FISSION OF U^{238}

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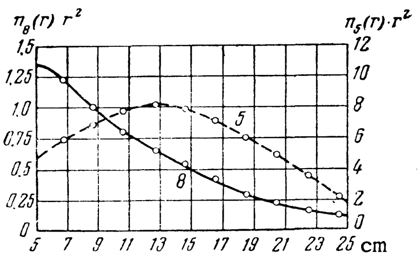
IN connection with the problem of the operation of many types of nuclear reactors, it becomes interesting to study the fission of U^{238} by fission neutrons in large masses of uranium. In this work we describe measurements, performed in 1954, of the total number D of fissions of U^{238}, that take place in an infinite block of uranium when a single fission neutron is admitted into the block.

The experiment was set up in the following manner. A disc of U^{235} ("converter") was placed in the center of a hollow sphere of natural uranium (outer radius 25 cm, inner radius 5 cm). A collimated beam of thermal neutrons, from the reflector of the reactor of the atomic electric station, was aimed at the converter, which served as a source of fission neutrons.

A system of shields made of cadmium and boron prevented the thermal neutrons from entering inside the uranium sphere. The effect of the neutrons over the cadmium was eliminated by measurements in which the neutron beam was covered with a sheet of cadmium. A vertical channel filled with uranium inserts was drilled through the upper hemisphere, and detectors could be placed between the inserts.

The detector employed were flat fission chambers with layers of natural and enriched uranium. Comparison of the counts of these chambers in an identical flux of thermal neutrons made it possible to calculate the distribution of fissions of U^{238} and U^{235} from the measured distributions.



r-distance from center of sphere

The diagram shows the distributions obtained in this manner. For convenience, the ordinates represent the quantities $n(r)r^2$. The values of these quantities, measured in the absence of a uranium sphere, are taken to be unity. During these measurements, the positions of the converter and of the shields remained the same as before. Were the uranium sphere used in these experiments infinitely thick and consisting of pure U^{238}, the value of D would satisfy the equation

$$D = N\sigma_{f8}\int_{r_0}^{\infty} n_8(r)\, r^2\, dr, \qquad (1)$$

where M is the number of nuclei per cm^3, $n_8(r)$ is the distribution of U^{238} fissions normalized in the manner indicated above, σ_{f8} the cross section for the fission of U^{238} by the fission neutron. The latter quantity was taken to be 0.31 ± 0.01 barns, a value previously obtained.*

Actually, in order to determine D it is necessary to take into account the fission of the U^{235} contained in the sphere, and the number of neutrons capable of fissioning U^{238} which may leak from the sphere. Corrections for these effects, which do not play an important role in our problem, were introduced by using the measured distribution of the U^{235} fissions and the value of the leakage, which was measured by means of an effective fission chamber with layers of U^{238}; the chamber was located at a large distance from the sphere.

The value of D was thus found to be 0.17 ± 0.01. Knowing D, it is possible to determine k_∞ for pure U^{238}:

$$k_\infty = D\nu_8 / (1 + D\nu_8), \qquad (2)$$

where ν_8 is the average number of neutrons, liberated by fission of U^{238}. Taking $\nu_8 = 2.85 \pm 0.06$ (Ref. 2), we obtain $k_\infty = 0.325 \pm 0.011$.

If the distribution of the neutrons, capable of fissioning U^{238}, is expressed in terms of the Peierls single-group kinetic equation, D will be related to the known parameters α and β of this equation by

$$D = \sigma_{f8} N / (\alpha - \beta). \qquad (3)$$

Using this relation and selecting one of the parameters such as to make the experimental distribution of the U^{238} fissions in the sphere fit best the values calculated by means of an exact solution of the kinetic equation, it is possible to determine the parameters α and β. Thus, we obtained $\alpha = 0.201 \pm 0.007$ and $\beta = 0.115 \pm 0.004$. The distribution of the U^{238} fissions, calculated with the aid of these parameters, is shown on the diagram (solid curve).

The procedure employed in these experiments can be used for the measurement of the transport parameters of various substances at various energies. For example, we placed a source of 0.8 –

1.0 photoneutrons (Na — Be) in the center of a uranium sphere, measured the distribution of the Np^{237} fissions, and were able to determine the transport parameters of U^{238} for a group of neutrons with energies 0.5 — 1.0 Mev. The values obtained in this case were $\alpha = 0.22 \pm 0.01$ and $\beta = 0.187 \pm 0.008$.

*This value is in excellent agreement with the results of measurements made by Leachman and Schmitt[1] (0.307 ± 0.005 barns).

[1] R. B. Leachman and H. W. Schmitt, J. Nucl. Energy **4**, 38 (1957).
[2] Kuz' minov, Kutsaeva, and Bondarenko, Атомная энергия (Atomic Energy) (in press).

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CONCERNING THE SYNTHESIS OF THE SHAPE OF THE FERMI SURFACE IN METALS

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THE synthesis of the shape of the Fermi surface $\epsilon(\mathbf{p}) = \epsilon_0$ (where ϵ and $\mathbf{p}$ are the energy and quasi momentum of the conduction electron, and ϵ_0 is the limiting Fermi energy) from the experimental results is a task of great importance to the theory. I. M. Lifshitz and A. V. Pogorelev proposed[1] a method of such a synthesis from the extremal areas S_{ext} of the cross-sections of the Fermi surface. These areas can be determined from the periods of the oscillations of the magnetic susceptibility χ in the de Haas — van Alphen effect.

As a rule, however, harmonic analysis of the experimental curves of $\chi(H)$ is a rather difficult task, owing to the large number of harmonics. In this work we propose a method whereby S_{ext} and the radius vector of the surface $\mathbf{p}$ can be determined directly as a function of the direction $\mathbf{p}/p$ for various harmonics.

Let us examine the de Haas — van Alphen effect in a film in a constant magnetic field oriented in an arbitrary manner.

For brevity we shall assume that the Fermi surface is a single closed convex surface. Then, if the orbit corresponding to the central cross-section "is not contained" in a film of thickness D, i.e.,

$$D < d = \left| \int_{t_0'}^{t_0''} v_\zeta \, dt_2 \right|_{p_z=0,\, \varepsilon=\varepsilon_0} = \left| \cos\Phi \int_{t_0'}^{t_0''} v_z \, dt_2 + \sin\Phi \, \frac{2cp_x^{\max}}{|eH|} \right|_{p_z=0,\, \varepsilon=\varepsilon_0},$$

$$v_\zeta(t_0') = v_\zeta(t_0'') = 0; \quad v_\zeta'(t_0') < 0; \quad v_\zeta'(t_0'') > 0$$

(t is the time of one electron revolution in the orbit, $\mathbf{v} = \nabla_p \epsilon$ is the electron velocity, and the other symbols are as indicated in the diagram), then all the electrons collide with the surface, and the amplitude of the quantum oscillations of χ is proportional to at least the second power of $\mu H/\epsilon_0$ (where μ is the Bohr magneton for the conduction electron. The second power is obtained under the case which is most favorable in this sense, namely of specular reflection of the electrons from the surface — see Ref. 2.)

If, however, the orbit corresponding to the central cross-section "is contained" in the film ($D > d$), with

$$(l / D) \cos\Phi \, (\mu H / \varepsilon_0)^{1/2} \ll 1$$

(ℓ is the mean free path of the electrons), then the electrons corresponding to the central cross section and contributing to the quantum oscillations will not collide with the surface. They satisfy the relation

$$\bar{v}_z(p_z) \approx \bar{v}_z(0) + \bar{v}_z'(0)\, p_z \sim v\, (\mu H / \varepsilon_0)^{1/2}.$$

Their energy spectrum coincides in the quasi-classical case with the spectrum in the bulk metal, and the amplitude of the corresponding quantum oscillations is proportional, as can be readily seen, to $(\mu H/\epsilon_0)^{3/2}$. In this case the magnetic moment differs from the magnetic moment of the bulk metal[3] only in that instead of D the formulas contain D – d, corresponding to those electrons