NONSTATIONARY ELASTIC SLOWING DOWN OF NEUTRONS IN GRAPHITE AND IRON

A. I. ISAKOV

P. N. Lebedev Physics Institute, Academy of Sciences, U.S.S.R.

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The slowing down time distribution for neutrons slowed down from 14 Mev to 4.9 Mev in graphite and iron has been measured with a pulsed neutron source. The results agree satisfactorily with the nonstationary theory of elastic slowing down of neutrons. The cross section for neutron capture in iron has also been measured and found to be 2.57 ± 0.04 bn for E = 0.0253 ev.

THE nonstationary slowing down of neutrons in lead was investigated in recent experiments.[1-3] A pulsed neutron source, together with a specimen having an isolated resonance at an energy E_0, was introduced into a lead prism. The intensity of the γ rays emitted upon capture of the neutrons in the specimen were measured as a function of the slowing-down time. In the limiting case of a very narrow resonance, the ratio of the intensity of the radiation emitted in the capture to the neutron density yields directly the distribution of the neutron slowing-down time to a final energy E_0. The average slowing-down time in the lead used in that investigation was in good agreement with theory, but the dispersion in the slowing-down times was 50 percent greater. In order to determine the causes of this discrepancy and to test the theory on other moderators, we undertook to measure the nonstationary elastic slowing down of neutrons in graphite and in iron.

The measurement procedure was the same as before.[1-3] The measurements were made on cylindrical gold specimens (E_0 = 4.906 ev) of effective thickness $\bar{l}$ = 0.4 mm. The γ rays from the capture of the slowed-down neutrons by the gold were registered with a proportional counter, over which the specimen was placed. The γ-ray count $I_\gamma(t)$ was normalized to a lithium-counter counting rate $I_{Li}(t)$ proportional to the neutron density.

The dots on Figs. 1 and 2 show the experimental results, obtained in graphite* and in iron respectively. The solid curve is a plot of the formula

$$I_\gamma(t)/I_{Li}(t) = \text{const} \cdot \int_0^\infty F(E, t)\, v\,(1 - e^{-N\bar{l}\sigma(E)})\, dE, \qquad (1)$$

*The measurements were made with the prism described by Dlougy.[4]

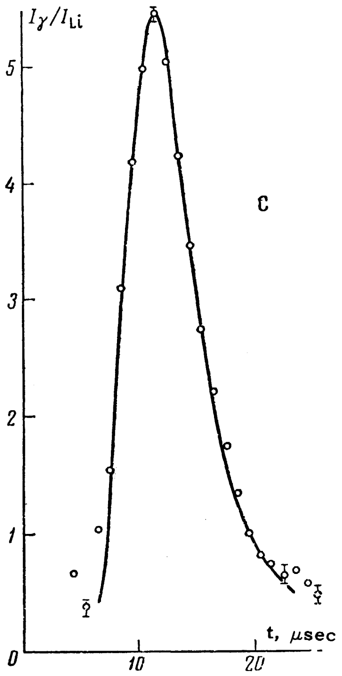

FIG. 1. Dependence of I_γ/I_{Li} on the slowing-down time for gold in a prism of graphite: o – experimental points; continuous curve – calculated line shape.

where F(E, t) is a function of the energy distribution of the slowed-down neutrons, calculated after Kazarnovskii,[5] with account of the small corrections for the apparatus spectral broadening, for broadening due to thermal motion of the atoms of the moderator, and for the 0.2% admixture of carbon in the case of iron; E and v are the energy and velocity of the moderated neutron; N is the number of nuclei per cm^3; $\sigma(E)$ is the total cross section for the interaction between the neutrons and the nuclei of the specimen. We neglect in (1) the potential scattering.

In the calculation of F(E, t) we used the tabulated[6] scattering cross sections of iron and copper.

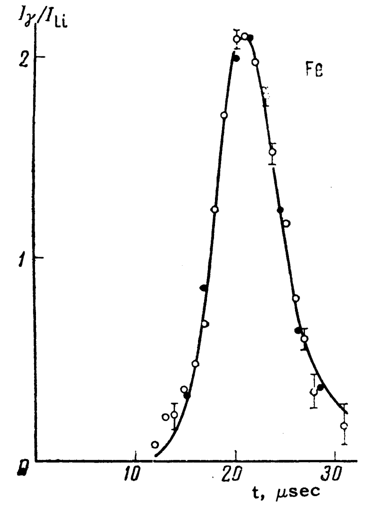

FIG. 2. Dependence of I_γ/I_{Li} on the slowing-down time for gold in an iron prism; o – experimental points, continuous curve – calculated line shape, • – points calculated under the assumption that the spectrum of the moderated neutrons is Gaussian.

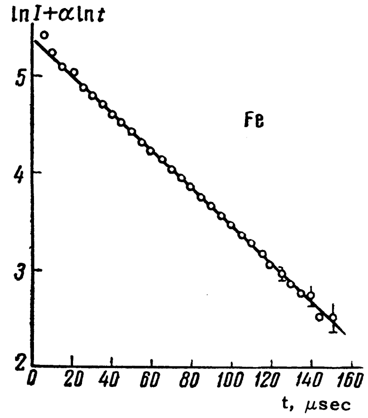

FIG. 3. Dependence of the neutron intensity I on the slowing-down time in an iron prism.

As can be seen from Figs. 1 and 2, the theoretical curves describe satisfactorily the shape of the line, its width, and its position, for either graphite or iron. The full circles of Fig. 2 have been calculated from (1) under the assumption that F(E, t) is a Gaussian function. As can be seen from the figure, the difference between the exact and approximate functions is insignificant.

We cannot use the Gaussian approximation for light moderators, since the spectrum of the moderated neutrons is not symmetrical, as can be seen from Fig. 1. The agreement with the theory of nonstationary elastic slowing down of neutrons, observed for graphite and iron moderators, enables us to conclude that the discrepancy between theory and experiment can be attributed in the case of lead to impurities of light nuclei.

We also undertook a direct measurement of the mean lifetime of neutrons in an iron prism. The intensity of registration of the neutrons with a lithium counter I_{Li} and the slowing-down time t are connected by the relation [1]

$$\ln I = -\alpha \ln t - t/T + \text{const},$$

where t is the neutron slowing down time and T the mean lifetime of the neutrons prior to capture. In a time interval 10 – 150 μsec, the neutron density decreased practically exponentially. The term α ln t, which characterizes the "leakage" of neutrons from the prism, was insignificant in this case. The measurement results are shown in Fig. 3.

The mean lifetime in iron is T = 22.2 ± 0.15 μsec. After introducing corrections for the impurities in the iron and for the effect of the measuring channel, we obtain for the lifetime T = 21.30 ± 0.30 μsec. From the measured values of the mean lifetime and the density of the iron prism we obtain for the capture cross section of 0.0253-ev neutrons σ_c = 2.57 ± 0.04 b. This result agrees with the latest published data σ_c = 2.53 ± 0.06 b [6a] and σ_c = 2.62 ± 0.06 b. [6b]

In conclusion I take this opportunity to thank F. L. Shapiro, at whose initiative the experiments were undertaken, for constant help and collaboration in this work.

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[5] M. V. Kazarnovskii, Dissertation, Phys. Inst. Acad. Sci., 1955; Trudy, Phys. Inst. Acad. Sci. **11**, p. 176.

[6] a) Neutron Cross Sections, BNL 325, Second ed., 1958;

b) Neutron Cross Sections, BNL-325, Supplement to Second ed., 1960.

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