FISSION OF $Pu^{238}$ BY s AND p NEUTRONS

S. B. Ermagambetov and G. N. Smirenkin
Submitted 27 March 1969
ZhETF Pis. Red. 9, No. 9, 510-513 (5 May 1969)

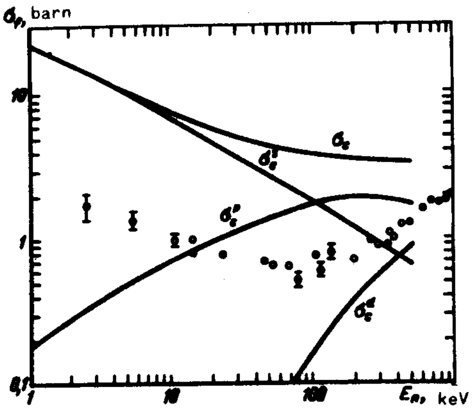
The question of the great disparity occurring in subbarrier fission, between the fission widths of the lowest resonances $\Gamma_f^r$ and the energy dependence of the average fission width $\overline{\Gamma}_f\ (E_n)$, observed in the fission by fast neutrons below the threshold, has been raised in the literature many times in recent years [1 - 5]. In most reliably investigated nuclei, the width $\overline{\Gamma}_f\ (0)$ extrapolated to zero neutron energy in larger than $\Gamma_f^r$ by 1 - 3 orders of magnitude [2, 3, 5].

The explanation of this effect within the framework of the notions accepted until recently encountered many difficulties. In connection with the analysis of the contradiction between $\Gamma_f^r$ and $\overline{\Gamma}_f\ (0)$, a hypothesis was advanced in [3] that the parity of the angular momentum introduced by the bombarding particles plays a special role in the mechanism of the fission process. This hypothesis leads to a suppression of the probability of fission by neutrons with even orbital angular momenta and, in particular, by s-neutrons. These considerations contradict data on the fission of even-even compound nuclei in (n, f) reactions on the target nucleus $Th^{232}$ [4].

A more natural and noncontradictory interpretation of the observed discrepancies in the widths $\Gamma_f^r$ and $\overline{\Gamma}_f\ (0)$ was offered in [5] within the framework of the concept of the two-lump fission barrier [6]. The discussed effect has a common nature with the recently discovered [7] phenomenon of modulation of the height of the fission resonances, and is essentially its consequence. According to [5], the scale of the fluctuations of $\Gamma_f^r$ is very large, much larger than given by the Porter-Thomas theory, and the main contribution to $\Gamma_f^r$ is made by relatively narrow groups of strong resonances near the levels in the well between the "humps." In the interval between the levels, which on the average is much smaller than the level width, we have $\Gamma_f^r \ll \overline{\Gamma_f^r}$. These relations explain the apparent effect of s-wave suppression. There is apparently no essential discrepancy at medium widths $\Gamma_f^r/\overline{\Gamma}_f\ (0) \sim 1$. This has been firmly established by an analysis of the level width in the reactions $Pu^{240}$ (n, f) and $Np^{237}$ (n, f) [7]. An experimental investigation of a wider group of nuclei is of interest.

In the present paper we report experimental data on the fission cross section of $Pu^{238}$ in the subbarrier and near-barrier region of the neutron energies $E_n$. For $Pu^{238}$ we have $\Gamma_f^r/\overline{\Gamma}_f\ (0) \sim 2 \times 10^{-2}$ [5, 8].

The results of individual measurements of $\sigma_f$ of $Pu^{238}$ with an electrostatic generator, using $U^{235}$ as a reference, are shown in the figure. In the region $E_n \geq 0.1$ MeV they are in satisfactory agreement with the renormalized data of [8, 9] (see [10]). A remarkable feature of the measured course of $\sigma_f\ (E_n)$ in the systematic increase of the fission cross section in the low-energy section of $E_n$, down to 2.7 keV. From the partial cross section for compound-nucleus production, shown in the figure for s-and p-neutrons, it follows that: 1) if $\Gamma_f^s \ll \Gamma_f^e$ were true, then $\sigma_f$ would not increase by three times in the investigated interval $E_n < 50$ keV, as in the experiment, but would decrease by approximately the same factor;




Neutron fission cross section of $Pu^{238}$. Curves - compound-nucleus production cross section and its partial components for s, p, and d neutrons (calculations in accordance with the optical model)

2) the rise of $\sigma_f$ with decreasing $E_n$ in the noted region, agrees fully with the character of variation of $\sigma_c \approx \sigma_c^s$.

We can conclude from the foregoing, even without resorting to a more detailed description of the variation of $\sigma_f$ $(E_n)$, which is beyond the scope of the present communication, that in the case of $Pu^{238}$ + n the average fission widths for the s and p neutrons are comparable, in contradiction to the conclusions of [3, 8].

The authors are grateful to V. F. Gerasimov for supplying the sample of isotopically pure $Pu^{238}$, A. V. Ignatyuk for a discussion of the results, and M. K. Golubeva for taking part in the experiment.


[1] N. S. Rabotnov and G. N. Smirenkin, JINR Preprint 1845, 112, 1964.
[2] E. R. Rac, Phys. and Chem. Fission, Vienna, 1, 187 (1965).
[3] P. E. Vorotnikov, Yad. Fiz. 5, 1021 (1967) [Sov. J. Nuc. Phys. 5, 728 (1967)].
[4] S. B. Ermagambetov, V. F. Kuznetsov, and G. N. Smirenkin, ibid. 5, 257 (1967) [5,181(1967)]
[5] A. V. Ignatyuk, N. S. Rabotnov, G. N. Smirenkin, Phys. Lett. (in press); FEI Preprint 158 (1969).
[6] V. M. Strutinsky and S. Bjornholm, Int. Symp. Nucl. Structure, Dubna, 1968.
[7] E. Migneco, G. Theobald, Nucl. Phys. A112, 603 (1968); A. Fubini, J. Blons, A. Michandon, and D. Paya, Phys. Rev. Lett. 20, 1373 (1968).
[8] P. E. Vorotnikov, S. M. Dubrovina, G. A. Otroshchenko, and V. A. Shigin, Yad. Fiz. 3, 479 (1966) [Sov. J. Nuc. Phys. 3, 348 (1966)].
[9] Neutron Cross Sections, BNL-3, 325 (1965).
[10] S. B. Ermagambetov and G. N. Smirenkin, Atomnaya energiya 25, 527 (1968).