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# Diffusion of Slow Neutrons

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The effect of a few elements on the diffusion of slow neutrons in water is investigated. The interpretation of data on the back scattering of neutrons is discussed.

THE results of most experiments on the absorption and scattering of slow neutrons depend very much on the detectors. In the hope to eliminate this difficulty we performed the following experiments.

A radon beryllium neutron source (200–60 mc) was placed in a cylindrical tank of water (diameter 56 cm, height 80 cm). A detector was placed in a radial position at 6 cm from the axis and its activity observed.[1] Next, the activity of the detector was measured again, but now with a layer of an absorber placed against one side of it. The idea was that the presence of the absorber would lower the density of the diffused neutrons in the neighborhood, without changing the velocity distribution. Therefore the change in activity of the detector would give direct information about the change in density. Unfortunately this ideal situation is not quite realized in the present experiments. The Maxwellian distribution will only be reestablished if the detector is placed at a few mean free path lengths away from the scatterer. The observed change in activity is very large for silver, much smaller for copper, and hardly observable for carbon. These differences show especially well if the thicknesses of the layers are expressed in gram atoms/cm$^2$ as is done in the accompanying graphs (Figs. 1, 2, 3 and 4). The graphs also show the intensity of the detector when it is placed between two layers of absorbing or scattering materials.

In order to test further the influence of cadmium on the diffusion of neutrons, we placed a cadmium sphere inside the tank and investigated the intensity of a rhodium detector in its neighborhood. Figs. 5, 6, and 7 show the neutron distribution without and with the cadmium sphere present, along the radius of the cylindrical tank and in a direction perpendicular to this radius.

The results obtained show that the change in intensity of the detectors is not just due to a screening off from one side, but the scatterers and absorbers cause an actual change in the neutron density. This change must also be present in back scattering experiments of the type done by A. C. G. Mitchell and his co-workers.[2] As a result, the coefficient of scattering given by them must be much too large because the presence of the

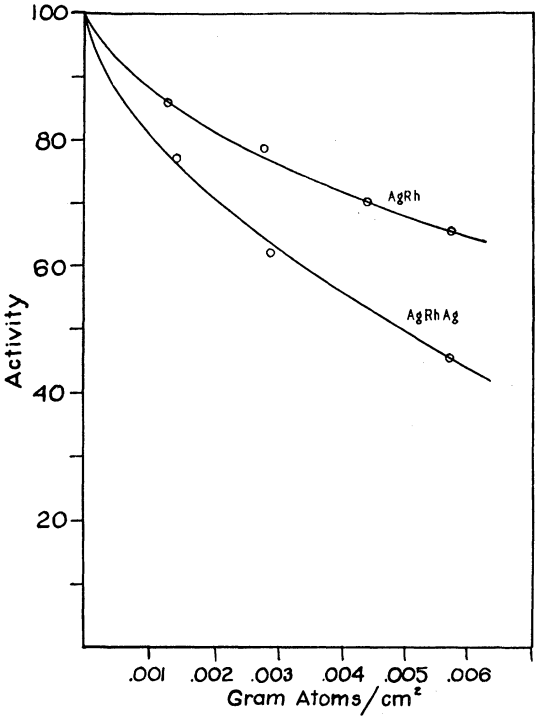

FIG. 1. The decrease of the activity of a rhodium foil (0.30 gram/cm$^2$) against (AgRh) and between layers of silver (AgRhAg) of various thicknesses. The foil and layers were placed radially in a cylindrical tank filled with water, which had the neutron source at its center.

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[1] The activity was measured with an ionization chamber placed on an Edelmann electrometer. The drift of the fiber was observed visually and recorded with a chronograph, which facilitated the measurements and increased the accuracy.

[2] A. C. G. Mitchell, E. J. Murphy, L. M. Langer and M. D. Whitaker, Phys. Rev. **48**, 653 (1935); **47**, 881 (1935); **49**, 400 (1936); **49**, 401 (1936).

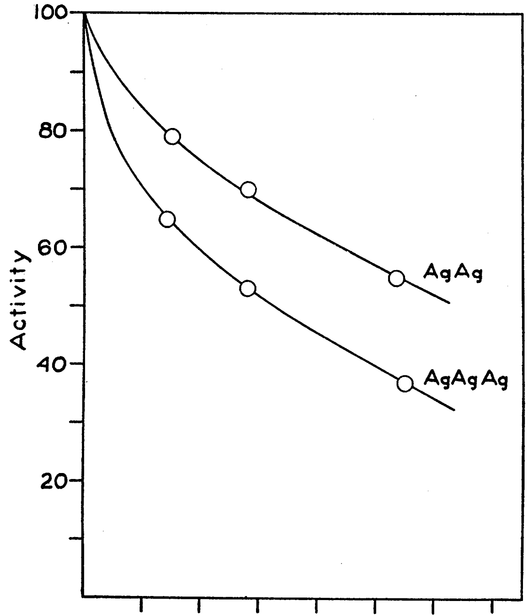

FIG. 2. The decrease of the activity of a silver foil (0.14 gram/cm$^2$) against (AgAg) and between layers of silver (AgAgAg).

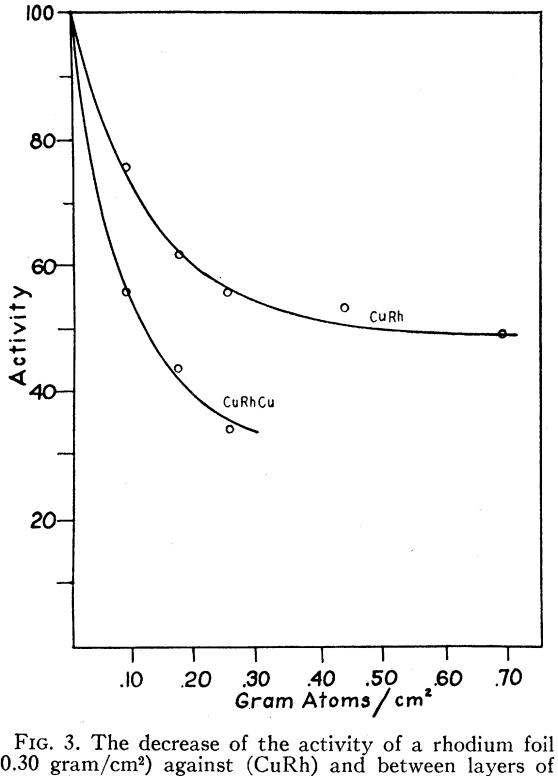

FIG. 3. The decrease of the activity of a rhodium foil (0.30 gram/cm$^2$) against (CuRh) and between layers of copper (CuRhCu).

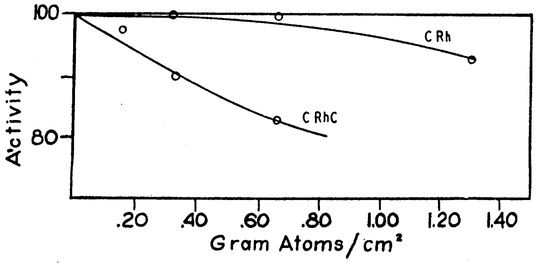

FIG. 4. The decrease of the activity of a rhodium foil (0.30 gram/cm$^2$) against (CRh) and between layers of carbon (CRhC).

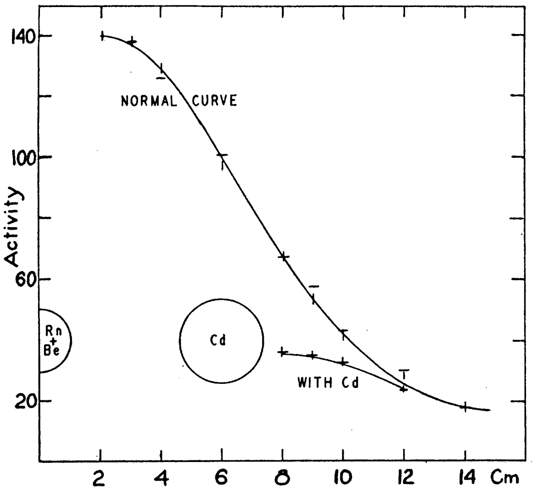

FIG. 5. The activity of a rhodium foil (0.30 gram/cm$^2$) as a function of the distance from the neutron source in a cylindrical water tank (28 cm radius, 80 cm deep) with and without a solid cadmium sphere (1.4 cm radius) at 6 cm from the source. The foil was placed perpendicular to (1) and along the radius (—) of the tank.

scatterer will usually increase the density of the neutrons in the paraffin right behind it. Or differently stated, the neutrons scattered back by the scatterer will again be returned through the detector by the paraffin. The error introduced this way may be 80 percent according to an estimate of this paraffin reflection by Amaldi and Fermi.[3]

If the original number of slow neutrons (for instance of group C of Amaldi and Fermi) is denoted by $N$, the fractions scattered back from the scatterer and the paraffin by $s$ and $S$, and the fraction transmitted by the detector by $\tau$, it follows that the number of neutrons traversing the detector from the side of the paraffin is

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[3] Amaldi and Fermi, Ric. Scient. 2, 544 (1935).

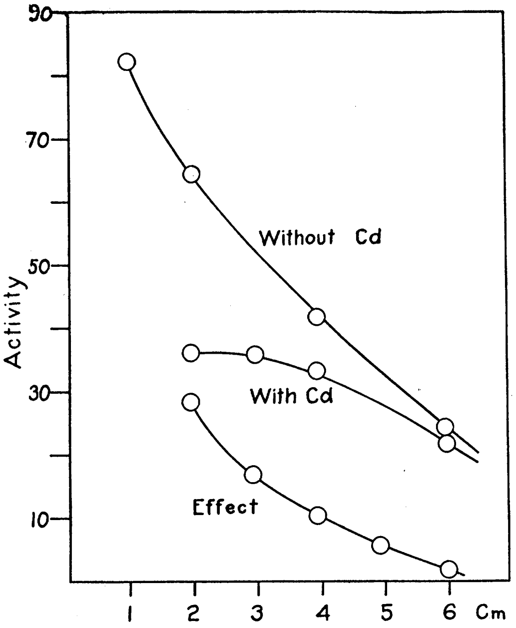

FIG. 6. The effect of a solid cadmium sphere on the activity of the rhodium foil in a cylindrical tank of water as a function of the distance from the center of the sphere measured along the radius of the tank.

$N/(1-\tau^2sS)$, from the side of the scatterer $N\tau s/(1-\tau^2sS)$. This expression is, of course, only qualitatively correct. It does not take into account such complications as arise, for instance, from the change of the velocity distribution in the process of scattering. If these corrections could be made with some certainty, the back scattering from thick layers would provide a way to obtain the ratio between absorption ($\sigma_a$) and scattering cross section ($\sigma_s$). The fraction scattered back is given by

$$(2\sigma_a+\sigma_s)/\sigma_s-\{((2\sigma_a+\sigma_s)/\sigma_s)^2-1\}^{\frac{1}{2}}.$$

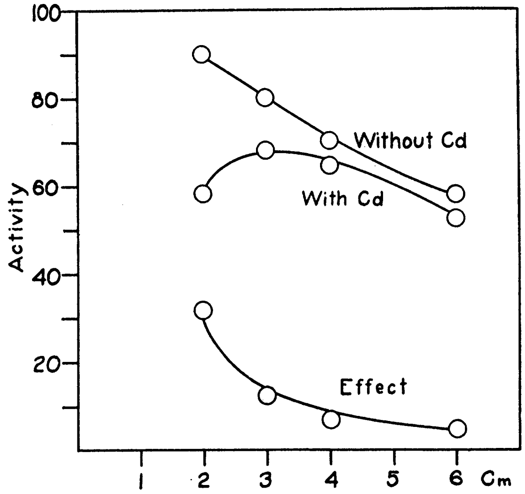

FIG. 7. The same as Fig. 6, but measured in a direction perpendicular to the radius of the tank.

The following experiment showed that the back-scattering from the paraffin is large. The source and a detector foil were both placed on a paraffin cylinder. The intensity of the foil was measured without and with a similar second cylinder covering the first. A large increase in the intensity was observed, but this increase depended upon the size of the gap between the two cylinders and the position of the foil. When the gap was about 2 cm and the foil placed vertically at the edge of the cylinder (to avoid changes due to absorption of the foil itself) the increase was about seven times for Rh. If the foil is placed flat on, and between, the cylinders its absorption causes this increase to be only 3 to 5 times for Rh, depending on the place of the foil. If we ascribe the increase to slow neutrons only, the reflection of paraffin would be about 70 percent.