On the Resonance Levels for Neutron Capture of Iodine and Indium

To explain discrepancies in the width of the iodine resonance level for neutron capture, Bethe[1] suggested that the level might be multiple. To investigate the situation more thoroughly, we have performed experiments following the procedure of Preiswerk and von Halban.[2] Instead of paraffin, however, carbon, iron and lead were used as slowing materials. Since the average fractional energy loss for neutrons colliding with a heavy atom of atomic weight A is approximately $2/A$, the resolving power is much increased.

In Figs. 1 and 2 the apparent transmissions are plotted against the thickness of slowing substances interposed between absorber and detector. The conditions under which the various curves were obtained are indicated in the figures. The iodine detectors contained 0.04 g/cm² I, the absorbers 0.077 g/cm² I (curves a) and 0.16 g/cm² I (curves b).

In general, the iodine curves show a gradual rise upon which, in the case of carbon and iron, several minima are superimposed. The rise is caused by the slowing of neutrons of slightly more than resonance energy into the resonance region. Minima occur at those thicknesses which slow down neutrons of one resonance level into the region of a lower level.

To make certain that the minima are not caused by accidental effects, experiments were performed under conditions identical with the ones of Fig. 1a, except that the iodine absorbers and detectors were replaced by 0.008 g/cm² of indium. The curve, Fig. 1c, so obtained, is smooth.

To evaluate the results, the average number N of collisions made by a neutron was computed from the known scattering coefficients,[3] the fractional energy loss being taken as $(1-2/A)^N$. For thin layers, $N \simeq 1$, this approximation is invalid, and the appropriate energy loss was obtained from the energy distribution of the slowed neutrons.

It is found that the spacings corresponding to the first two carbon minima and the last two iron minima are equal. The relative spacings $\Delta E/E$ (ΔE the spacing, E the average resonance energy) are approximately: 0.05, 0.09, 0.15, 0.26, 0.34, and 0.46. The maximum value of $\Delta E/E$ obtained with lead is 0.04. These six minima can be explained by assuming at least four levels for iodine.

From the initial slope of the curves, the average width of the levels can be estimated. If the half-width Γ of the

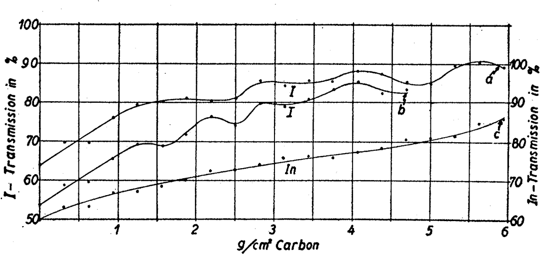

FIG. 1. Apparent transmission as a function of thickness of slowing substance between absorber and detector.

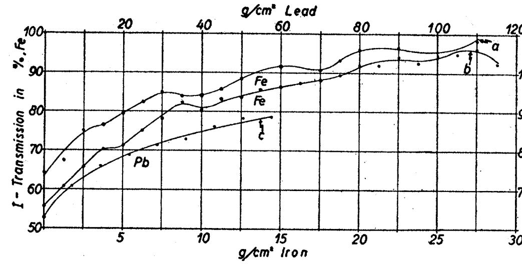

FIG. 2. Apparent transmission as a function of thickness of slowing substance between absorber and detector.

level is not $\ll 2E/A$, some of the neutrons, slowed into the resonance region (thus causing the rising curve), are absorbed, so that the flattening of the absorption band requires a greater thickness of slowing material. Values for the average width of the levels have been computed from the theoretical expression for the shape of a resonance level, the energy distribution after one or two collisions, and the absorption due to the flattened level. Because of large geometrical corrections, the result is not too reliable.

The curve, Fig. 1a, is in agreement with the assumption $\Gamma/E \ll 2/A$. From Fig. 2a an upper limit $\Gamma/E < 0.012$ was found. Fig. 2c gives $\Gamma/E = 0.005 \pm 0.002$.

This value may be compared with an average width obtained from the absorption coefficients ($K_{\text{res}} = 5$ cm²/g for iodine[4]), namely, $\Gamma/E = 0.008$ for $E = 140$ ev,[1,5] or 0.012 for $E = 30$ ev.[4,6] We have compared the activabilities of iodine and of rhodium, finding for iodine $\Gamma/E = 0.0045$ or 0.011, using for rhodium[1] $\Gamma/E = 0.054$ or 0.13, respectively.

Measurements of self-absorption of iodine at room and at liquid-air temperatures showed no evidence of Doppler broadening, giving $\Gamma/E > 0.003$.

From Fig. 1c, the relative width $\Gamma/E = 0.1 \pm 0.05$ is found for indium. From the absorption coefficients, $\Gamma/E = 0.08$. In separate experiments, we measured the coefficient for self-absorption of indium as 50 ± 10 cm²/g.

Fuller details and additional data will appear shortly. The authors wish to express their gratitude to Professor E. O. Salant for his helpful support and steady interest in the work.

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The Scattering of the D − D Neutrons

Recently, we measured the atomic scattering cross section of 21 elements for D − D neutrons,[1] and found that it varies in a complicated manner with the atomic number. In the new series of experiments we extended the measurement to 37 elements. The high accuracy could now be obtained by measuring the neutron intensity by means of an ionization chamber filled with methane at 20 atmospheres pressure connected to a quadrant electrometer. The ionization current was usually about 10^4 times the natural leakage current. The ionization chamber was of cylindrical form 8 cm in effective length and 6 cm in effective diameter. The absorbers were mostly of cylindrical form 6 cm in diameter. The distance of the center of the chamber from the deuterium target was 40 cm, where the wall effect was about 10 percent of the total ionization current. The accelerating voltage was about 300 kv and the neutrons emitted at right angle to the deuteron beam were used. The energy of the neutron is therefore 2.4 Mev. The results for the elements of low atomic number are shown in Fig. 1. As will be seen the cross section is by no means a monotonic increasing function of the atomic number. It is an interesting problem to study, if the points are distributed quite irregularly or if they lie along a certain smooth curve. Though it is difficult to draw a definite conclusion, it will be interesting to note that, if we exclude a few elements, the points seem to lie along a smooth curve indicated in the figure by a dotted line. A similar trend is seen even in the region of high atomic number.

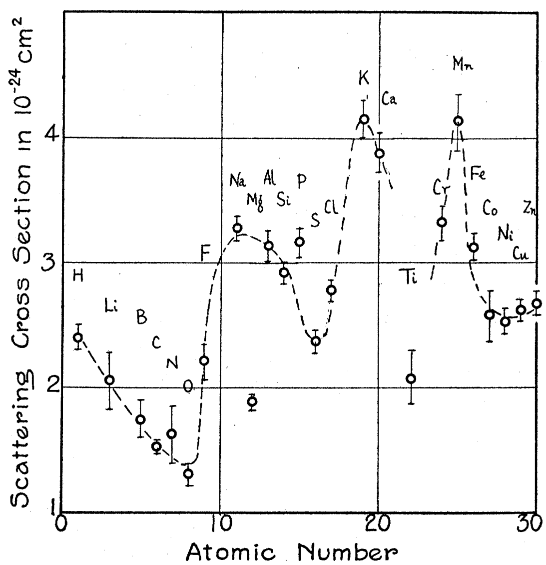

FIG. 1. Scattering cross section for D—D neutrons for elements of low atomic number.

The results seem to be very important in connection with the theory of interaction of the neutron with the atomic nucleus. The discussions will be given later when the experiments with neutron source of different energy spectrum, now going on, will be finished.

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A New Periodic Orbit in the Field of a Magnetic Dipole

In his classical paper on periodic orbits in the field of a magnetic dipole, Störmer[1] has exhibited examples of the following types of periodic orbits:

(a) Orbits intersecting the equator at right angles and reaching the boundary of the forbidden region $Q=0$. To this type belong the principal periodic orbits studied by Lemaitre and Vallarta and by Lemaitre, which play a fundamental role in the theory of cosmic rays.

(b) Orbits intersecting the equator at right angles more than once and not reaching the boundary $Q=0$.

(c) Orbits not intersecting the equator at right angles and reaching the boundary $Q=0$.

It does not appear that among the known examples of type *c* an orbit has ever been found having one or more loops. In the course of an investigation of reentrant orbits,[2] carried out in the spring of 1937 by means of Bush's differential analyzer,[3] the writer accidentally discovered an example of such an orbit. This is exhibited in Fig. 1.

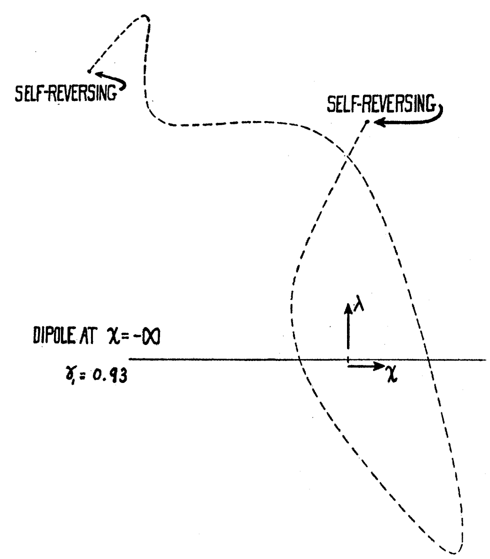

FIG. 1.

In the $x\lambda$-plane[4] the coordinates of the two points of reversal of this interesting orbit, as given directly by Bush's machine, are: $x=-0.547$, $\lambda=0.608$; $x=0.041$, $\lambda=0.510$. The intersections with the equator are at $x=-0.103$ and $x=0.167$, and the corresponding angles $-72.5°$ and $-75.0°$. The equatorial inclinations are thus seen to be nearly equal.

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