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Contents

MEASUREMENT AND ANALYSIS OF NEUTRON TRANSMISSION AND SELF-INDICATION OF THE NEUTRON RADIATIVE CAPTURE CROSS-SECTION FOR ^{238}U IN THE 5-110 keV ENERGY REGION

M.V. Bokhovko, V.N. Kononov, G.N. Manturov, E.D. Poletaev
V.V. Sinitsa, A.A. Voevodskij

Modern design methods for fast reactors require that accurate account be taken of effects related to the resonance structure of neutron cross-sections. Data on neutron transmission and self-indication of the radiative capture cross-section in the unresolved resonance region are an important source of information when trying to ascertain the parameters which characterize the influence of cross-section resonance behaviour. As shown in Refs [1-3], this type of data enables us to determine the resonance self-shielding factors for the neutron capture cross-section experimentally, and to improve the accuracy of mean resonance parameter values. This paper presents the results of the measurement and analysis of neutron transmission using the total cross-section and of self-indication of the neutron capture cross-section for ^{238}U in the 5-110 keV neutron energy region; the measurements and analysis were performed on a neutron spectrometer employing the EhG-1 pulsed-electrostatic accelerator at the Power Physics Institute.

The experiment to measure neutron transmission using the total cross-section T_t and the capture cross-section (self-indication) T_c was performed on the EhG-1 accelerator using the time-of-flight method to determine neutron energy and background discrimination.

Partial transmission T_c was measured using the self-indication method in which the neutron capture events in the sample indicator (thickness: $6.46 \cdot 10^{-3}$ atoms/b) were registered from prompt capture gamma quanta using a large liquid scintillation detector, and the neutron flux was recorded by a thin (1.0 mm) ^{6}Li-glass detector placed in front of the sample indicator. Sample filters made of metallic ^{238}U in seven different thicknesses (from $4.7 \cdot 10^{-3}$ to $1.9 \cdot 10^{-1}$ atoms/b) were used in the experiment to measure transmission values from 0.94 to 0.1. In a separate experiment, transmission

Table I

Results of transmission measurements using the total cross-section $T_t(E)$ for ^{238}U

E_n, keV	Filter thickness, atoms/b						
	4,7·I0^{-3} (I мм)	9,I·I0^{-3} (2 мм)	2,37·I0^{-2} (5 мм)	4,74·I0^{-2} (I0 мм)	7,07·I0^{-2} (I5 мм)	9,43·I0^{-2} (20 мм)	I,9·I0^{-I} (40 мм)
4–6	0,933±0,008	0,88I±0,008	0,7I9±0,007	-	-	0,296±0,009	0,098±0,008
6–8	0,939±0,008	0,88I±0,007	0,7I7±0,006	-	-	0,295±0,007	0,I03±0,007
8–I0	0,940±0,007	0,872±0,006	0,7I9±0,006	-	-	0,299±0,006	0,I03±0,006
I0–I4	0,940±0,005	0,884±0,006	0,7I8±0,005	0,525±0,009	0,398±0,008	0,299±0,005	0,I04±0,005
I4–I8	0,937±0,005	0,876±0,006	0,7I7±0,004	0,523±0,007	0,405±0,007	0,296±0,003	0,I02±0,004
I8–22	0,935±0,004	0,880±0,004	0,7I9±0,004	0,53I±0,006	0,400±0,005	0,288±0,002	0,093±0,003
22–26	0,937±0,004	0,88I±0,004	0,724±0,003	0,527±0,006	0,402±0,004	0,295±0,002	0,094±0,002
26–30	0,939±0,004	0,88I±0,004	0,722±0,003	0,527±0,006	0,398±0,004	0,292±0,002	0,093±0,002
30–40	0,939±0,004	0,883±0,004	0,73I±0,003	0,536±0,005	0,408±0,004	0,298±0,002	0,095±0,002
40–50	0,942±0,004	0,887±0,004	0,739±0,003	0,540±0,004	0,4I7±0,004	0,304±0,002	0,099±0,002
50–60	0,943±0,004	0,887±0,004	0,743±0,003	0,549±0,004	0,420±0,004	0,308±0,002	0,I00±0,002
60–70	0,945±0,004	0,893±0,004	0,748±0,003	0,554±0,004	0,425±0,004	0,3I6±0,002	0,I03±0,002
80–90	0,946±0,004	0,896±0,004	0,75I±0,003	0,563±0,004	0,435±0,004	0,324±0,002	0,I08±0,002
90–I00	0,950±0,005	0,899±0,004	0,757±0,003	0,565±0,003	0,440±0,003	0,328±0,002	0,II0±0,002
I00–I20	0,950±0,004	0,904±0,004	0,760±0,003	0,573±0,003	0,447±0,003	0,337±0,002	0,II4±0,002

Table 2

Results of transmission (self-indication) measurements using the capture cross-section $T_c(E)$ for ^{238}U

E_n, keV	Filter thickness, atoms/b				
	2,37·I0^{-2} (5 мм)	4,74·I0^{-2} (I0 мм)	7,07·I0^{-2} (I5 мм)	9,43·I0^{-2} (20 мм)	I,9·I0^{-I} (40 мм)
I0–I4	0,64I±0,069	0,438±0,060	0,329±0,060	0,22I±0,049	0,084±0,030
I4–I8	0,672±0,033	0,457±0,029	0,353±0,029	0,247±0,03I	0,083±0,02I
I8–22	0,683±0,025	0,477±0,02I	0,363±0,024	0,254±0,025	0,085±0,0I7
22–26	0,694±0,0I8	0,486±0,0I7	0,374±0,020	0,267±0,0I8	0,086±0,0I3
26–30	0,698±0,0I6	0,488±0,0I4	0,365±0,0I5	0,26I±0,0I2	0,083±0,0I2
30–40	0,7I8±0,0I5	0,507±0,0I2	0,375±0,0I2	0,27I±0,0I0	0,085±0,0II
40–50	0,726±0,0I4	0,5II±0,0I2	0,390±0,0II	0,279±0,0I0	0,084±0,0I0
50–60	0,73I±0,0I2	0,526±0,0I2	0,407±0,0II	0,290±0,009	0,095±0,009
60–70	0,738±0,0II	0,54I±0,0I2	0,4I2±0,0II	0,30I±0,008	0,093±0,007
70–80	0,745±0,0II	0,544±0,0I2	0,4I9±0,0I0	0,3II±0,008	0,I00±0,006
80–90	0,745±0,0I0	0,544±0,009	0,422±0,009	0,3I6±0,008	0,094±0,006
90–I00	0,749±0,0I0	0,55I±0,009	0,433±0,009	0,32I±0,008	0,098±0,006
I00–I20	0,753±0,008	0,562±0,007	0,443±0,008	0,327±0,007	0,I09±0,006

was also measured on the basis of the total cross-section T_t using a 1 cm thick ^{6}Li-glass detector. The experimental facility, the measurement methodology, and the background conditions are described in detail in Ref. [3]. Thanks to recent improvements in the experimental facility, the background conditions were significantly improved and more reliable results obtained.

Measurement results and their analysis. Tables 1 and 2 show the results of measuring transmission using the total cross-section T_t and the capture cross-section T_c as a function of energy and filter thickness, which values were obtained by averaging the data from three measurement runs. The transmission values T_t measured using "thin" and "thick" ^{6}Li-glass detectors agreed within the limits of measurement error and were averaged. The statistical accuracy of the data obtained for T_t is 0.2-0.5% for small sample filter thicknesses and deteriorates to 2-3% for a filter with a thickness of $1.9 \cdot 10^{-1}$ atoms/b (40 mm). For T_c the statistical error is higher and amounts to 1.5-4.0% and 5-20% for the above-mentioned filter thicknesses. The total error (given in Tables 1 and 2) includes - in addition to statistical uncertainty - uncertainty due to subtraction of the background, the level of which increases as one approaches lower neutron energies, and uncertainties due to the introduction of corrections for "dead" time in the recording apparatus, the isotopic composition of the sample filters, and other insignificant corrections.

Figure 1 compares the experimental data for T_t and T_c obtained for different filter thicknesses at various energies with the results calculated using the GRUKON software package, in which the neutron cross-sections and their functionals in the unresolved resonance region are computed using the Breit-Wigner formula, taking into account inter-level interference of levels and a correction for the contribution of distant resonances [4].

When we analysed the sensitivity of the T_t and T_c functionals to the effective potential scattering radius and the mean resonance parameters, we

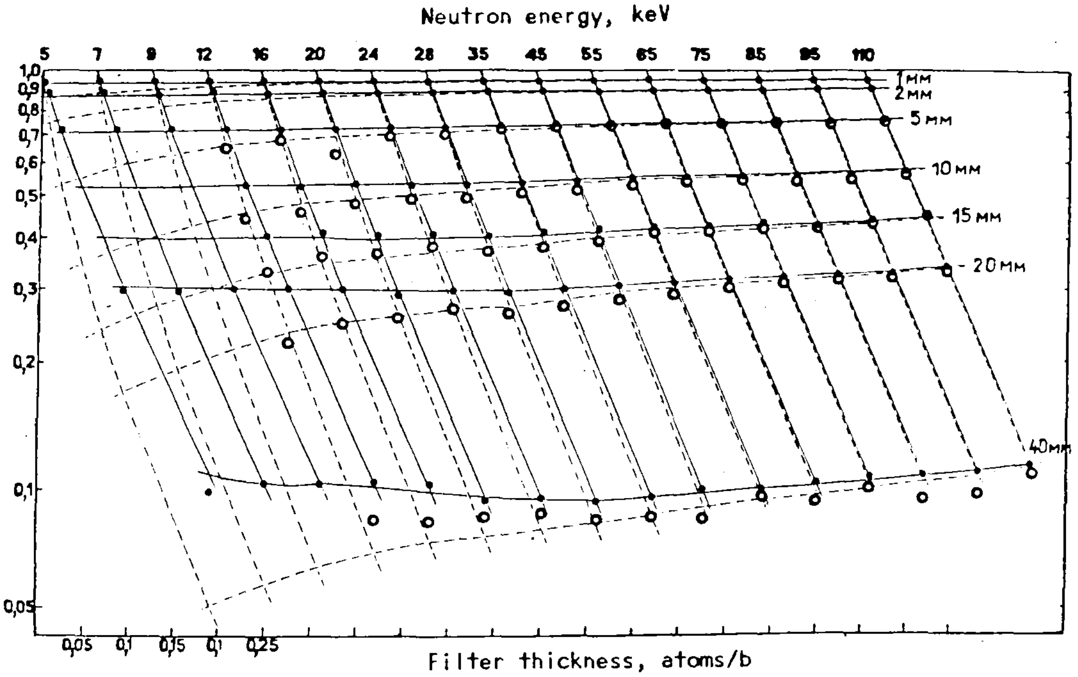

Fig. 1. Transmission values derived from the total cross-section T_t and the capture cross-section T_c as a function of neutron energy and filter thickness. Experiment: • – T_t, o – T_c; calculation: ——— – T_t, - - - – T_c.

found that T_t and T_c transmission values in the energy region in question were mainly dependent on s-neutron parameters and in particular the scattering radius R_0', sensitivity to which was an order higher than for other parameters. Therefore, when we fitted the calculated T_t and T_c transmission curves to the experiment, the mean resonance parameter values did not vary and were selected as follows: for s-neutrons (neutron Γ_n and radiation Γ_γ widths, and level spacing D) the values were taken from the analysis of resolved resonances in Ref. [5]; for neutrons with an orbital momentum $\ell = 1$ and $\ell = 2$ they were taken from the analysis of the neutron radiative capture cross-section in the 5-500 keV energy region in Ref. [6]. The energy dependence of the mean resonance parameters was taken from the data in Ref. [7].

When the calculated curves were fitted to the experimental data for T_t and T_c, we found that to achieve a satisfactory description of the experiment over the whole neutron energy range we needed to reduce the potential scattering radius R_0' smoothly from 9.35 fm at 1 keV to 8.9 fm at E_n = 110 keV. This result is not unexpected since calculations using the

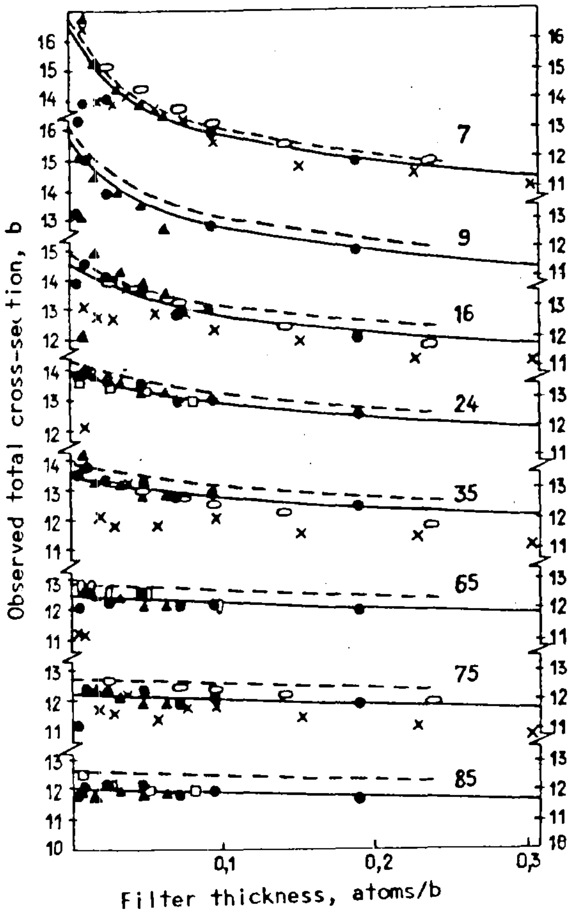

Fig. 2. Observed total cross-section as a function of filter thickness at various neutron energies: • - our results; ▲ - [9]; 0 - [10]; □ - [11]; x - [12]; ⊂⊃ - [13]; —— - calculated value with R_0' dependent on neutron energy; - - - - calculated value with $R_0' = 9.35$ fm.

optical model and the coupled-channel method [7, 8] indicate that, as neutron energy increases, there is a reduction in the absolute value of R_0^{∞}, which takes into account the contribution of distant resonances and the resonance linked to R_0' in the following manner: $R_0' = a(1-R_0^{\infty})$, where a is the radius of the nucleus and is $1.23\ A^{1/3} + 0.8 = 8.42$ fm. An alternative way of producing a satisfactory description of the experiment is to change the reduced neutron strength function S_n^0 in line with energy, but this would mean increasing it by approximately 40% at $E_n = 100$ keV, which is difficult to explain within the framework of generally accepted assumptions. Comparing our transmission results with the results of other authors is difficult since they all used different filter thicknesses and energy ranges. Therefore it is easier to compare them in terms of the so-called observed total cross-section $\sigma_t^{obs} = -(1/\tau)\ln T_t$, where τ is the filter thickness in atoms/b. Figure 2 shows the dependences $\sigma_t^{obs}(\tau)$ for the individual, selected energy intervals used in our work. The data from Ref. [9] are also given, averaged in

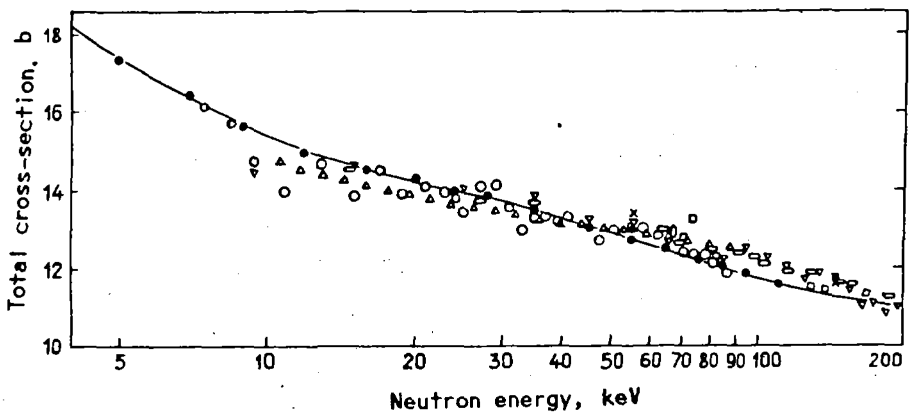

Fig. 3. Total neutron cross-section for ^{238}U: • – our results; o – [1]; Δ – [9]; 0 – [10]; □ – [11]; ⊂⊃ – [13]; ∇ – [14]; x – [15]; —— – value calculated using the GRUKON program.

Table 3

Total cross-section and resonance self-shielding factors f_t and f_c for ^{238}U obtained in our work

E_n, keV	σ_t,	f_t	f_c
4-6	17,32±0,52	0,564±0,045	-
6-8	16,43±0,45	0,637±0,045	-
8-10	15,64±0,40	0,680±0,041	-
10-14	14,96±0,38	0,731±0,037	0,827±0,041
14-18	14,49±0,35	0,782±0,035	0,873±0,035
18-22	14,28±0,33	0,818±0,034	0,903±0,033
22-26	13,95±0,30	0,842±0,033	0,922±0,031
26-30	13,82±0,29	0,863±0,032	0,937±0,028
30-40	13,42±0,28	0,888±0,031	0,934±0,024
40-50	12,98±0,27	0,915±0,030	0,970±0,022
50-60	12,68±0,25	0,932±0,029	0,974±0,021
60-70	12,46±0,25	0,945±0,028	0,979±0,020
70-80	12,16±0 25	0,953±0,029	0,983±0,019
80-90	12,04±0,25	0,962±0,029	0,985±0,018
90-100	11,84±0,25	0,967±0,029	0,989±0,018
100-120	11,55±0,25	0,973±0,029	0,991±0,018

Table 4

Comparison of the group constants obtained by us for ^{238}U with those in BNAB-78

BNAB group	E_n, keV	σ_t, b		f_t		f_c	
		Our result	BNAB	Our result	BNAB	Our result	BNAB
12	4,65-10,0	16,46±0,45	15,88	0,617±0,044	0,668	-	0,719
11	10,0-21,5	14,58±0,35	14,48	0,777±0,035	0,755	0,868±0,035	0,830
10	21,5-46,5	13,73±0,29	13,464	0,864±0,031	0,855	0,931±0,024	0,910
9	46,5-100	12,36±0,25	12,571	0,946±0,029	0,915	0,980±0,019	0,958

accordance with our energy intervals. The data from Ref. [10] for E_n = 66 keV, Ref. [11] for 24 and 82 keV, and Refs [12, 13] for the BNAB energy groups are presented in order to provide a fuller picture. The large spread of the experimental data at low filter thicknesses is evidence of the difficulties involved in high-precision measurements of transmissions for these thicknesses, and it can be inferred from this spread that the total cross-section values in the unresolved resonance region obtained by extrapolating the $\sigma_t^{obs}(\tau)$ dependence to zero filter thickness depend in large measure on the calculation model used. We used the GRUKON model with the parameters from Ref. [6] and an R_0' radius dependent on neutron energy. The results obtained for $\sigma_t(E)$ for ^{238}U are shown in Table 3, and Fig. 3 compares them with data from other sources [1, 9-11, 13-15].

The experimental data on self-indication $T_c(\tau)$ and the data on transmission $T_t(\tau)$ were used to determine the resonance self-shielding factors for the capture cross-section f_c in accordance with the expression $f_c = \int_0^\infty T_c(\tau)/\int_0^\infty T_t(\tau)$. The GRUKON calculation model was used to extrapolate the values of $T_c(\tau)$ and $T_t(\tau)$ to infinite filter thickness. The proportion of the extrapolated area under the transmission curves was approximately 15% of the total area.

Table 3 gives the resonance self-shielding factors obtained in this manner for the capture cross-section as a function of neutron energy $f_c(E)$, the evaluated error for this value, and the resonance self-shielding factors for the total cross-section calculated using the GRUKON program.

Comparing our experimental values for the total cross-section and the self-shielding factors with the data from BNAB-78 [16], we find (Table 4) that, on the whole, they agree with the values currently used for reactor calculations.

In conclusion, we should point out that experimental data on self-indication are no more help than transmission data when it comes to improving the accuracy of mean resonance parameters; however, they offer the only way of determining resonance self-shielding factors directly by experiment.

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RE-EVALUATION OF THE RESONANCE PARAMETERS OF ^{241}Pu

G.B. Morogovskij

The data for ^{241}Pu in the resolved resonance region need to be re-evaluated since the previous evaluation, on which the nuclear data file for ^{241}Pu [1] is based, was done in 1977-79. In the interim, evaluation software has improved (we ourselves have produced the RPSFC program [2], designed for use on EC-type computers, which permits the use of large quantities of experimental data on machine carriers and extends the scope for parametrization) and data have been produced on the radiative capture cross-section which did not exist previously. In addition, when the resonance parameters in Ref. [1] were calculated the criteria of the ENDF/B format were not kept to and conversion of the parameters into a form which complies with the requirements of that format did not yield entirely satisfactory values. For all the above reasons it was essential that the data for ^{241}Pu in the resonance region be re-evaluated, but the overriding factor was the availability of data on the σ_γ cross-section. The previous evaluation had determined parameters only for the σ_t and σ_f cross-sections, and the parameters for σ_γ (Adler parameters) were extrapolated from the latter in such a way that the mean group scattering cross-sections did not differ much from the potential scattering cross-section.

In our work we used experimental data on σ_t from Refs [3, 4], on σ_f from Refs [5, 6], and on σ_γ from Ref. [5].

All the samples used by the above authors contained impurities of ^{239}Pu, ^{240}Pu, ^{242}Pu, and ^{241}Am. Only in the experiment in Ref. [3] are the quantities of these impurities sufficiently small; in the rest they make a significant contribution to the cross-sections. This is particularly true of Refs [4, 5] for σ_γ. Certain of the impurity resonances practically coincide with the ^{241}Pu resonances, which makes processing of the experiment particularly difficult. Consequently, the contribution made by the impurities must be excluded from the experimental data to reveal the true shape of the ^{241}Pu cross-sections for the purposes of subsequent parametrization. The resonance parameters from Refs [7-10] and the data on sample thicknesses, resolution functions and temperatures from Refs [3-6] were used to solve this problem; the single-level Breit-Wigner formalism was used to calculate the contribution made by the impurities. In this way we obtained the σ_t, σ_f and σ_γ cross-sections for ^{241}Pu free of the above impurities, at least within the limits of available experimental data and the assumptions made in the calculations.

While not wishing to dwell on the quality of the source data used for the parametrization process in our paper, we should point out that, as can be clearly seen from Ref. [11], the quantity of experimental points for the cross-section is limited, they do not always describe the structure of the cross-section, and after the impurities have been excluded there are even fewer of them; also, there are no data at all on σ_γ for the 90.68, 91.81 and 95.36 eV resonances, which makes for additional difficulties in the calculations.

As in our previous paper [12], parametrization was carried out in two stages. First of all, the Breit-Wigner parameters were ascertained for the energy interval up to 100 eV (the source data set was a selection based on Refs [1, 11]), then they were used as source data in obtaining the set of Adler parameters. As in Ref. [12], the quality of the parametrization was evaluated on the basis of three criteria: 1. Mean divergence from experimental cross-sections of the shape of the cross-sections calculated using the parameters (in barns per experimental point); 2. The same in percentages; 3. The same for cross-sections averaged over the interval of one resonance. The set of parameters which best fulfilled all the criteria for all types of cross-section was selected, the parametrization being carried out for different weightings of the experiments processed both for the Breit-Wigner parameters and the Adler-Adler parameters.

The calculations revealed the following:

1. For practically all weightings the Adler-Adler parameters describe the experimental data on the total cross-section significantly better than the Breit-Wigner parameters. We cannot be quite so definite about the fission cross-section, and for the radiative capture cross-section preference should be given to the Breit-Wigner parameters. However, taking all the cross-section types together for all the criteria, the Adler parameters are to be preferred;
2. The use of a smooth file significantly improves agreement between the calculated shape of the cross-section and the experimental results for all cross-section types except σ_γ under criterion No. 2.

These results give us a clearer idea of the quality of the experimental data. The measurements of the total cross-section appear to be satisfactory, the fission cross-section measurements not quite so good, and the accuracy of the radiative capture cross-section measurements is poor [11]. Also, any experimental spread (and where there is only a small number of points on one resonance its weight increases) causes a rise in the interference parameter H for that resonance, which immediately worsens the description of the neighbouring levels. This effect is particularly noticeable in the radiative capture cross-section, and for that reason it is better to use the Breit-Wigner parameters for it. Since in many energy ranges this cross-section in the inter-resonance region is almost zero, the use of a smooth file for it would clearly significantly impair agreement between the calculated values and the experimental results under criterion No. 2, whereas it would significantly improve agreement for the total cross-section and the fission cross-section in those energy ranges. In general, the experimental data on ^{241}Pu are in poor agreement (a similar conclusion is drawn in Ref. [13]), since negative values for the scattering cross-section obtained by subtraction are produced both in the case of an independent description of each type of cross-section and when there is partial correlation of parameters (correlation of G parameters, as in Ref [12]). However, in the current situation, we need to correlate both the G and H parameters, even though this may adversely affect the description of the experimental results. The other possibility - plotting the scattering cross-section using a smooth file - is less desirable.

The best of the Breit-Wigner sets was used as the source set for obtaining correlated G and H resonance parameters. In the final set of parameters there is no interference for the majority of resonances (in all there are 13 resonances for which the H_t, H_f and H_γ parameters are not equal to zero), and parametrization was carried out for 78 levels in the 0-100 eV energy range. However, in a system where only the G parameters are correlated there are 47 such resonances. An analogous zero-interference parameter system is given in Ref. [14], where the authors parametrized their own fission and radiative capture experiments. Zero interference for the majority of resonances is proof not that there is no interference but, as stated above, that the experimental data do not tally. Given the requirement that the G and H parameters need to be consistent for all cross-section types, a parameter system entirely, or almost entirely, of the Breit-Wigner type reproduces the totality of the data best when the criteria outlined above are used.

A comparison of the cross-section results calculated using the final parameter set and parameters correlated only for G (best variant) revealed that the fully correlated parameter set was better for three types of cross-section (σ_t, σ_f and σ_γ) using criterion No. 1, for the total cross-section using criteria Nos 2 and 3 and for the radiative capture cross-section using criterion No. 3 whereas, for the σ_f and σ_γ cross-sections using criterion No. 2 and the σ_f cross-section using criterion No. 3, the best description was obtained using the set of partially correlated (for G only) parameters. Overall, for all three cross-section types and all three criteria, the fully correlated parameters reproduce the experimental cross-sections with somewhat greater accuracy than the partially correlated ones, and yield physically uncontradictory values for the scattering cross-section.

It should be pointed out that, at present, whatever parametrization system is used, the energy region up to 4 eV remains problematic. New measurements of the total cross-section and the radiative capture cross-section are needed to eliminate the current divergences in the experimental data caused by the high ^{240}Pu, ^{242}Pu and ^{241}Am impurity content of the samples; the accuracy with which the ^{240}Pu 1.06 eV and the ^{242}Pu 2.66 eV impurity resonances are taken into account has a direct impact on the calculated results for the σ_t and σ_γ cross-sections and, where all the cross-section types are being processed jointly, on the σ_f cross-section too. In the group cross-sections (see Table) this effect is very pronounced in groups 22-25, where the cross-sections are determined mainly using the parameters of the first three ^{241}Pu resonances at 0.26, 4.28 and 4.58 eV and also from the presence of the above-mentioned impurities in the 0.5-3.5 eV range. A comparison between mean group cross-sections calculated using a fully correlated parameter system supplemented by a smooth file and data from various libraries [15] shows that the fission cross-sections tally well in all groups up to 100 eV (only in group 25 the is the agreement not so good). The radiative capture cross-section is systematically lower in groups 22 and 24, and systematically higher in groups 18-21. In group 25 agreement can be considered good. The same is true of the total cross-section, although the level of agreement in groups 18-24 is good. The scattering cross-section is lower in groups 21-25, and in the remaining groups agrees well with data from other libraries. Thus there is a clear correlation between the σ_t and σ_γ cross-sections calculated using the parameters, which was only to be expected in view of the quality of the experimental data on the σ_γ cross-section. The smooth file for the 0.01-100 eV energy range contains approximately

Comparison of group constants

Group	σ_t					σ_f				
	ENDF/B	JENDL	SOKRAT	KEDAK	Our results	ENDF/B	JENDL	SOKRAT	KEDAK	Our results
25	1245,0	1188,7	1196,5	1380,6	1188,1	842,0	820,50	784,34	941,72	786,20
24	77,84	72,93	82,52	74,87	74,27	43,22	43,93	52,96	50,37	44,93
23	43,75	40,16	41,07	33,73	41,80	26,79	26,93	26,37	22,42	25,67
22	196,0	194,38	180,30	198,52	194,67	112,53	115,84	116,36	112,80	118,65
21	302,65	290,51	283,07	261,01	318,66	248,52	246,14	239,38	215,91	264,22
20	225,84	227,48	198,14	232,37	229,87	137,32	138,19	138,55	149,37	137,82
19	90,49	89,36	90,54	104,38	93,83	64,46	62,66	61,99	76,47	64,55
18	62,88	65,74	64,25	70,68	64,64	37,93	40,62	39,34	44,46	38,50

Group	σ_γ					σ_n				
	ENDF/B	JENDL	SOKRAT	KEDAK	Our results	ENDF/B	JENDL	SOKRAT	KEDAK	Our results
25	389,97	356,40	398,86	428,48	390,59	13,03	11,80	13,3	10,4	11,33
24	22,86	18,22	15,21	15,03	19,23	11,76	10,78	14,33	9,47	10,11
23	6,25	3,64	2,80	2,76	7,96	10,71	9,59	11,90	8,55	8,18
22	69,76	69,90	54,20	77,50	67,75	13,71	8,64	9,74	8,22	8,27
21	40,10	33,07	26,48	34,82	43,78	14,03	11,30	17,21	10,28	10,66
20	69,75	72,79	43,11	66,54	73,30	18,77	16,50	16,48	16,46	18,15
19	13,35	13,51	10,09	15,42	16,54	12,66	13,19	18,46	12,49	12,75
18	11,80	11,35	10,02	12,92	12,79	13,15	13,77	14,89	13,30	13,34

190 points and provides much better agreement between the values calculated and both the experimental data and the mean group cross-sections from the various libraries.

The mean resonance parameters obtained by direct averaging are as follows: $\langle D\rangle = 1.29$ eV, $\langle\Gamma_n^o\rangle = 0.308$ meV, $S_0 = 1.10\cdot10^{-4}$, $\langle\Gamma_f\rangle = 319.0$ meV, $\langle\Gamma_\gamma\rangle = 41.4$ meV. The $\langle\Gamma_\gamma\rangle$ value is obtained by averaging over the 44 resonances with Γ_γ values in the 0.02-0.06 eV range. Of the remaining 34 resonances, 24 have an anomalously high Γ_γ value and 8 an anomalously low Γ_γ value, which is further proof of the poor quality of the experimental data on the radiative capture cross-section (averaging over all levels yields a value of $\langle\Gamma\gamma\rangle = 45.4$ meV.

The resonance parameters derived in this paper and the smooth file replace the analagous parameters in the evaluated nuclear data file for ^{241}Pu in Ref. [1], and can be used for calculations in the 1-100 eV range. Below 1 eV the file remains unchanged.

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