[5] Tsyganov, Shafranova, Markov, et al., loc. cit. reference 3.

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MEASUREMENTS OF THE ENERGY DEPENDENCE OF RADIATIVE NEUTRON CAPTURE IN IRON, SILVER, AND GOLD AT ENERGIES UP TO 30 kev

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A spectrometer employing the neutron slowing-down time in lead[1] was used to measure the energy dependence of the cross section for radiative capture of neutrons in chlorine,[2,3] iron, silver, and gold. The measurement procedure and the reduction of the experimental data were described in detail in reference 2.

1. Iron. The measurements were made on samples of varying thicknesses of Armco iron (type "A", approximately 99.7% iron) and iron oxide (chda). The cross section of the (n, γ) reaction was obtained up to neutron energies of approximately 50 kev (Fig. 1). In the region up to 600 ev, the cross section obeys the 1/v law within 3 to 5%. For the iron level at $E_0 = 1180 \pm 80$ ev, a value $\sigma_0\Gamma_\gamma = 74 \pm 7$ ev-bn was obtained (only the statistical error is indicated). This value is half the preliminary result reported earlier.[3]

Measurements of the area of the resonance peak as a function of $\overline{l}^{-1/2}$, where $\overline{l}$ is the effective thickness of the sample, are presented in Fig. 2. The crosses denote the points used to calculate the preliminary value of $\sigma_0\Gamma_\gamma$. The reason for the deviation of the points is not clear, but numerous subsequent measurements, performed with considerably better statistics, lead us to assume the value indicated above for the strength of the level.

If the peak at $E_0 = 1180$ ev is due to one level, then $\Gamma_\gamma \gtrsim 0.8$ ev regardless of the isotope to which this level is assigned. At the same time, the neutron width Γ_n depends substantially on the spin and the isotope to which this resonance is ascribed (in particular, for s neutrons and Fe^{56}, $\Gamma_n \sim 5 \times 10^{-2}$ ev). This level cannot explain the thermal cross section of the iron.

From the results shown in Fig. 1, it follows that for iron the resonant capture integral $R_\gamma = \int \sigma_\gamma(E)\, dE/E$ should differ little, within the range from 0.49 to 2×10^6 ev, from the value $R_\gamma(1/v) = 1.1 \pm 0.03$ bn, calculated by extrapolating the capture cross section from the thermal region in accordance with the 1/v law, namely $R'_\gamma = R_\gamma - R_\gamma(1/v) = 0.12 \pm 0.02$ bn. The principal contribution, 0.1 ± 0.01 bn, is made to this quantity by the 1180 ev level. The contribution of the levels $E_0 = 7$ to 8 kev amounts to approximately 0.01 bn; all the higher levels make contributions that add up to approximately the same value.* The given value of R'_γ is one order of magnitude less than the value obtained by subtracting $R_\gamma(1/v)$ from the experimental data of references 4 — 6. The reason for the discrepancy remains unclear.

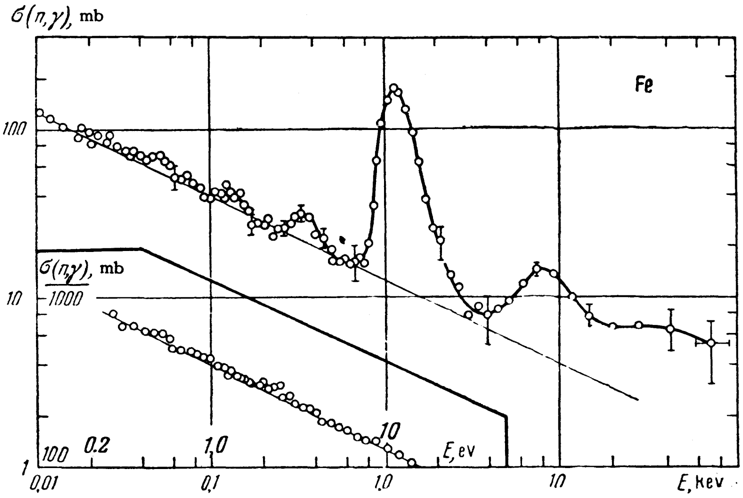

FIG. 1. Energy dependence of the neutron capture cross section in iron. The curve was normalized to the capture cross section $\sigma = 2.53 \pm 0.06$ bn at $E = 0.025$ ev.[8]

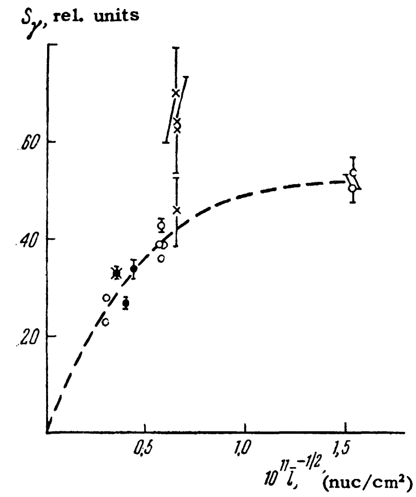

FIG. 2. Dependence of the effective resonance integral for the resonance of iron at 1180 ev on the effective thickness of the specimen $\bar{l}$ (in number of nuclei per cm²). For the points × and •, the γ rays were registered with a scintillation counter; for the points ○ they were registered with a proportional counter.

On the other hand, the contribution to R'_γ, which we measured in the energy region $E > 6$ kev, agrees with the value calculated by Goldstein and Kolos[7] on the basis of the parameters of known resonances of iron.

2. Silver and Gold. Measurements of the average cross sections were made with samples of metallic silver (effective thicknesses 0.6 and 0.2 mm) and gold (effective thicknesses 0.6 and 0.2 mm) with the aid of scintillation counters.

Figures 3 and 4 show the energy dependence of the cross sections of the (n, γ) reactions for silver and gold (dark and light circles — measurement data with samples of 0.2 and 0.6 mm effective thickness, respectively). For $R < 1$ kev, at an effective specimen thickness $\bar{l} \gtrsim 0.2$ mm, the result is influenced by the thickness of the specimen (the well known effect of the blocking of strong resonances).

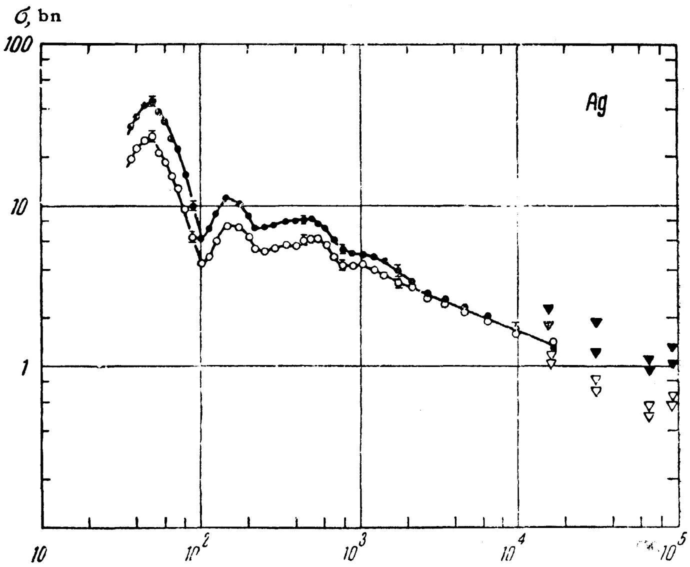

FIG. 3. Energy dependence of the neutron-capture cross section in silver. ▽ – points taken from the first edition of the handbook[8] (1955). ▼ – points taken from the second edition of the handbook[8] (1958).

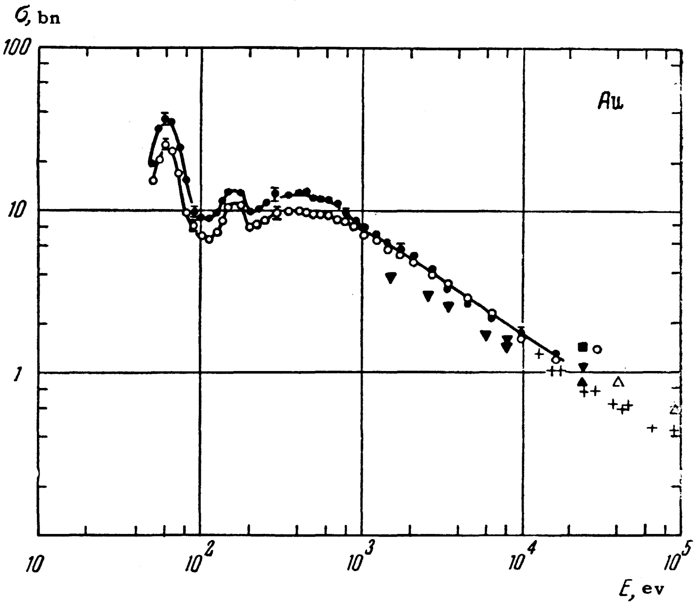

FIG. 4. Energy dependence of the neutron-capture cross section in gold. The points outside the smooth curve were taken from the handbook.[8] The notation of reference 8 was retained.

In the case of silver, the measurements of the average cross sections of the reaction (n, γ) were carried out earlier only for $E > 10$ kev, but the data given in the first and second editions of the cross-section handbook[8] differ from each other by a factor of 2.

The energy variation of the cross section in the region $E \sim 10$ kev agrees in the case of gold with other data,[8] but for $E \sim 1$ kev our results are 30 to 40% higher.

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*To explain the irregularities in the regions of 50, 130, and 360 ev it is enough to propose the presence of molybdenum (0.03%, based on the number of nuclei), cobalt (0.008%), and manganese (0.05%) impurities. No chemical analysis of the specimens was made. The total contribution of these impurities to R'_γ amounts to approximately 1×10^{-2} bn and is not included in the value of $R'_\gamma = 0.12$ bn.

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[1] Bergman, Isakov, Murin, Shapiro, Shtranikh, and Kazarnovskiĭ, Paper P-642, Transactions of the Geneva Conference **4**, 166 (1955).

[2] Kashukeev, Popov, and Shapiro, Атомная энергия (Atomic Energy), in press.

[3] Bergman, Isakov, Popov, and Shapiro, JETP **33**, 9 (1957), Soviet Physics JETP **6**, 6 (1958); Ядерные реакции при малых и средних энергиях (Nuclear Reactions at Small and Medium Energies), Academy of Sciences Press, 1958, p. 140.

[4] Spivak, Erozolimskiĭ, Dorofeev, and Lavrenchik, Transactions of the Geneva Conference **5**, 113 (1955).

[5] R. McClean and H. Pomeranz, ibid. **5**, 119 (1955).

[6] V. B. Klimentov and V. M. Gryazev, Атомная энергия (Atomic Energy) **3**, 507 (1957).

[7] H. Goldstein and M. Kolos, Transactions of the International Conference on the Interaction Between Neutrons and Nuclei, New York, 1957, p. 30.

[8] D. J. Hughes and R. B. Schwartz, Neutron Cross Sections, 2nd edition BNL, 1958, p. 325.

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STRUCTURE OF THE GIANT RESONANCE IN PHOTONUCLEAR REACTIONS

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IT was shown in the work of Danos[1] and Okamoto[2] that, in the case of nuclei having the shape of an ellipsoid of revolution, the cross section for photonuclear reactions should have two maxima, rather than one as in the case of spherical nuclei. These authors began from a two-fluid model of the nucleus, which leads to the equation and boundary condition

$$\nabla^2 \Psi + k^2\Psi = 0, \qquad (\mathbf{n}\,\mathrm{grad}\,\Psi)_S = 0, \qquad (1)$$

where Ψ is the deviation of the proton density from its equilibrium value, k is the wave vector connected with the frequency of vibration ω by the relation $k = \omega/u$ (u is the velocity of "sound" in the nucleus), n is the normal to the surface of the nucleus and S is the surface of the nucleus.

Solution of Eq. (1) in spheroidal functions, and subsequent calculation of eigenvalues k for dipole oscillations, showed that the eigenvalues could be approximately represented by the formula $k_i = 2.08/R_i$, where R_i is the corresponding axis of the ellipsoid. The question arises as to whether this result is still valid in the general case of an ellipsoid with three axes. This is of particular interest in connection with the theory of nonaxially symmetric nuclei, developed by Davydov and his collaborators.[3] In fact, the presence of three maxima in the region of the giant resonance would be the most direct demonstration of the existence of nonaxially symmetric nuclei.

In calculating the eigenvalues we use a variational principle,[4] according to which the eigenvalues of (1) are obtained from the minima of the corresponding functional

$$k^2 = \min \int (\nabla\Psi)^2\, dV \Big/ \int \Psi^2\, dV, \qquad (2)$$

where the integration is carried out over the nuclear volume. In so far as (2) possesses a stationary property, we can choose as trial functions the functions Ψ_i^0 which are solutions to (1) for a spherical nucleus of equal volume:

$$\Psi_1^0 = j_1(k_0 r)\cos\vartheta, \qquad \Psi_2^0 = j_1(k_0 r)\sin\vartheta\cos\varphi,$$
$$\Psi_3^0 = j_1(k_0 r)\sin\vartheta\sin\varphi, \qquad (3)$$

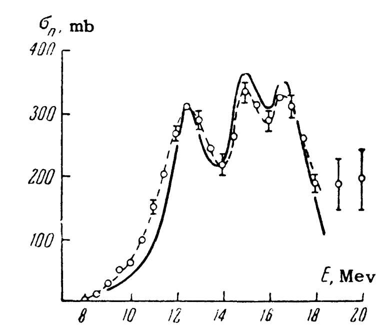
where $k_0 = 2.08/R_0$ (R_0 is the radius of the nucleus). Since the values k_0 are three-fold degenerate, then, in general, one should take linear combinations of the functions (3) as trial functions and then vary the coefficients in these linear combinations. However, there is no need for this in our case; the functions (3) are already the correct functions. This is connected with the fact that they transform according to different representations of the symmetry group of the ellipsoid (group D_{2h}).

Substitution of (3) into (2) and calculation of the integrals to within quantities of first order in the deformation of the nucleus leads to the result

$$k_i = \frac{2.08}{R_i}\left(1 + 0.08\,\frac{\Delta R_i}{R_0}\right), \qquad \Delta R_i = R_i - R_0. \qquad (4)$$

Comparison of this formula in the axially symmetrical case with exact calculations of Danos[1] shows that the values of k_i are given, in the worst case, to an accuracy of 1%.

Splitting of the giant resonance into three maxima, as given by (4), appears to be shown in the experiments of Fuller and Weiss[5] in the nucleus Tb^{159} (see the figure), although this has not been noted by them. Approximating the experimental data by the sum of three resonance curves gives



Giant resonance in the (γ, n) reaction in Tb^{159}. The circles show the experimental points, and the dashed curve is drawn through these points. The solid curve represents the sum of three resonance curves within the parameters indicated in the text.