Average resonance parameters of 236^{236}U

L. L. Litvinskiĭ, M. F. Vlasov, and G. M. Novoselov
Institute of Nuclear Research, Ukrainian Academy of Sciences, 252028 Kiev, Ukraine

(Submitted 16 June 1994)
Pis'ma Zh. Eksp. Teor. Fiz. **60**, No. 3, 155–157 (10 August 1994)

The average resonance parameters for s and p waves are determined through an analysis of data in the literature on the total neutron cross sections and the cross sections for the radiative capture of neutrons by ^{236}U, averaged over the resonances. © *1994 American Institute of Physics.*

1. Information on the average resonance parameters of nuclei in the mass-number region $A\sim 230-240$ is extremely scanty and often contradictory. The most reliable neutron data for these nuclei correspond to the region of resolved resonances. [1] Information of this sort leads to a comparatively reliable determination of local values of the average resonance parameters of an s-neutron wave, such as the potential-scattering radius R_0', the average distance between s resonances, D_0, their average radiative width $\Gamma_{\gamma 0}$, and the s-neutron strength function S_{n0}. Even these properties, however, are afflicted by comparatively large fluctuation errors, which stem from the limited number of neutron resonances whose parameters have been determined experimentally.

For the p partial wave, the parameters extracted from data from the region of resolved resonances are extremely unreliable. Information of this sort would be of considerable interest in connection with the existence of a $4p$ one-particle peak in the p-neutron strength function S_{n1} in the region $A\sim 230-240$ (Ref. 1).

Reliable information on the average resonance parameters for partial waves with orbital angular momenta $l\geqslant 1$ can be found only through an analysis of neutron cross sections at intermediate energies, $E_n\leqslant 0.5$ MeV, averaged over the resonances. Only for ^{232}Th, ^{235,236,238}U, and ^{239}Pu in this region of mass numbers do we have comparatively comprehensive and reliable information on the average nuclear cross sections. [2] Experimental data on the cross sections of ^{238}U were analyzed in Refs. 3–5. In this letter we are reporting an analysis of data on the average total neutron cross section σ_t and the cross section for radiative capture of neutrons, σ_γ, of ^{236}U. This analysis was carried out in order to determine average resonance parameters of this nucleus. For the analysis we used what appeared to be the most reliable data [6] on σ_t (Fig. 1) and on [7] σ_γ(Fig. 2). The σ_t data were found by a method of high-flux beams of filtered neutrons. The data on $\sigma_\gamma$were obtained with the help of a multiplicity detector, which is currently one of the most reliable methods because of the high background-discrimination level.

A similar analysis of σ_t and σ_γ for ^{236}U, based on the experimental data available for energies $E_n\leqslant 1$ MeV before the publication of Refs. 6 and 7, was carried out in Ref. 8. The present paper differs from Ref. 8 in that it draws on more recent data and also in that a different energy range is being analyzed. The cross section for radiative capture was analyzed for energies $E_n\leqslant 40$ keV, which correspond to a closed inelastic-scattering channel. The maximum energy for σ_t was $E_n=144$ keV (Ref. 6). The present paper is

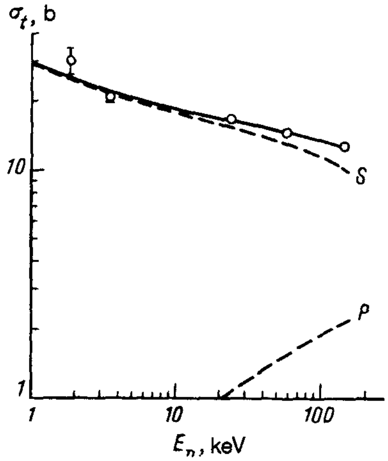

FIG. 1. Total neutron cross section of ^{236}U. Points—Experimental data of Ref. 6; solid curve—approximation of these data; dashed curves—contributions of the s and p partial waves.

thus free of the uncertainties stemming from the ambiguity of the optical-model parametrization of the cross sections in the case of open inelastic-scattering channels and partially overlapping resonances.

2. The method for analyzing the average cross sections was described in detail in Refs. 3 and 9 for the cases of ^{238}U and ^{187}Os. The cross sections were parametrized with the help of expressions derived in a single-level formalism of R-matrix theory, which is fairly rigorous in the vicinity of isolated resonances.[10] The parametrization of σ_t and σ_γ incorporated contributions to the interaction from neutron partial waves with $l \leqslant 3$. Fluctuation errors were assigned, along with experimental errors, to the data to be analyzed, in accordance with the approach described in Ref. 3.

Figures 1 and 2 show the results of a model-dependent approximation of the experimental data.[6,7] Also shown here are the contributions of the s and p partial waves to σ_t and σ_γ. The values found for the average resonance parameters of ^{236}U are

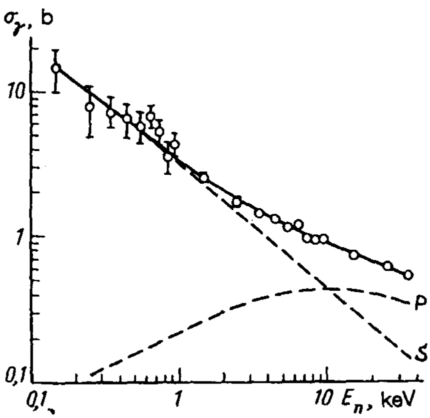

FIG. 2. Cross section for the radiative capture of neutrons by ^{236}U. Points—Experimental data; [7] solid curve— approximation of these data; dashed curves—s- and p-wave partial contributions.

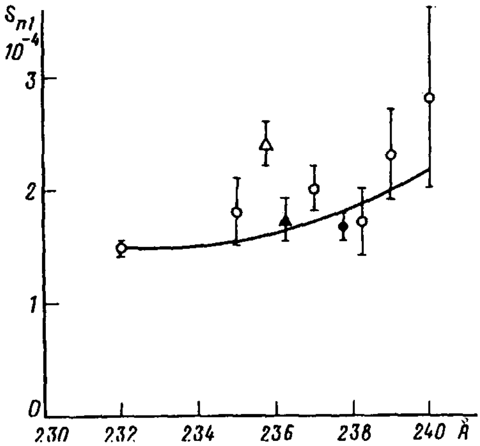

FIG. 3. Mass dependence of the p-neutron strength function in the region $A\sim 230$–240. Open circles, filled circles, open triangles, filled triangles—Results of Refs. 1, 3, and 8 and the present study, respectively.

$$S_{n0}=(1.22\pm 0.15)\times 10^{-4}, \quad \Gamma_{\gamma 0}=23.2\pm 2.0 \text{ meV}, \quad R_0'=10.40\pm 0.1 \text{ F},$$

$$S_{n1}=(1.73\pm 0.19)\times 10^{-4}, \quad \Gamma_{\gamma 1}=19.2\pm 2.0 \text{ meV}.$$

The value found for the s-neutron strength function agrees well with the results of other studies: $S_{n0}=(1.0\pm 0.1)\times 10^{-4}$ (Refs. 1 and 8), $S_{n0}=(1.23\pm 0.12)\times 10^{-4}$ (Ref. 6), and $S_{n0}=(0.95\pm 0.09)\times 10^{-4}$ (Ref. 11). A good agreement is also found for other parameters of the s-neutron wave: the potential-scattering radius [$R_0'=10.32\pm 0.12$ F (Ref. 6), $R_0'=10.15\pm 0.20$ F (Ref. 8)] and the average radiative width [$\Gamma_{\gamma 0}=23.0\pm 1.5$ meV (Ref. 1), $\Gamma_{\gamma 0}=22.8\pm 2.3$ meV (Ref. 8), and $\Gamma_{\gamma 0}=22.3\pm 2.0$ meV (Ref. 11)].

The value found for the p-neutron strength function agrees with the result of Ref. 11, $S_{n1}=(1.96\pm 0.16)\times 10^{-4}$, and is quite different from the data of Ref. 8, $S_{n1}=(2.4\pm 0.2)\times 10^{-4}$. The values recommended for S_{n1} in Refs. 1 and 6 have a fairly large error, $S_{n1}=(2.3\pm 0.6)\times 10^{-4}$, and cannot resolve the contradiction. Note that the value found for S_{n1} in Ref. 11 and the present study agrees better than the data of Ref. 8 with the systematics of data on the p-neutron strength function of nuclei in the mass-number region $A\sim 230$ –240 (Fig. 3). This circumstance is further evidence in favor of the validity of the value found for S_{n1}.

The value found for $\Gamma_{\gamma 1}$ in the present study agrees well with the data of Ref. 8: $\Gamma_{\gamma 1}=19.8\pm 1.0$ meV. A point which deserves special mention is that the results of Ref. 8 and the present study indicate a possible difference between the average radiative widths of the s and p resonances of ^{236}U, although these results cannot solidly confirm this difference. A similar indication was found in Ref. 3 for the nucleus ^{238}U: $\Gamma_{\gamma 0}=19.6\pm 1.5$ meV and $\Gamma_{\gamma 1}=18.0\pm 1.5$ meV. If this effect were to be confirmed, it would be evidence that the density of levels depends significantly on the parity of the states. This matter would deserve close attention.

In conclusion we should point out that the analysis of the present study did not make use of data of Ref. 6 on resonance self-screening in σ_t. Incorporating such data will seriously complicate the analysis procedure, but it will ultimately make it possible to increase the number of parameters of ^{236}U that can be determined and to improve their accuracy significantly.

[1] S. F. Mughabghab, in *Neutron Cross Sections* (Pergamon, New York, 1984), Vol. 2.
[2] V. McLane *et al.*, in *Neutron Cross Sections* (Academic, New York, 1988), Vol. 2, Neutron Cross Section Curves.
[3] L. L. Litvinskiĭ *et al.*, Yad. Fiz. **52**, 1025 (1990) [Sov. J. Nucl. Phys. **52**, 652 (1990)].
[4] G. M. Novoselov *et al.*, Preprint KIYaI-89-25, Institute of Nuclear Physics, Kiev, 1989.
[5] L. L. Litvinskiĭ and V. A. Libman, JETP Lett. **59**, 462 (1994).
[6] O. A. Purtov *et al.*, At. Energ. **75**, 396 (1993).
[7] Yu. V. Adamchuk *et al.*, *Neutron Physics* [in Russian] (TsNII, Atominform, 1988), Vol. 2, p. 242.
[8] L. E. Kazakov *et al.*, At. Energ. **64**, 152 (1988).
[9] L. L. Litvinskiĭ *et al.*, Yad. Fiz. **56**, 31 (1993) [Phys. At. Nucl. **56**, 17 (1993)].
[10] A. M. Lane and R. G. Thomas, Rev. Mod. Phys. **30**, 257 (1958).
[11] V. P. Lunev *et al.*, *Neutron Physics* [in Russian] (TsNII, Atominform, 1984), Vol. 1, p. 97.

Translated by D. Parsons