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Preparation of Nuclear Data for Detailed Calculation of the Neutron Spectrum in Fast Systems

V.V. Vozyakov, A.I. Voropaev, Kh.Sh. Abdullaev, M.F. Vorotyntsev, A.A. Van'kov, A.S. Krivtsov and V.A. Pivovarov

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PREPARATION OF NUCLEAR DATA FOR DETAILED CALCULATION OF THE NEUTRON SPECTRUM IN FAST SYSTEMS

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ABSTRACT

Various evaluations of nuclear data which are important in fast reactor calculations have been compared. The nuclear data tape which forms the basis of the calculation of detailed neutron and other physical characteristics of fast systems is described. The aim of these calculations is to compare the data with experimental results, to check the approximations used in the preparation of constants and to gain experience in the production and use of an evaluated nuclear data library.

In this paper we compare various evaluations of nuclear data for materials which are important in fast reactor claculations. The data are taken from the UKNDL (United Kingdom), KEDAK (Federal Republic of Germany) and ENDL (United States) libraries and evaluations produced in the USSR (Tables 1 and 2) [12-17].

Tables 3-14 list the group average capture and fission cross-sections for ^{235}U, ^{238}U, ^{239}Pu, ^{240}Pu, ^{241}Pu, Fe, Ni, Cr and Na calculated by means of the GRUKON and SPRUT programs [18, 19]. Tables 5-18 show the resonance self-shielding coefficients.

It has been assumed in the calculations that the intragroup spectrum corresponds to the Fermi form for energies $E < 2.5$ MeV and to a fission spectrum at high energies. The energy-range divisions correspond to those of the Bondarenko system of constants. A linear interpolation on a doubly logarithmic scale has been used for the cross-sections.

The tables also show the cross-sections corresponding to the ENDF/BIV evaluations. These were obtained by recalculating the self-shielded cross-sections derived at ANL for standard reactor conditions [1, 2]. The recalculation was based on evaluations from the BNAB-70 system of constants, the dilution cross-sections σ_0 and the resonance self-shielding coefficients f.

The numbers in the "working tape" columns of Tables 3-14 correspond to the nuclear data which have been used to form the intermediate library. This library forms the basis of an improved program for the detailed neutron spectrum in fast systems [3, 4]. The calculations are of interest for comparison with results of spectrometry measurements and for checking the various approximations used to prepare constants in reactor calculations.

The raw nuclear data on which the library is based are shown in Table 1. The library is recorded on two magnetic tapes. These contain point values of the cross-sections σ_t, σ_a, σ_S, σ_{in}, σ_f and σ_c, for the elements listed in Table 1, auxiliary arrays for E_i, Δu_i and exp $(\Delta u_i/2)$ and also the information required for calculating elastic scattering cross-sections at the points $u-r_j$ (r_j is the mean logarithmic energy loss for elastic scattering of the j-th isotope). The working tapes also contain the inelastic transition matrices from the 70-group JAERI system of constants, normalized by the accepted inelastic scattering cross-sections, the ^{238}U self-shielding coefficients in a sub-group representation in the unresolved resonance region and the Legendre-polynomial expansion coefficients of the angular distribution. The total amount of information on the tapes is ~2.5 x 10^6 numbers.

A single energy grid (~12 500 non-uniformly distributed data points between 10 MeV and 10 eV) is used for all the isotopes and makes it possible to retain a local description of the resonance characteristics of the cross-sections which is within 0.2% of the values in the raw files. It is clear from Table 2 that the number of data points per decade on the working tape is a factor of 2-3 greater than the number of points for the isotopes which are described in the greatest detail on the raw files.

The authors have carried out a number of test calculations to estimate the error in the detailed neutron spectrum and the group cross-sections averaged over this spectrum and to determine how these errors depend on the assumed cross-section interpolation law, the choice of the integration formulae, the density of the energy grid and so on [5]. It was found that the selected energy grid enables the error in the group constant calculation to be kept to ~0.5%.

From the data in Tables 3-18, it is possible to derive certain conclusions about the reliability of the accepted nuclear data and also to get an idea of the differences between the BNAB-70 system of constants (which is widely used in calculations) and more recent evaluations.

^{238}U (see Tables 3 and 15). The UKNDL (1972 evaluation) capture cross-section values are 10-15% higher in the energy range 2-0.1 MeV and 20% lower in the range 1-0.2 keV than the more recent ENDF/BIV and BNAB-Eh evaluations. The large difference in groups 19 and 20 between the ENDF/BIV cross-sections (obtained by recalculating the self-shielded cross-sections for standard reactor conditions) and the other evaluations indicates that in the calculation of fast systems one should not use the common procedure of allowing for the resonance self-shielding in terms of the "dilution" cross-section in the low-energy region, where there is a pronounced "skew" in the collision density. There is good agreement between the UKNDL and BNAB-Eh resonance self-shielding coefficients of the capture cross-section in the resolved resonance region (see Table 15), although the difference between the average cross-sections in this region is 10-15%. This is due to the fact that the self-shielding coefficients are considerably less sensitive (by a factor of 2-3) to the set of resonance parameters than to the average cross-sections [6].

^{235}U (see Tables 4 and 5). In general, the UKNDL fission cross-section agrees well with the evaluation by Kon'shin and Nikolaev. The exception is the energy range 20-5 keV (groups 10 and 11), where the difference is as much as 10%. The last column in Table 4 gives the ENDF/BV evaluation, which is based on the latest experimental data [7]. Although the difference between these data and the other evaluations is small, it has to be remembered that the ^{235}U fission cross-section is often used as a reference value. There is considerable scatter in the evaluations of the ^{235}U capture cross-section in the region below 100 keV. For a typical fast reactor composition, 18% of the captures in ^{235}U and ^{239}Pu are associated with this region.

^{239}Pu (see Tables 6, 7 and 18). In the energy region above 1 keV (groups above 15), the UKNDL evaluations of the fission cross-section are within 5% of later evaluations; groups 13 and 14 form an exception. In fast reactor compositions, ~90% of the ^{239}Pu fissions are associated with the 1 keV-1 MeV region and so the large scatter in the region $<$1keV does not have a very pronounced effect on the reactor characteristics. There is a large difference between the ENDF/BIV evaluations of the radiative capture cross-section and the Kon'shin and Nikolaev data below 100 keV (9 groups). This should lead to a difference of ~0.1 in the breeding ratio of a large breeder reactor. The difference between the UKNDL and BNAB resonance self-shielding coefficients in the resolved resonance region $E \leq 100$ keV (18 groups) is worthy of note. It may be recalled that the calculation of the resonance self-shielding coefficients involves the use of the point cross-section values in the UKNDL library with no recourse made to theoretical models in the unresolved resonance region.

^{240}Pu and ^{241}Pu (see Tables 8-10). Few experimental data are currently available on the radiative capture of these isotopes. The real accuracy of the evaluations is probably ~30%. As a result of experiments now being carried out in a number of countries, it will probably become necessary to change the existing data [8, 9]. There is considerable scatter in the region of the ^{240}Pu sub-barrier fission. Kon'shin's data on the ^{241}Pu fission cross-section agree more closely with the latest experimental results [10] than does the UKNDL evaluation.

Fe, Ni, Cr and Na (see Tables 11-14, 16 and 17). It is the resonance structure of the cross-sections of these isotopes which is mainly responsible for the fine structure in the neutron spectrum of fast systems. The correct calculation of the transport and moderation cross-sections in these regions is a problem if BNAB-type group-system constants are used in the calculations.

The uncertainty in the capture cross-section of these elements also has a pronounced effect on the characteristics of a large breeder. There is generally good agreement between the ENDF/BIV and TsYaD evaluations of the capture cross-sections for chromium and nickel. For iron, the difference is more noticeable. The ENDF/BII, III [11] data in the tables give an idea of the changes in the evaluations that have occurred over the last 7-8 years. It is clear from Table 14 that there is considerable scatter near the principal sodium resonance.

The selection of the accepted nuclear data has to a large extent been determined by the desire to speed up the derivation of numerical results and by the availability of technical resources. We have not therefore made use of the rather well documented evaluations by Kon'shin and his colleagues because of difficulty in mastering the programs for generating the detailed form of the cross-sections in the resonance region. However, a comparison shows that the difference between the accepted nuclear data and more recent evaluations is generally within the limits of existing errors (with the possible exception of the data for Ni, Cr and Na). We can therefore assume that we shall get a correct estimate of the difference between the physical characteristics derived with approximate and rigorous preparation of the constants by using the accepted working tape. During the comparison with results from experiments on critical assemblies, it will be possible to make operational changes in accordance with a given law in the principal cross-sections on the working tape (capture, fission and inelastic scattering) over wide energy ranges.

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Table 1

Nuclear data files included on the working tape

Nuclide	Library	File No.	Year of Evaluation
^{235}U	UKNDL	D-27I	1972
^{239}Pu	UKNDL	D-269	I972
^{240}Pu	UKNDL	B-402	I970
^{24I}Pu	UKNDL	B-408	I970
^{238}U	UKNDL	A-272	I972
Na	UKNDL	D-I82	I967
Be	ENDL	7009	I970
Mn	ENDL	7I3I	I970
H	ENDL	700I	I970
N	ENDL	70I2	I970
Cr	KEDAK		I969
Ni	KEDAK		I969
C	KEDAK		I969
Al	KEDAK		I969
O	KEDAK		I969
Fe	Ts Ya D Evaluation		I975
^{10}B	UKNDL	B-90	I970

Table 2

Number of data points per decade in the raw files and on the working tape

Nuclide	Energy ranges					
	IO–IOO eV	0,I-I keV	I-IO keV	IO-IOO keV	0,I-I MeV	I-IO MeV
^{235}U	770	504	260	I00	30	40
^{238}U	I54	II50	2I75	II	4I	67
^{239}Pu	468	560	I670	52	3I	56
^{240}Pu	30	7	I8	40	43	62
^{24I}Pu	478	72	22	26	23	27
Fe	7	9	227	450	I252	598
Ni	II	I4	44	I75	360	440
Cr	II	6	30	34	I65	293
Al	6	6	I5	27	I0I	I28
Na	20	7I	49	96	96	400
Number of data points on working tape	I794	2646	2663	937	235I	2I36

Table 3

$^{238}U(n,\gamma)$

Group No.	Energy range	UKNDL (working tape)	BNAB-70	ENDL-2	BNAB-Eh	ENDF/BIV	σ_0	f_c
I	10-6,5 MeV	0,006I	0,007(I5)	0,0057(-7)	0,0056(-8)	0,0036(-59)		
2	6,5-4	0,0I07	0,0I2(I2)	0,0I0 (-6)	0,0II (3)	0,0092(-I4)		
3	4-2,5	0,0253	0,024(-5)	0,020 (-2I)	0,02I (-I7)	0,024 (-5)		
4	2,5-I,4	0,0666	0,060(-I0)	0,047 (-29)	0,049 (-26)	0,059 (-I2)		
5	I,4-0,8	0,I38	0,I3 (-6)	0,II6 (-I6)	0,II3 (-I8)	0,II (-20)		
6	0,8-0,4	0,I32	0,I3 (-I)	0,I34 (2)	0,II8 (-I4)	0,II (-I6)		
7	0,4-0,2	0,I34	0,I4 (4)	0,I30 (-3)	0,I25 (-7)	0,I2 (-I0)		
8	0,2-0,I	0,I74	0,I8 (4)	0,I49 (-I4)	0,I59 (-9)	0,I6 (-8)		
9	I00-46,5 keV	0,268	0,26 (-3)	0,299 (I2)	0,262 (-2)	0,26 (-3)		
I0	46,5-2I,5	0,45I	0,45 (<I)	0,385 (-I5)	0,459 (2)	0,4I6 (-8)	60	0,99
II	2I,5-I0	0,663	0,66 (<I)	0,563 (-I5)	0,650 (-2)	0,59I (-II)	27	0,93
I2	I0-4,65	0,856	0,90 (5)	0,774 (-I0)	0,832 (-3)	0,868 (I)	30	0,83
I3	4,65-2,I5	I,00	I,3 (30)	I,07 (7)	I,34 (+34)	I,00 (<I)	2I6	0,85
I4	2,I5-I	I,52	2,0 (32)	I,83 (20)	I,8I (I9)	I,92 (26)	37	0,5I
I5	I000-465 eV	2,90	3,0 (3)	3,57 (23)	3,33 (I5)	3,25 (I2)	36	0,34
I6	465-2I5	3,9I	4,6 (I8)	4,65 (I9)	4,55 (I6)	5,2 (33)	39	0,22
I7	2I5-I00	20,3	20 (-2)	20,0 (-2)	20,0 (-I)	I5,9 (-22)	4I	0,II
I8	I00-46,5	I5,2	I7 (8)	I7,2 (I3)	I6,8 (I0)	I4,2 (-7)	54	0,I0
I9	46,5-2I,5	55,4	56 (I)	55,6 (<I)	60,9 (I0)	84,8 (53)	44	0,046
20	2I,5-I00	77,2	83 (8)	8I,3 (5)	82,2 (6)	359 (365)	65	0,058

Notes (on Tables 3-14). (1) The numbers in brackets are the differences (%) from the constants calculated according to the working tape. (2) The last two columns in Tables 3, 6, 7 and 11-14 give the dilution cross-sections and the resonance self-shielding coefficients for standard-reactor conditions. (3) The symbol * indicates that an (n, γ)-reaction cross-section includes the cross-sections for the (n, α) and (n, p) reactions. (4) The data in Tables 4-7 in the BNAB-Eh column correspond to the evaluations by M.N. Nikolaev and his colleagues (1975-77).

Table 4 - $^{235}U(n,f)$

Group Number	UKNDL (working tape)	BNAB-70	ENDL-2	Evaluation by V.A. Kon'shin	BNAB-Eh	ENDF/BV
I	I,54	I,67 (8)	I,7I (II)	I,63 (6)	I,63 (6)	I,68 (9)
2	I,08	I,I2 (4)	I,I0 (2)	I,I2 (4)	I,I2 (4)	I,I0 (2)
3	I,I6	I,22 (5)	I,I8 (2)	I,20 (4)	I,22 (5)	I,22 (5)
4	I,30	I,29 (-I)	I,28 (-2)	I,27 (-3)	I,27 (-2)	I,25 (-4)
5	I,24	I,2I (-2)	I,20 (-3)	I,22 (-2)	I,22 (-2)	I,I7 (-6)
6	I,I4	I,I6 (2)	I,I2 (-2)	I,I6 (2)	I,I5 (I)	I,I2 (-2)
7	I,28	I,32 (3)	I,25 (-2)	I,28 (0)	I,28 (0)	I,23 (-4)
8	I,50	I,52(I)	I,40 (-7)	I,47 (-2)	I,47 (-2)	I,50 (0)
9	I,77	I,80 (2)	I,64 (-7)	I,75 (-I)	I,77 (0)	I,76 (0)
I0	2,03	2,26 (9)	I,98 (-5)	2,07 (-I)	2,06 (-I)	2,03 (0)
II	2,86	2,87 (0,4)	2,56 (-I0)	2,55 (-II)	2,54 (-II)	
I2	3,72	3,60 (-3)	3,57 (-4)	3,47 (-7)	3,52 (-5)	
I3	4,96	5,2 (4)	4,70 (-5)	5,03 (2)	5,04 (2)	
I4	6,82	7,4 (8)	5,99 (-I2)	7,04 (3)	7,27 (6)	
I5	II,2	II,6 (4)	II,I (-I)	II,5 (3)	II,6 (4)	
I6	I6,8	I6,7 (-I)	I7,2 (2)	I6,5 (-2)	I6,7 (-I)	
I7	20,3	2I,3 (5)	2I,6 (6)	22,0 (8)	2I,3 (5)	
I8	34,0	34,5 (I)	34,5 (I)	35,0 (3)	34,3 (I)	
19	42,6	43,0 (I)	42,6 (I)	47,7 (3)	42,8 (I)	
20	48,0	50,0 (4)	52,5 (9)	49,7 (7)	49,8 (4)	

Table 5

$^{235}U\ (n,\gamma)$

Group number	UKNDL (working tape)	BNAB-70	ENDL-2	Evaluation by V.A. Kon'shin	BNAB-Eh
I	0,0024	0,02	0,005 (I08)	0,009 ([illegible])	[illegible] (358)
2	0,0045	0,03	0,0094 (I35)	0,018 ([illegible])	0,020 (400)
3	0,0II	0,04 (264)	0,0I7 (55)	0,030 (I7)	0,036 (272)
4	0,039	0,06 (54)	0,04I (5)	0,053 (36)	0,059 (5I)
5	0,096	0,I2 (25)	0,092 (-4)	0,I03 (7)	0,I09 (I4)
6	0,I44	0,I7 (I8)	0,I34 (-7)	0,I60 (II)	0,I62 (I2)
7	0,2I7	0,25 (I5)	0,226 (4)	0,253 (I7)	0,250 (I5)
8	0,357	0,38 (6)	0,343 (-4)	0,388 (9)	0,366 (3)
9	0,559	0,58 (4)	0,554 (-I)	0,539 (-4)	0,537 (-4)
I0	0,730	0,80 (I0)	0,794 (9)	0,754 (3)	0,742 (2)
II	0,978	I,05 (8)	0,987 (I)	I,00 (2)	I,07 (9)
I2	I,38	I,4 (I)	I,I5 (-I[illegible])	I,3I (-5)	I,23 (-II)
I3	I,86	2,I (I3)	I,42 (-24)	I,73 (-7)	I,64 (-I2)
I4	2,56	3,3 (29)	3,II (22)	3,40 (33)	2,78 (9)
I5	3,94	5,0 (27)	5,20 (32)	4,55 (I6)	4,55 (I6)
I6	7,69	8,[illegible] (I6)	8,I2 (6)	7,44 (-3)	7,25 (-I6)
I7	II,9	II,9 (0)	9,38 (-2I)	II,2 (-6)	I2,I (2)
I8	I3,7	I5,9 (I6)	I5,0 (9)	I7,2 (25)	I5,8 (-I5)
I9	27,6	24 (-I3)	23,4 (-I5)	29,5 (7)	24,0 (-I3)
20	43,0	42 (2)	46,4 (8)	46,4 (8)	4I,8 (-3)

Table 6

$^{239}Pu\ (n,f)$

Group number	UKNDL (working tape)	BNAB-70	ENDL-2	Evaluation by V.A. Kon'shin	BNAB-Eh	ENDF/BIV	ε_0	f_t
I	2,I0	2,2I (5)	2,I2 (I)	2,I7 (4)	2,23 (6)	2,22 (6)		
2	I,73	I,72 (-I)	I,68 (-3)	I,77 (2)	I,79 (4)	I,73 (0)		
3	I,82	I,86 (2)	I,8I (-I)	I,83 (0)	I,86 (2)	I,85 (7)		
4	I,98	I,97 (-I)	I,92 (-3)	I,93 (-3)	I,93 (-3)	I,93 (-3)		
5	I,75	I,76 (I)	I,76 (I)	I,78 (2)	I,78 (2)	I,75 (0)		
6	I,55	I,59 (3)	I,6I (4)	I,6I (4)	I,65 (6)	I,6I (4)		
7	I,46	I,53 (4)	I,57 (8)	I,50 (3)	I,5I (3)	I,5I (3)		
8	I,49	I,50 (I)	I,50 (I)	I,50 (0)	I,50 (I)	I,53 (3)		
9	I,6I	I,47 (-9)	I,56 (-3)	I,57 (-3)	I,6I (0)	I,60 (-I)		
I0	I,6I	I,60 (-I)	I,63 (I)	I,60 (-I)	I,6I (0)	I,72 (7)		
II	I,77	I,76 (-I)	I,84 (4)	I,68 (-5)	I,74 (-2)	I,74 (-2)	264	I,00
I2	2,08	2,20 (6)	2,I4 (3)	2,I5 (3)	2,I3 (2)	2,II (I)	360	0,98
I3	3,00	2,90 (-3)	2,64 (-I2)	3,04 (I)	3,28 (9)	2,73 (-9)	I443	I,00
I4	3,8I	4,30 (I3)	3,64 (-I4)	3,98 (4)	4,05 (6)	4,68 (23)	32I	0,9I
I5	8,II	7,70 (-5)	8,8I (9)	8,3I (2)	8,33 (3)	7,62 (-6)	539	0,89
I6	I3,9	I3,0 (-6)	I2,6 (-I0)	I3,I (-6)	I2,9 (-7)	I2,0 (-I4)	3I8	0,80
I7	20,7	I8,0 (-I3)	I9,4 (-6)	I9,4 (-6)	I8,9 (-8)	I8,4 (-II)	702	0,90
I8	50,8	56,0 (I0)	59,2 (I6)	6I,2 (20)	56 (I0)	70,3 (38)	455	0,54
I9	22,0	2I,0 (-4)	2I,4 (-2)	2I,2 (-3)	2I (-4)	8,70 (-60)	I075	0,[illegible]
20	I05	I05 (0)	I07 (2)	98,6 (-6)	I04,7 (-7)	40,0 (-62)	95I	0,67

Table 7

$^{239}Pu (n,\gamma)$

Group number	UKNDL (working tape)	BNAB-70	ENDL-2	Evaluation by V. A. Kon'shin	BNAB-Eh	ENDF/BIV	σ_0	f_c
I	0,002	0,0I	0,002 (0)	0,00I (-50)	0,0044 (I20)	0,0006 (-70)		
2	0,004	0,02	0,0035(-I2)	0,002 (-50)	0,0066 (32)	0,00I5 (-62)		
3	0,008	0,03	0,0048(-40)	0,003 (-62)	0,0I08 (35)	0,0032 (-60)		
4	0,0I8	0,04 (I22)	0,0II(-39)	0,0I3(-28)	0,0223(24)	0,0094(-48)		
5	0,043	0,04 (-7)	0,034(-2I)	0,048 (I2)	0,05I (20)	0,025 (-42)		
6	0,093	0,I0 (8)	0,057 (-28)	0,097 (4)	0,II2 (20)	0,09I (-2)		
7	0,I65	0,I6 (-3)	0,I25 (-24)	0,I55 (-6)	0,I54 (-6)	0,I80 (9)		
8	0,224	0,23 (3)	0,I90 (-I8)	0,2I0(-6)	0,20I(-I0)	0,220(-2)		
9	0,282	0,26 (-8)	0,24I(-I4)	0,296(5)	0,297(5)	0,350(24)		
I0	0,497	0,48 (-3)	0,4I3(-17)	0,492(-I)	0,536(8)	0,500(6)		
II	0,884	0,83 (-6)	0,720(-I9)	0,686(-22)	0,840(5)	0,9I7 (4)	264	I,00
I2	I,9I	I,70 (-II)	I,50 (-22)	I,62 (-I5)	I,52(-20)	I,70(-II)	360	0,88
I3	2,92	2,90(-0,7)	2,3I(-2I)	2,76(-5)	2,73(-6)	3,47(I9)	I443	I,00
I4	4,06	4,00(-I,5)	3,95(-3)	3,79(-7)	3,77 (-7)	5,47(35)	32I	0,9I
I5	5,I7	6,I0 (I8)	6,26 (2I)	6,56 (27)	6,89 (33)	9,84 (90)	339	0,89
I6	I0,9	II,0 (0,9)	II,I(I,4)	II,3(4)	I2,0 (I0)	I8,8 (72)	3I8	0,80
I7	I5,0	I5,0 (0)	I6,7 (II)	I5,0 (0)	I6,4 (9)	23,4 (56)	70I	0,80
I8	29,0	48,0 (65)	37,2 (28)	36,4 (26)	48,0 (65)	73,5 (I53)	455	0,55
I9	23,5	32,0 (36)	33,7 (44)	29,6 (26)	32,0 (36)	41,6 (77)	I075	0,72
20	70,9	67,0 (-5,5)	72,5 (2)	63,4 (-II)	66,8 (-I6)	29,5 (-58)	95I	0,67

Table 8

$^{240}Pu (n,f)$

Group number	UKNDL (working tape)	BNAB-70	ENDL-2	Evaluation by V. A. Kon'shin
I	I,9I	2,00	2,06	I,98
2	I,50	I,55	I,58	I,58
3	I,50	I,62	I,55	I,58
4	I,49	I,60	I,60	I,58
5	I,45	I,50	I,45	I,45
6	0,568	0,58	0,8I	0,569
7	0,I34	0,I2	0,25	0,I35
8	0,098	0,05	0,I5	0,076
9	0,064	0,03	0,I0	0,08I
I0	0,098	0,02	0,I0	0,II7
II	0,099	0,02	0,I0	0,II7
I2	0,079	0,02	0,I24	0,097
I3	0,I07	-	0,I66	0,I53
I4	0,I50	-	0,I68	0,287
I5	0,I58	-	0,26	0,269
I6	0,042	-	0,074	0,059
I7	0,042	-	0,20	0,I30
I8	0,048	-	0,35	0,I54
I9	0,I33	-	0,45	0,285
20	0,240	-	0,29	0,669

Table 9

$^{240}Pu(n,\gamma)$

Group number	UKNDL (working tape)	BNAB-70	ENDL-2	Evaluation by V.A. Kon'shin
I	0,0065	0,0I	0,0I4	0,007
2	0,0I2	0,02	0,02I (75)	0,0I4 (I7)
3	0,026	0,04 (54)	0,03 (I5)	0,030 (I5)
4	0,063	0,09 (43)	0,057 (I0)	0,078 (24)
5	0,I38	0,24 (74)	0,II3 (-I8)	0,I73 (25)
6	0,I75	0,26 (49)	0,I49 (-I5)	0,I66 (-5)
7	0,I8I	0,34 (88)	0,I2 (-33)	0,I87 (3)
8	0,2I8	0,45 (I06)	0,I5 (-3I)	0,254 (I6)
9	0,356	0,65 (83)	0,253 (-29)	0,425 (I9)
I0	0,598	0,90 (50)	0,487 (-I9)	0,750 (25)
II	0,832	I,30 (56)	0,696 (-I6)	I,08 (30)
I2	I,I5	I,80 (56)	0,994 (-I4)	I,37 (I9)
I3	I,65	2,70 (64)	I,60 (-3)	I,88 (I4)
I4	2,62	4,50 (72)	2,65 (I)	3,27 (25)
I5	4,89	6,50 (33)	4,54 (-7)	4,8I (-2)
I6	6,82	I2,0 (76)	7,24 (6)	7,85 (I5)
I7	20,3	I8,0 (-II)	2I,0 (3)	24,0 (I8)
I8	38,I	49 (29)	36,9 (-3)	42,4 (II)
I9	65,3	44 (-33)	63,2 (-3)	68,2 (5)
20	3I,I	28 (-I0)	32,6 (5)	30,9 (-I9)

Table 10

	$^{241}Pu(n,f)$			$^{241}Pu(n,\gamma)$		
Group number	UKNDL (working tape)	BNAB-70	Evaluation by V.A. Kon'shin	UKNDL (work. tape)	BNAB-70	Evaluation by V.A. Kon'shin
I	2,I2	I,70 (-20)	I,84 (-I3)		0,00	0,006
2	I,54	I,35 (-I2)	I,39 (-I0)		0,0I	0,007
3	I,53	I,40(-8)	I,49 (-2)		0,02	0,0II
4	I,74	I,45 (-I7)	I,68 (-4)	0,024	0,03	0,058
5	I,60	I,30 (-I9)	I,6I (I)	0,047	0,06	0,098
6	I,5I	I,30 (-I4)	I,52 (0)	0,I02	0,09	0,096
7	I,72	I,60 (-7)	I,74 (I)	0,I86	0,I6	0,II6
8	2,05	2,I0 (2)	2,02 (-2)	0,3I6	0,26	0,224
9	2,42	2,80 (I6)	2,29 (-5)	0,54I	0,39	0,359
I0	2,92	3,80 (30)	2,70 (-8)	0,8I2	0,6I	0,5I0
II	3,58	5,40 (5I)	3,24 (-I0)	I,I4	0,97	0,703
I2	4,49	6,50 (45)	4,32 (-4)	I,50	I,30	I,06
I3	6,I4	9,00 (47)	6,I5 (0)	I,99	2,00	I,64
I4	9,40	I2,0 (23)	7,52 (-20)	3,I5	2,90	I,95
I5	I4,3	I6,0 (I2)	I3,0 (-9)	5,64	4,00	3,90
I6	20,2	2I,0 (4)	I9,3 (-4)	8,94	5,50	6,02
I7	29,0	30,0 (3)	28,8 (-I)	I3,6	8,00	9,2I
I8	39,8	40,0 (I)		20,2	II,0	
I9	I29,4	60,0 (-54)		20,8	I6,0	
20	284,4	I30,0 (-54)		77,2	35,0	

Table 11

$Fe(n,\gamma)$

Group number	UKNDL (working tape)	BNAB-70	KEDAK	ENDF/BII	ENDF/BIII	ENDF/BIV	σ_0	f_c
I	0,00I	0,036^x	0,0003			0,0004		
2	0,00I	0,005^x	0,0005			0,0005	I4	I,00
3	0,002	0,002	0,0009			0,0009	I5	0,99
4	0,002	0,003	0,002			0,00I5	I5	0,99
5	0,002	0,004	0,003			0,0032	20	0,94
6	0,005	0,005	0,005	0,0050	0,0050	0,0056	25	0,89
7	0,005	0,006	0,006	0,0056	0,0057	0,0065	22	0,88
8	0,007	0,006	0,007	0,0035	0,0059	0,0069	23	0,86
9	0,0II	0,007	0,022	0,0204	0,0090	0,0I0	26	0,78
I0	0,0I7	0,0I7	0,029	0,027I	0,0I7I	0,024	25	0,58
II	0,005	0,005	0,0I8	0,0I87	0,0050	0,0050	29	0,93
I2	0,022	0,004	0,047	0,050	0,02I7	0,025	36	0,87
I3	0,009	0,0II	0,0II	0,0I2	0,0067	0,008	I72	0,98
I4	0,I9I	0,I06	0,202	0,I53	0,30I	0,246	32	0,6I
I5	0,0I0	0,0I5	0,0I6			0,0I5		
I6	0,0I8	0,023	0,023			0,022		
I7	0,030	0,037	0,033			0,032		
I8	0,047	0,053	0,05			0,045		
I9	0,07I	0,072	0,07			0,068		
20	0,I05	0,I05	0,I06			0,096		

Table 12

$Ni(n,\gamma)$

Group number	UKNDL (working tape)	BNAB-70	TsYaD	ENDF/BII	ENDF/BIII	ENDF/BIV	σ_0	f_c
I	0,0006	0,230^x	0,0007			0,0005		
2	0,0008	0,I90^x	0,00I			0,00I3	I56	I
3	0,00I5	0,I35^x	0,002			0,0025	I7I	I
4	0,0032	0,072^x	0,0045			0,0052	I66	I
5	0,0065	0,050^x	0,007			0,0076	2I2	0,99
6	0,0079	0,0II	0,008	0,0067	0,0077	0,0077	258	0,99
7	0,0083	0,009	0,0I0	0,0080	0,0088	0,0088	229	0,99
8	0,0096	0,0I0	0,0I5	0,0I44	0,0I4	0,0I5	238	0,98
9	0,0220	0,0I6	0,020	0,0204	0,020	0,02I	286	0,98
I0	0,0II5	0,0I6	0,027	0,0367	0,036	0,037	229	0,93
II	0,I27	0,033	0,096	0,I56	0,0968	0,III	272	0,84
I2	0,0I80	0,0I8	0,0I3	0,04I4	0,0283	0,029	400	I
I3	0,0339	0,048	0,026	0,0442	0,0442	0,052	I656	0,98
I4	0,0226	0,0I9	0,0I9	0,0225	0,0226	0,022		
I5	0,0284	0,028	0,027			0,029		
I6	0,04I4	0,04I	0,04I			0,040		
I7	0,0608	0,06I	0,058			0,058		
I8	0,0892	0,089	0,086			0,08I		
I9	0,I3I	0,I3I	0,I26			0,I2I		
20	0,I92	0,I93	0,I85			0,I7I		

Table 13

Cr(n, γ)

Group number	UKNDL (working tape)	BNAB-70	TsYaD	ENDL-2	ENDF/BII	ENDF/BIII	ENDF/BIV	σ_0	f_c
I	0,00033	0,035^x	0,0006	0,00II			0,00038		
2	0,00054	0,003^x	0,0008	0,00I3			0,00II		
3	0,00I0	0,003^x	0,00I	0,00I6			0,0024		
4	0,0022	0,003	0,002	0,0020			0,0045		
5	0,0038	0,004	0,004	0,0023			0,0073		
6	0,0040	0,004	0,004	0,004I	0,0033	0,0032	0,0045		
7	0,0044	0,005	0,05	0,0037	0,0034	0,004	0,0039		
8	0,0051	0,005	0,0I	0,0040	0,0072	0,0072	0,0073	65	0,95
9	0,0045	0,008	0,0I3	0,0049	0,0I32	0,0I32	0,0I28	I22	0,98
I0	0,0073	0,0I0	0,022	0,0037	0,03I9	0,03I9	0,0298	584	
II	0,0I2	0,0I3	0,0I6	0,009I	0,0284	0,0285	0,0294	I28	0,96
I2	0,038	0,020	0,073	0,035	0,0779	0,0779	0,075	I63	0,98
I3	0,037	0,030	0,04	0,038	0,0389	0,0389	0,050	7I2	0,97
I4	0,056	0,050	0,I84	0,068	0,I55	0,I546	0,I89	2I0	0,82
I5	0,022	0,080	0,02	0,023			0,0258	I66	0,84
I6	0,028	0,030	0,03	0,024			0,029		
I7	0,04I	0,04I	0,04	0,034			0,040		
I8	0,060	0,060	0,06	0,057			0,056		
I9	0,088	0,087	0,I0	0,082			0,082		
20	0,I30	0,I29	0,I4	0,I09			0,II6		

Table 14

Na(n, γ)

Group number	UKNDL (working tape)	BNAB-70	ENDL-2	ENDF/BIV	σ_0	f_c
I	0,000I6	0,050^x	0,000I7	0,000I7		
2	0,000I2	0,005^x	0,000I5	0,000I6		
3	0,000II	0,0002	0,000I8	0,000I7		
4	0,000I3	0,0002	0,0002I	0,00020		
5	0,000I9	0,0002	0,00024	0,00023		
6	0,00035	0,0003	0,00037	0,0003I	I4,6	I
7	0,0006I	0,0006	0,00066	0,00070	I3,I	0,89
8	0,0009I	0,00I2	0,00II	0,00I6	I5,3	0,88
9	0,00I3	0,00I6	0,00II	0,00I3	I6,I	0,82
I0	0,00I9	0,0026	0,0035	0,003I	22,4	0,63
II	0,0028	0,00I	0,00I3	0,00027	I7,2	I
I2	0,0042	0,00I	0,00I5	0,00I5	22,2	I
I3	0,I60	0,I0	0,085	0,II4	20,3	0,38
I4	0,0II	0,0I	0,0I4	0,0I6	20,7	I
I5	0,0036	0,005	0,0059	0,0082		
I6	0,0060	0,006	0,0058	0,0080		
I7	0,0078	0,007	0,0074	0,0088		
I8	0,0II	0,0I0	0,0092	0,0I04		
I9	0,0I6	0,0I5	0,0I6	0,0I42		
20	0,023	0,022	0,022	0,020		

Table 15

Resonance self-shielding coefficients f_c for ^{238}U at T = 300 K

Group number	UKNDL			BNAB-Eh		
	σ_0			σ_0		
	0	I0	I00	0	I0	I00
II	0,999	I,00	I,00	0,830	0,834	0,968
I2	I,00	I,00	I,00	0,718	0,795	0,929
I3	0,58I	0,678	0,856	0,479	0,558	0,786
I4	0,259	0,350	0,63I	0,290	0,38I	0,629
I5	0,I62	0,222	0,473	0,I8I	0,233	0,474
I6	0,II9	0,I65	0,376	0,I28	0,I68	0,359
I7	0,046	0,056	0,I28	0,048	0,059	0,I30
I8	0,044	0,056	0,I29	0,049	0,059	0,I28
I9	0,032	0,039	0,074	0,033	0,039	0,073
20	0,0I9	0,025	0,062	0,0I9	0,026	0,062

Table 16

Resonance self-shielding coefficients $f_t(\sigma_0)$ for iron at T = 300 K

Group number	TsYaD evaluation			BNAB-70		KEDAK		
	σ_0			σ_0		σ_0		
	I00	I0	0	I0	0	I00	I0	0
8	0,956	0,746	0,365	0,85	0,39	0,966	0,806	0,38I
9	0,949	0,806	0,454	0,77	0,34	0,948	0,78I	0,545
I0	0,720	0,367	0,086	0,25	0,03	0,698	0,348	0,0823
II	0,992	0,94I	0,775	I,00	I,00	0,987	0,9II	0,70I
I2	0,947	0,789	0,63I	0,98	0,86	0,949	0,793	0,662
I3	0,988	0,943	0,903	I,00	I,00	0,999	0,994	0,983
I4	0,984	0,972	0,965	I,00	I,00	0,996	0,98I	0,963
I5	I,00	0,998	0,996			I,00	0,998	0,996

Table 17

Resonance self-shielding coefficients $f_c(\sigma_0)$ for iron at T = 300 K

Group number	TsYaD evaluation			BNAB-70			ENDF/BIII		
	σ_0			σ_0			σ_0		
	I00	I0	0	I00	I0	0	I00	I0	0
8	I,00	I,00	I,00	0,97	0,79	0,50	I,000	0,999	0,994
9	I,00	I,00	0,99	0,90	0,70	0,53	0,99I	0,943	0,853
I0	0,907	0,725	0,427	0,66	0,52	0,39	0,896	0,696	0,499
II	0,972	0,949	0,666	0,98	0,88	0,75	0,989	0,937	0,78I
I2	0,962	0,825	0,68I	0,95	0,76	0,60	0,968	0,853	0,752
I3	0,978	0,930	0,793	0,98	0,88	0,77	0,997	0,982	0,96I
I4	0,642	0,327	0,223	0,78	0,49	0,27	0,696	0,359	0,258
I5	0,999	0,996	0,992	1,00	I,00	I,00	-	-	-

Table 18

Resonance self-shielding coefficients f_f and f_c for ^{239}Pu at T = 300 K

Group number	UKNDL			BNAB-70			UKNDL			BNAB-70		
	f_f for σ_0, equal to						f_c for σ_0, equal to					
	0	I00	I000	0	I00	I000	0	I00	I000	0	I00	I000
II	0,999	I,00	I,00	0,93	I,00	I,00	0,994	I,00	I,000	0,92	I,00	I,00
I2	0,989	0,998	I,00	0,84	0,98	I,00	0,98I	0,997	I,00	0,82	0,98	I,00
I3	0,954	0,993	0,999	0,64	0,93	I,00	0,955	0,993	0,999	0,62	0,93	I,00
I4	0,908	0,983	0,998	0,49	0,87	0,98	0,904	0,982	0,998	0,46	0,85	0,98
I5	0,802	0,887	0,992	0,38	0,80	0,96	0,935	0,969	0,998	0,32	0,72	0,95
I6	0,537	0,775	0,950	0,29	0,63	0,91	0,5I6	0,768	0,947	0,2I	0,57	0,90
I7	0,4I7	0,663	0,907	0,20	0,54	0,84	0,4I7	0,664	0,907	0,I4	0,42	0,79
I8	0,425	0,626	0,874	0,I6	0,32	0,66	0,255	0,457	0,783	0,I0	0,22	0,55
I9	0,225	0,439	0,786	0,I5	0,33	0,70	0,I68	0,375	0,748	0,I3	0,28	0,65
20	0,I49	0,326	0,645	0,I7	0,33	0,68	0,II6	0,268	0,59I	0,I6	0,29	0,65