data[1–3] for the scattering cross section of hydrogen for neutrons of energies between 2 and 16 Mev are available, which agree comparatively well with Wigner's "two level formula" corrected for the finite range of the nuclear forces.[4] For lower neutron energies the cross section depends more sensitively on energy, and the singlet scattering becomes more important. Since no attempt has yet been made to check this formula between 400 kev[5] and 2 Mev, it seemed interesting to measure the cross section for an intermediate energy. For this purpose we used the neutrons produced in beryllium by the 2.62-Mev gamma-rays of ThC″. It is very likely that these neutrons are mainly due to the reaction $Be^9+h\nu \rightarrow Be^8+n^1$ and that they are consequently monokinetic. In this case, according to various determinations of the threshold energy[6–8] of the reaction, their energy is about 900 kev.

The arrangement used is shown in Fig. 1. The source consisting of about 13 mC RdTh, contained in a platinum tube of 1 cm length and 2 mm diameter, was surrounded by a cylinder of beryllium metal. The individual fast neutrons were detected by means of an ionization chamber filled with 5 atmos. of hydrogen, which was connected to a four-stage linear amplifier and a scaling circuit. The pulses could be visually observed by means of an oscilloscope. Recoil protons of more than 350 kev energy were recorded. The gamma-ray background reduced by a lead cone mounted in front of the source was well below this limit. The natural background of the chamber was 0.40 ± 0.03 count per min. The RdTh+Be source if placed in the position indicated in Fig. 1 yielded a count I_0 of 7.69 ± 0.19 pulses per min. The RdTh source itself was "neutron free." The scatterers consisted of paraffin cylinders of lengths varying between 1 and 9 cm. They were placed halfway between source and ionization chamber.

In Fig. 2 the logarithm of the ratio I/I_0 of the numbers of counts obtained per min. with and without scatterer is plotted (open circles) against the thickness in g/cm² of the scatterer. The points corresponding to smaller thicknesses lie well on a straight line indicating that at least the majority of the neutrons are monokinetic. From this straight line we obtain a value of 2.43 g/cm² for the mean free path of the RdTh+Be neutrons in paraffin. The deviation from the straight line for the points corresponding to the thickest scatterers is due partly to multiple scattering and partly to the neutrons scattered under a small angle which are still detected by the ionization chamber.

The neutron absorption in carbon was determined in the same way as that in paraffin by using graphite cylinders as absorbers. The full circles in Fig. 2 show the results from which a scattering cross section for carbon of $(2.63 \pm 0.25) \times 10^{-24}$ cm² follows.

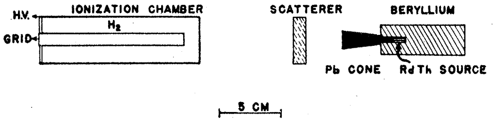

FIG. 1. Arrangement for absorption measurements of RdTh+Be photo-neutrons in paraffin and carbon.

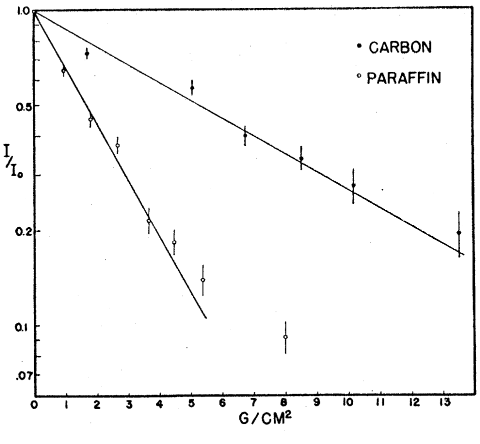

FIG. 2. Logarithmic absorption curves of RdTh+Be photo-neutrons in paraffin (○) and carbon (●).

The correction for the obliqueness of the neutron paths within the scatterer is negligible. An estimate of the effect of small angle scattering was made assuming the scattering to be spherically symmetrical in the center of gravity system. This yielded an "ideal" mean free path of 2.28 g/cm² in paraffin. The average composition of the paraffin we used corresponded to the formula $C_{25}H_{52}$. From this we obtain a proton-neutron cross section of $(3.70 \pm 0.35) \times 10^{-24}$ cm², which lies somewhat below the value 4.65×10^{-24} cm² calculated from Kittel and Breit's[4] expression for 900-kev neutrons, and closer to the value given by Wigner's "zero range formula."

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Spontaneous Fission of Uranium

With 15 plates ionization chambers adjusted for detection of uranium fission products we observed 6 pulses per hour which we ascribe to spontaneous fission of uranium. A series of control experiments seem to exclude other possible explanations. Energy of pulses and absorption properties coincide with fission products of uranium bombarded by neutrons. No pulses were found with UX and Th. Mean lifetime of uranium follows ten to sixteen or seventeen years.

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