Evaluation: **^{235}U Incident Neutron Library, Release 1, 2, 3, 4 (MAT 9228)**
Energy Range: 10^{-5} eV to 20 MeV
Files: 1, 2, 3, 4, 5, 6, 12, 13, 14, 15, 31
Evaluators: L. Weston (ORNL), P. G. Young (LANL), W. Poenitz (ANL), C. Lubitz (KAPL)

ENDF/B-VI MOD 5 REVISION 4 (V. McLane, NNDC, November 1996)

The following changes were made in File 1.
MT=455: Obsolete fields on second LIST record set to zero.
MT=456, prompt $\bar{\nu}$ updated.

ENDF/B-VI MOD 4 REVISION 3 (C. R. Lubitz, KAPL, November 1993)

The resonance parameters below 900 eV were adjusted as described in Lubitz [1]. The principal change was to increase the capture areas under the resonance so that the average capture cross section agreed with the data of Perez, et al. [4]. A smaller adjustment has been made to make the fission averages agree with the lower of several measurements, principally the work of Schrack [2], Weston [3], and Todd [5]. The thermal parameter $K_1 = (\nu\text{-}1)*$fission-capture (Maxwellian averages) was increased slightly by making small changes to the resonances below 0.5 eV. $\bar{\nu}$ and the fission widths were increased, and the capture widths were decreased iteratively, until the desired value of K_1 was reached, subject to the constraint that the 2200 m/sec values of $\bar{\nu}$, σ_f, and $\sigma_{n,\gamma}$ all differed from the Standards Committee recommendations (quoted below) by equal fractions of their uncertainties. This fraction ended up being 0.5 of one standard deviation.

The following thermal cross sections (0.0253 eV) and the resonance integrals for a 1/E spectrum (0.5 eV to 20 MeV) were computed using NJOY 91.38, at 293°K, with the following convergence criteria:

```
RECONR* 0.001    0   6    .01  1.E-6 / ERR    TEMPR  NDIGITS ERRMAX ERRINT
BROADR* 0.001 1.E6 .01 1.0E-6        / ERRTHN THNMAX ERRMAX  ERRINT
```

Other choices will give slightly different values.[5]

	Thermal (b)	Resonance Integral (b)	g-factors
$\sigma_{n,\gamma}$	98.59	143.4	0.9897
σ_f	584.81	277.5	0.9786
$\sigma_{n,\gamma}/\sigma_f$	0.517		
$\bar{\nu}$	2.4338		
K_1	723.0		

The uncertainties attached to the above values are the same as given by the Standards Committee and by Mughabghab [6]. For the g-factors, the Committee gives ±.0008 and for $\bar{\nu}$, ±.0036 [7].

[5] Some of these numbers are slightly different from those given in Ref. [1], and supersede them, although the underlying data are the same.

REFERENCES

1. C. R. Lubitz, **Nuclear Data for Science and Technology**, Int. Conference, Gatlinburg, TN, 9-13 May 1994 (American Nuclear Soc. 1994) Vol. 1, p. 646
2. R. C. Schrack, **Nuclear Data for Science and Technology**, Int. Conference, Mito, Japan, 30 May - 3 June 3 (Saikon Publishing 1988) p. 101
3. L. W. Weston and J. H. Todd, ***Nucl. Sci. Eng.* 88**, 567 (1984)
4. R. B. Perez, et al., ***Nucl. Sci. Eng.* 52**, 46 (1973)
5. J. H. Todd and L. W. Weston, private communication (1988)[6]
6. S. F. Mughabghab, **Neutron Cross Sections, Vol 1, Neutron Resonance Parameters and Thermal Cross Sections**, Part B (Academic Press, 1984)
7. A. D. Carlson, et al., **NISTIR 5177 (ENDF-351)** (1993) National Inst. of Standards and Technology

ENDF/B-VI MOD 3 REVISION 2 (L. W. Weston, February 1993)

Missing File 1 section added.

ENDF/B-VI MOD 1 NEW EVALUATION (L. Weston (ORNL), P. Young (LANL), W. Poenitz (ANL), April 1989)

See Summary Documentation, 4th Edition (1991), page 356, for complete summary of evaluation.

GENERAL INFORMATION (File 1)

The uncertainties on the fission cross section recommended by the CSEWG Standards Committee are listed. The updated description of File 2, the resolved resonance parameters, is given.

RESONANCE PARAMETERS (File 2)

The resolved resonance parameters were changed extensively. The neutron energy region below 4 eV was made a separate group. η decreases with decreasing neutron energy below 0.1 eV. At the higher neutron energies, the resonance parameters are more refined.

SMOOTH CROSS SECTIONS (File 3)

Smooth cross sections above 100 keV have minor corrections.

COVARIANCE FILES

File 31: $\bar{\nu}$ covariance files were updated.

File 33: All covariance files were removed as correct new files were not yet available.

The following reference is missing from the file 1 comments.

Ma88 D. G. Madland, **Preequilibrium Nuclear Reactions**, Specialists Meeting, Semmering, Austria, 10-12 February 1988, **NEANDC-245** (1988) p. 103.

[6] These measurements done on a flight path of 80 m. have a much better resolution than those of [3] and have been used above 110 eV.

Evaluation:	**^{237}U Incident Neutron Sublibrary, Release 2 (MAT 9234)**
Energy Range:	10^{-5} eV to 20 MeV
Files:	1, 2, 3, 4, 5, 8, 12, 13, 14, 15
Evaluators:	R. Benjamin, F. McCrosson (SRL); R. Howerton (LLNL) (Assembled by R. Kinsey NNDC)

ENDF/B-VI MOD 2 REVISION 1 (NNDC, May 1993)

Missing fission neutron angular distribution added; assumed to be isotropic.

ENDF/B-VI MOD 1 EVALUATION (NNDC, February 1990)

ENDF/B-V MAT 8237 converted to ENDF-6 format. The ENDF/B-V evaluation is a combination of the evaluation of Benjamin and McCrosson[7] (SRL) and the ENDL evaluation of Howerton [5]. Important changes or modifications are noted.

GENERAL INFORMATION (File 1)

The thermal $\bar{\nu}$ value is computed from the semi-empirical work of Gordeeva and Smirenkin [1] as revised by Manero and Konshin [2]. The energy dependence is based on Howerton. Renormalization of the Howerton shape was done at BNL.

$\bar{\nu}_d$ taken from Brady and England [6].

RESONANCE PARAMETERS (File 2)

The resolved region is 0 to 102.5 eV. Resolved resonance parameters are determined by the GENPAR code [3] based on the SRL data set and an average level spacing of 3.5 eV [4]. A bound level at -2.109 eV was removed from the SRL parameters and appropriate backgrounds were inserted into the total, fission, and capture cross sections.

The unresolved resonances were evaluated on the same basis as the resolved over the region is 102.5 eV to 10 keV.

<u>2200 m/s cross sections and resonance integrals</u>

	σ (0.0253 eV)	I (0.5 eV - 20 MeV)
Total	487.106	
Elastic	9.131	
Fission	2.000	9.209
Capture	475.975	309.585

SMOOTH CROSS SECTIONS (File 3)

<u>Total cross section</u> The sum of capture and fission bound level backgrounds up to 10 keV are joined at 10 keV to the Howerton evaluation.

<u>Elastic scattering</u>, a zero background file up to 10 keV was joined to the Howerton evaluation.

---

[7] Unable to locate documentation for this evaluation (VM).

Inelastic scattering, (n,2n), and (n,3n) Taken from Howerton evaluation; threshold points inserted.

Fission and capture cross sections The background from the deleted bound level up to 10 keV was joined to the Howerton evaluation.

ANGULAR DISTRIBUTIONS (File 4)

Elastic taken from Howerton.

For (n,2n), (n,3n), and neutron production, dummy isotropic distributions were inserted.

SECONDARY NEUTRON ENERGY DISTRIBUTIONS (File 5)

Inelastic scattering, (n,2n), and (n,3n) taken from Howerton evaluation.

Fission taken from McCrossen evaluation, simple Maxwellian with energy dependent temperature.

PHOTON PRODUCTION (Files 12, 13, 14, and 15)

The energy ranges of Howerton were extended to agree with File 3 ranges.

REFERENCES

1. L. D. Gordeeva and G. N. Smirenkin, ***Sov. At. En.*** **14**, 562 (1963); translated from ***At. En.*** **14**, 530 (1963)
2. F. Manero and V. A. Konshin, ***At. En. Rev.*** **10**, 637 (1972)
3. F. J. McCrosson, **Neutron Cross Sections for Science and Technology**, Conference, 15-17 March 1971, Knoxville, TN (National Technical Information Service 1971) p.714
4. J. H. McNally, et al., ***Phys. Rev. C*** **9** , 717 (1974)
5. R. Howerton, **UCRL 50400**, Vol. 15, Part D, Rev. 1, p. 323(1978) Lawrence Livermore National Laboratory
6. M. C. Brady and T. R. England, ***Nucl. Sci. Eng.*** **103**, 129 (1989)

Evaluation: **^{238}U Incident Neutron Sublibrary, Release 1, 2 (MAT 9237)**
Energy Range: 10^{-5} eV to 20 MeV
Files: 1, 2, 3, 4, 5, 6, 12, 13, 14, 15, 31, 33
Evaluators: L. W. Weston (ORNL), P. G. Young (LANL), W. Poenitz (ANL)

ENDF/B-VI MOD 3 REVISION 2 (L. Weston, ORNL, January 1993)

The preliminary evaluation of Moxon and Sowerby in the resolved resonance region has been replaced with the final version [1][8]. Fröhner's evaluation [2] of the unresolved resonance region up to 149 keV is used in this evaluation.

1. M. C. Moxon and M. G. Sowerby, Reactor Physics Conference, Jackson Hole, WY, 1988, Volume I, p. 281.
2. F. H. Fröhner, Reactor Physics Conference, Jackson Hole, WY, 1988, Volume III, p. 171.

ENDF/B-VI MOD 2 REVISION 1 (NNDC, July 1991)

Covariance files for total, fission, and capture were removed, since the correct files are not yet available.

ENDF/B-VI MOD 1 NEW EVALUATION (L. Weston (ORNL), P. Young (LANL), W. Poenitz (ANL), et al., November 1989)

See Summary Documentation, 4th Edition (1991), page 386, for summary documentation of ENDF/B-VI evaluation.

[8] This evaluation is identical to that in JEF-2.2 up to 149 keV.

Evaluation: **^{237}Np Incident Neutron Sublibrary, Release 1 (MAT 9346)**
Energy Range: 10^{-5} eV to 20 MeV
Files: 1, 2, 3, 4, 5, 6, 8, 9, 12, 13, 14, 15
Evaluators: P. G. Young, E. D. Arthur (LANL); F. M. Mann (HEDL)

ENDF/B-VI MOD 2 REVISION 1 (P. G. Young, E. D. Arthur (LANL), F. M. Mann (HEDL), July 1991)

Angular distribution data (isotropic) for 1st-, 2nd-, 3rd- and 4th-chance fission removed from File 4 because no energy spectra are available.

ENDF/B-VI MOD 1 NEW EVALUATION (P. G. Young, E. D. Arthur (LANL), F. M. Mann (HEDL), April 1990)

See Summary Documentation, 4th Edition (1991), page 397, for summary documentation of ENDF/B-VI evaluation.

Evaluation: **^{238}Np Incident Neutron Sublibrary, Release 2 (MAT 9349)**
Energy Range: 10^{-5} eV to 20 MeV
Files: 1, 2, 3, 4, 5, 8
Evaluators: R. W. Benjamin, F. J. McCrosson (SRL)

ENDF/B-VI MOD 2 REVISION 1 (NNDC, May 1993)
The missing fission neutron angular distributions are added; assumed to be isotropic.

ENDF/B-VI MOD 0 (NNDC, February 1990)
ENDF/B-V MAT 8338 was converted to ENDF-6 format.

ENDF/B-V EVALUATION (R. W. Benjamin and F. J. McCrosson, SRL, August 1975)

GENERAL INFORMATION (File 1)
$\bar{\nu}$ thermal value computed from semi-empirical work of Gordeeva and Smirenkin [1] as revised by Manero and Konshin [2]. Energy dependence based on Howerton [3].
$\bar{\nu}_d$ taken from M. C. Brady and T. R. England [5].

RESONANCE PARAMETERS (File 2)
Resolved resonance parameters in the region 0 to 100.2 eV are determined by the GENRPAR code [4] based on the SRL data set and an average level spacing of 1.05 eV.
Unresolved resonance parameters in the region 100.2 to 10 keV are determined on the same basis as the resolved with average resonance parameters.

2200 m/s cross sections and resonance integrals

	σ(0.0253 eV)	I (0.5 eV - 20 MeV)
Total	2250.99	
Elastic	21.25	
Fission	2026.90	895.60
Capture	202.83	100.03

SMOOTH CROSS SECTIONS (File 3)
The data in File 3 are given only so that the various processing codes will work. Continuity with the unresolved region is provided, but the cross sections drop immediately to zero. The elastic scattering cross section above 10 keV is the potential scattering cross section calculated with a spherical optical model potential at 10 keV.

ANGULAR DISTRIBUTIONS (File 4)
The elastic distributions are taken from ENDF/B-V ^{238}U.

SECONDARY NEUTRON ENERGY DISTRIBUTIONS (File 5)
A simple fission Maxwellian with energy dependent temperature is used.

REFERENCES

1. L. D. Gordeeva and G. N. Smirenkin, ***Sov. At. En.*** **14**, 562 (1963); translated from ***At. En.*** **14**, 530 (1963)
2. F. Manero and V. A. Konshin, ***At. En. Rev*. 10**, 637 (1972)
3. R. J. Howerton, ***Nucl. Sci. Eng.*** **46**, 42 (1971)
4. F. J. McCrosson, **Neutron Cross Sections for Science and Technology**, Conference, 15-17 March 1971, Knoxville, TN (National Technical Information Service 1971) p.714
5. M. C. Brady and T. R. England, ***Nucl. Sci. Eng.*** **103**, 129 (1989)

Evaluation: **^{236}Pu Incident Neutron Sublibrary, Release 4 (MAT 9428)**
Energy Range: 10^{-5} eV to 20 MeV
Files: 1, 2, 3, 4, 5
Evaluators: R. Q. Wright (ORNL); T. Hojuyama (MAPI); Y. Kikuchi, T. Nakagawa (JAERI)

ENDF/B-VI MOD 1 NEW EVALUATION (R.Q. Wright, ORNL, September 1995)

This evaluation is an update of the JENDL-3.2 Evaluation. The following changes were made.

GENERAL COMMENTS (File 1)

$\bar{\nu}_p$ Tabulated data added.

RESONANCE PARAMETERS (File 2)

Resolved resonance parameters are given in the range 1.0×10^{-5} to 10 eV using a MLBW formalism. Parameters are given for the -1.27, 3.16, 6.30, 12.0 eV resonances.

Average Γ_γ = 0.044 meV, Γ_f = 0.325 meV, Γ_n^0 = 5.71193×10^{-4} meV. D_0 = 4.42333 eV, S_0 = 1.72176×10^{-4} eV, and the scattering radius = 9.46 fm.

SMOOTH CROSS SECTIONS (File 3)

Total cross section (MT=1) Revised from 10 eV to 20 MeV. The cross section was obtained by addition of all partial cross sections in the revised evaluation. The total cross section was reduced by 0.6 barns for the energy range 7-20 MeV; this change is due to the lower fission cross section (see discussion of the revised fission cross section).

Comparison of revised total with ^{239}Pu total

Energy (MeV)	^{236}Pu/^{239}Pu total
3.0	1.000
5.0	0.966
7.0	0.981
10.0	0.979
12.0	0.986
14.0	1.008
16.0	1.037
20.0	1.050

Elastic cross section (MT=2) Revised from 10 ev to 50 keV, based on the unresolved resonance calculation described above. Above 50 keV, the elastic from the JENDL-3.2 evaluation is revised to get the final elastic cross section.

Inelastic cross section Revised from 5 to 7 MeV.

Fission cross section Revised:

a) from 10 eV to 6 MeV based on measured data Gromova, et al., [1], tables 2 and 3.

b) above 6 MeV, revised based on the measured value at 5.78 MeV of Gromova, et al. [1], table 3.

c) for the energy range 7-20 meV, the fission cross section is reduced by 0.6 barns.

Comparison of evaluated fission with Gromova, et al. [1]

Maximum energy (eV)	Ref. 1 (barns)	Evaluation (barns)
46.5×10^3	4.3 ± 0.2	4.270
21.5×10^3	5.2 ±0.3	5.225
10.0×10^3	6.8 ± 0.3	6.686
4.65×10^3	8.9 ± 0.4	8.913
2.15×10^3	13.5 ± 0.8	13.43
1.000×10^3	20.9 ± 0.8	21.11
465	33.3 ± 1.5	33.12
215	46.0 ± 1.3	42.35
100	47.2 ± 1.5	50.88
46.5	72.0 ± 2.0	72.31
21.5	91.0 ± 2.0	91.09
10.0	50.0 ± 3.0	250.1
4.65	615.0 ± 6.0	614.3
2.15	25.0 ± 2.0	32.05
1.0	33.0 ± 3.0	29.62

In the range 10 eV to 50 keV, the elastic scattering and α were obtained from an unresolved resonance calculation using the following parameters: $S_0 = 9.92\times10^{-5}$, $\langle D_0\rangle = 2.5$ eV, $\langle\Gamma_\gamma\rangle = 0.044$ eV, $\langle\Gamma_f\rangle = 0.400$ eV, scattering radius = 9.33 fm.

First-chance fission cross section (MT=19) Revised to reflect the changes in MT=18.

Capture cross section (MT=102) Revised from 10 eV to 300 keV based on the estimated value of α (capture/fission ratio) obtained from an unresolved resonance calculation for the energy range 10 eV to 50 keV. The value of α obtained from this calculation is almost constant; thus a value of 0.17 is used.

For the range 20-300 keV, the capture cross section is obtained by log-log interpolation using the following values: (20 kev, 799 mb) and (300 kev, 419 mb). The corresponding values of α are 0.170 and 0.166, at 20 and 300 keV, respectively.

Calculated 2200 m/s cross sections and resonance integrals

	σ(0.0253 eV)	I (0.5 eV - 20 MeV)
Total	205.4	
Elastic	9.2	
Fission	165.0	992
Capture	31.2	286
Absorption	196.2	1278.

REFERENCES

1. E. A. Gromova, et al., ***Sov. At. En.*, 68**, 223 (1990); translated from ***At. En.* 68**, 193 (1990)

Evaluation: **^{239}Pu Incident Neutron Sublibrary, Release 2 (MAT 9437)**
Energy Range: 10^{-5} eV to 20 MeV
Files: 1, 2, 3, 4, 5, 6, 12, 13, 14, 15
Evaluators: P. Young (LANL); L. W. Weston, H. Derrien (ORNL); W. Poenitz (ANL); T. Nakagawa (JAERI)

ENDF/B-VI MOD 2 REVISION 1 (L. Weston, H. Derrien (ORNL); T. Nakagawa (JAERI), January 1993)

The resonance region evaluation by H. Derrien and T. Nakagawa has been added, and has extended the resonance region to 2.5 keV. The resonance parameters have been obtained from a SAMMY [1] fit analysis[9] of high resolution experimental data. The file contains three independent sections:

1) Energy range 0 to 1 keV. The set of resonance parameters contains 398 resonances in the energy range 0 to 1 keV, 4 fictitious negative energy resonances and 3 fictitious resonances above 1 keV;
2) Energy range 1 to 2 keV. The set of resonance parameters contains 435 resonances in the energy range 0.980 to 2.02 keV, 3 fictitious resonances below 0.9 keV and 3 fictitious resonances above 2.02 keV;
3) Energy range 2 to 2.5 kev. The set of resonance parameters contains 218 resonances in the energy range 1.98 to 2.53 keV, 3 fictitious resonances below 1.98 keV and 3 fictitious resonances above 2.53 keV.

In all sections, the fictitious resonance parameters take into account the contribution of all the external truncated resonances in such a way that no total, scattering, fission and capture smooth files are needed in the corresponding energy ranges for the reproduction of the cross sections within the experimental errors.

The following experimental data base has been used in the SAMMY fits: absorption and fission from Gwin, et al. [2,4]; fission from Gwin et al. [5,6], Blons [3], Weston, et al. [7,8]; transmission from Spencer, et al. [10], Harvey, et al. [9].

Prior to the fits, the experimental fission and absorption cross sections were normalized, directly or indirectly, to the 0.0253 eV values obtained by the ENDF/B-VI standard evaluation group [11]. The transmission data were considered as accurate absolute measurements (the Spencer total cross section at 0.0253 ev is 1025.0 b, in excellent agreement with the 1027.3 b standard value). Details on the analysis are found in references [8,12,13].

293˚K cross sections calculated from resonance parameters

	SAMMY	RESEND	Proposed
Fission	747.64	747.90	747.99±1.87
Capture	271.10	270.73	271.43±2.14
Scattering	7.97	7.99	7.88±0.97
Total	1026.71	1026.62	1027.30±5.00

9 Performed at ORNL by H. Derrien and G. deSaussure and at JAERI by H. Derrien and T. Nakagawa

REFERENCES

1. a. N. M. Larson, et al., **ORNL/TM-7485** (1980) Oak Ridge National Laboratory
   b. N. M. Larson, **ORNL/TM-9179** (1984) Oak Ridge National Laboratory
   c. N. M. Larson, **ORNL/TM-9719/R1** (1985) Oak Ridge National Laboratory
2. R. Gwin, et al., ***Nucl. Sci. Eng.*** **45**, 25 (1971)
3. J. Blons, ***Nucl. Sci. Eng.*** **51**, 130 (1973)
4. R. Gwin, et al., ***Nucl. Sci. Eng.*** **59**, 79 (1976)
5. R. Gwin, et al., ***Nucl. Sci. Eng.*** **61**, 116 (1976)
6. R. Gwin, et al., ***Nucl. Sci. Eng.*** **88**, 37 (1984)
7. L. W. Weston, et al., ***Nucl. Sci. Eng.*** **88**, 567 (1984)
8. L. W. Weston, et al., to be published (high resolution 1988 data)
9. J. A. Harvey, et al., **Nuclear Data for Science and Technology**, Int. Conference, Mito, Japan, 30 May - 3 June 3 (Saikon Publishing 1988) p. 115
10. R. R. Spencer, et al., ***Nucl. Sci. Eng.*** **96**, 318 (1987)
11. A. Carlson, et al., preliminary results of the ENDF/B-6 Standard Evaluation (Sep. 8, 1987)
12. H. Derrien and G. de Saussure, **ORNL-TM-10986** (1988) Oak Ridge National Laboratory
13. H. Derrien and G. de Saussure, ***Nucl. Sci. Eng.*** **106**, 434 (1990)

ENDF/B-VI MOD 1 NEW EVALUATION (P. Young (LANL), L. Weston (ORNL), W. Poenitz (ANL), April 1989)

See Summary Documentation, 4th Edition (1991), page 415, for summary documentation of ENDF/B-VI evaluation.

Evaluation: **^{240}Pu Incident Neutron Sublibrary, Release 1,2 (MAT 9440)**
Energy Range: 10^{-5} eV to 20 MeV
Files: 1, 2, 3, 4, 5, 8, 12, 13, 14, 15, 31, 32, 33
Evaluators: L. W. Weston, E. D. Arthur
Laboratory: ORNL, LANL

ENDF/B-VI MOD 3 REVISION 2 (L. Weston, ORNL, January 1993)
Added missing fission neutron angular distributions in File 4 (MT=19, MT=20 and MT=21); assumed to be isotropic.
Corrected U value for File 5, MT=20.
Fixed incorrect NER value in File 32, MT=151.

ENDF/B-VI MOD 2 REVISION 1 (L. Weston, ORNL, July 1991)
Covariance File 33 for fission (MT=18) deleted.

ENDF/B-VI MOD 1 NEW EVALUATION 1 (L. Weston (ORNL), E. Arthur (LANL), August 1993)
See ENDF-102 Summary Documentation, 4th Edition (1991), page 434, for documentation of ENDF/B-VI evaluation.

Evaluation: **^{241}Pu Incident Neutron Data, Release 1, 3 (MAT 9443)**
Energy Range: 10^{-5} eV to 20 MeV
Files: 1, 2, 3, 4, 5, 8, 12, 13, 14, 15, 31
Evaluators: L. W. Weston, R. Q. Wright, H. Derrien, et al. (ORNL)

ENDF/B-VI MOD 3 REVISION 2 (L. Weston, ORNL, August 1994)

Covariances, which are dependent in the ^{235}U covariances which are not completed, were stripped off the file.

ENDF/B-VI MOD 2 REVISION 1 (L. Weston, ORNL, June 1991)

The following changes were made for Revision 2:

1. insertion of revised resonance parameters by Derrien;
2. renormalization of capture above the resolved resonance region to be 4.8% lower than ENDF/B-V and upward from 14% down in original ENDF/B-VI evaluation. Scattering was adjusted to make up difference. The renormalization was the suggestion of Derrien after study of the new measurements by Wagemans, et al. [1].

<u>Revision of the ^{241}Pu</u> (H. Derrien, Japanese Atomic Energy Research Institute)

Resonance parameters of the neutron cross sections of ^{241}Pu were obtained by Derrien and de Saussure [2] in the energy range from thermal to 300 eV by a Bayesian fit of selected experimental effective total, fission, and capture cross sections using the Reich-Moore fitting code SAMMY [3]. The results of this work were used in the ENDF/B-VI MOD1 evaluated data file. Some difficulties were encountered in the normalization of the experimental fission cross sections due to the discrepancies in the shape of the available experimental data both in thermal and high energy ranges. The consistency among the experimental data base could not be obtained without large renormalization and background correction parameters in the SAMMY fits. Particularly, it was shown that the discrepancy between the fission cross sections in the thermal energy range was due to a deviation from the 1/v shape below about 0.05 eV.

New fission cross section measurements were recently performed by Wagemans, et al. [1,4][10] in the energy range from 0.002 eV to 20 eV in order to check the shape of the cross section in the thermal energy range. They showed a shape which was a contradiction to all the previous measurements reported in the literature. Consequently, the normalization of all the previous results using the low energy region could be erroneous. Particularly, the discrepancy observed in the average fission cross section over the 0.26 eV resonance could be due to the errors of normalization in the thermal region. Wagemans, et al., compared the ENDF/B-VI MOD1 data to their 1991 results and concluded that the evaluated data files using the evaluation of Derrien and de Saussure should be revised in the energy range up to 300 eV.

In the energy range from 0.01 eV to 3 eV the 1991 data of Wagemans are on average 2.2% smaller than ENDF/B-VI MOD1. This difference is mainly due a difference of 3% between the 1976 Wagemans, et al. [5] and 1991 Wagemans, et al. [1]. The 1976 Wagemans data were used in the evaluation of Derrien and de Saussure in the low energy region.

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[10] Hereinafter called Wagemanns 1991.

In the intermediate energy range from 3 eV to 12 eV, the average fission of ENDF/B-VI MOD1 is in excellent agreement with the 1991 Wagemans data. In this energy range, the SAMMY fits of Derrien and de Saussure were performed on the fission cross section of Weston and Todd [6], of Blons [7] and of Migneco, et al. [8], with an adjustment of the normalization factor and of the background correction parameters of all the experimental data; the agreement between the 1991 Wagemans data and ENDF/B-VI MOD1 shows that, at least in this energy range, SAMMY performed on the data of Weston and Todd a renormalization equivalent to that recommended by 1991 Wagemans.

In the higher range up to 300 eV, the SAMMY fits relied mainly on the high resolution measurements of Blons and of Migneco, et al., for the accurate determination of the resonance parameters. Quite large normalization coefficients and background correction parameters were also needed in this energy range to obtain the consistency between the calculated cross sections and the experimental data. However, the result of the fits was in quite good agreement with the data of Weston and Todd normalized to the 1976 Wagemans data in the low energy region, which is also equivalent to the normalization to the 1983 Wagemans, et al. [9] data. Since the 1976 Wagemans data should decrease by 3% to be consistent with the 1991 data, it is likely that the ENDF/B-VI MOD1 fission cross section could be too large by about 3% in the energy range above 12 eV.

REVISION OF THE RESONANCE PARAMETERS

An accurate up-dating of the ^{241}Pu resonance parameters could be obtained by renormalizing the fission experimental data base according to the 1991 Wagemans data, and by redoing the SAMMY fits of the new experimental data base, including the high resolution transmission data of Harvey and Simpson [10]. Due to lack of time a new SAMMY analysis was performed only in the energy range from 0.002 eV to 3 eV. In the energy range above 3 eV, the updating was performed by applying some small corrections to the resonance parameters.

The SAMMY analysis of the 1991 Wagemans data along with the total cross section of Young and Smith [11] was performed in the energy range from 0.002 eV to 3 eV, by starting with the ENDF/B-VI MOD1 resonance parameters. Only the parameters of the 3+ resonances at -0.122 eV and at 0.265 eV were adjusted in this energy range. The values of the cross sections calculated at 0.0253 eV are compared to the standard data [12] in Table 1. The average total, fission and capture cross sections calculated with the new resonance parameters are displayed on Table 2, 3 and 4 with the corresponding experimental data and the values obtained from ENDF/B-VI MOD1. One should point out that an energy shift of $dE/E = +0.00384$ was applied to the data of Young and Smith in order to achieve a good consistency with the energy scale of the fission 1991 Wagemans data over the resonance at 0.0265 eV.

In the energy range above 3 eV, the small corrections applied to the resonance parameters result in a decrease of the average fission cross section and in an increase of the average capture cross section,with a variation of the average total cross section smaller than the errors of the experimental data of Harvey and Simpson. The average values of the fission and capture cross sections calculated with the new resonance parameters are shown in Table 5 and 6 along with the renormalized fission cross section of Weston and Todd and the values calculated from ENDF/B-VI MOD1.

Table 1
Cross sections at 0.0253 eV

	Present results	ENDF/B-VI Standard [14]
Fission	1012.50(-0.0%)	1012.68±6.58
Capture	361.52(+0.1%)	361.29±4.95
Scattering	11.36(-7.1%)	12.17±2.62
Total	1385.38(-0.1%)	1386.14±8.64

Table 2
The total cross section integral in the energy range from 0.0021 eV to 3 eV.

Energy range (eV)	Present work (b.eV)	ENDF/B-VI (b.eV)	Young and Smith [13] (b.eV)
0.0021-0.020	43.54	43.09(-1.0%)	43.25(-0.7%)
0.0200-0.030	14.03	14.02(-0.1%)	14.01(-0.1%)
0.0300-0.100	65.09	66.17(+1.7%)	64.99(-0.1%)
0.1000-0.500	378.38	385.27(+1.8%)	380.10(+0.4%)
0.5000-1.000	29.74	29.41(-1.1%)	31.19(+4.4%)
1.0000-3.000	83.36	83.92(+0.7%)	82.50(-1.0%)
0.0021-3.000	614.14	621.88(+1.3%)	616.04(+0.3%)

Table 3
The fission cross section integral in the energy range from 0.0021 eV to 3 eV.

Energy range (eV)	This work (b.eV)	ENDF/B-VI (b.eV)	Wagemans, et al. (b.eV) [1]	Weston and Todd (b.eV) [8]
0.0021-0.020	31.06	30.61(-1.5%)	31.09(+0.1%)	
0.0200-0.030	10.24	10.22(-0.2%)	10.24(0.0%)	
0.0300-0.100	49.02	50.02(+2.0%)	48.70(-0.6%)	
0.1000-0.500	262.76	270.84(+3.1%)	264.58(+0.7%)	262.53(-0.1%)
0.5000-1.000	17.93	17.64(-1.6%)	17.60(-1.8%)	17.67(-1.4%)
1.0000-3.000	54.88	55.62(+1.3%)	54.40(-0.9%)	55.06(+0.3%)
0.0021-3.000	425.89	434.95(+2.1%)	426.61(+0.2%)	
0.1000-3.000	335.57	344.10(+2.5%)	336.58(+0.3%)	335.26(-0.1%)

Weston and Todd experimental data were normalized to 1991 Wagemans in the energy range from 0.1 eV to 12 eV.

Table 4
The capture cross section integral in the energy range from 0.0021 eV to3 eV.

Energy range (eV)	Present work (b.eV)	ENDF/B-VI (b.eV)	Weston and Todd [8] (b.eV)
0.0200-0.030	3.67	3.68(+0.3%)	
0.0300-0.100	15.28	15.39(+0.7%)	15.27(-0.1%)
0.1000-0.500	110.58	109.47(-1.0%)	110.49(-0.1%)
0.5000-1.000	5.90	5.87(-0.5%)	6.51
1.0000-3.000	7.30	7.14(-2.2%)	8.96
0.0021-3.000	154.98	153.83(-0.7%)	
0.0300-3.000	139.06	137.87(-0.9%)	141.29(+1.6%)

Weston and Todd experimental data were normalized to the calculated average capture cross section over the resonance at 0.264 eV; in the energy range from 0.5 eV to 3 eV the experimental data are not accurate due to large corrections for the impurities.

Table 5
The fission cross section integral in the energy range from 3 eV to 300 eV.

Energy range (eV)	Present work (b.eV)	ENDF/B-VI (b.eV)	Weston and Todd [8] (b.eV)
3- 20	3038.63	3066.37(+0.9%)	3036.23(-0.1%)
20- 50	1683.69	1739.68(+3.3%)	1705.50(+1.3%)
50-100	1971.15	2030.10(+3.0%)	1931.50(-2.0%)
100-200	2554.85	2628.39(+2.9%)	2531.00(-0.9%)
200-300	2741.23	2820.75(+2.9%)	2747.00(+0.2%)
3-300	11989.55	12285.29(+2.5%)	1951.23(-0.3%)

Weston and Todd experimental data were normalized to 1991 Wagemans in the energy range from 0.1 eV to 12 eV.

Table 6
The capture cross section integral in the energy range from 3 eV to 300 eV.

Energy range (eV)	Present work (b.eV)	ENDF/B-VI (b.eV)	Weston and Todd [8] (b.eV)
3- 20	1213.07	1138.52(-6.5%)	1192.90(-1.7%)
20- 50	330.34	307.48(-7.5%)	338.09(+2.3%)
50-100	605.40	585.88(-3.2%)	594.83(-1.8%)
100-200	609.83	581.77(-4.8%)	652.68(+7.0%)
200-300	684.97	661.12(-3.6%)	700.53(+2.3%)
3-300	3443.36	3274.77(-5.1%)	3479.04(+1.0%)

Weston and Todd experimental data normalized to the calculated average capture cross section over the resonance at 0.265 eV.

CONCLUSION

The results of the 1991 Wagemans fission cross section measurements in the energy range from 0.002 eV to 4 eV were used in a new evaluation of the resonance parameters. The accuracy of the calculated cross sections was greatly improved in the resonance at 0.265 eV. The cross sections averaged over this resonance should have the same accuracy as the standard values at 0.0253 eV. In the high energy region up to 300 eV the SAMMY analysis of the new experimental data base obtained by the renormalization of the experimental data is recommended in order to improve the corrections to the resonance parameters performed in the present work.

REFERENCES

1. C. Wagemans, et al., **Nuclear Data for Science and Technology**, Conference, Jülich, Germany, 13-17 May 1991 (Springer-Verlag, 1992) p. 35
2. H. Derrien and G. de Saussure, ***Nucl. Sci. Eng.*** **106**, 415 (1990)
3. N. M. Larson and F. G. Perey, **ORNL/TM-9719/R1** (1985) Oak Ridge National Laboratory
4. C. Wagemans, P. Schillebeeckx, A. Deruytter and R. Barthelemy, PHYSOR 90, Conference, Marseille, France, 23-26 April 1990 (1990), Vol.1, III-9
5. C. Wagemans and A. J. Deruytter, ***Nucl. Sci. Eng.*** **60**, 44 (1976)
6. L. W. Weston and J. H. Todd, ***Nucl. Sci. Eng.*** **65**, 454 (1978)
7. J. Blons, ***Nucl. Sci. Eng.*** **51**, 130 (1973)
8. E. Migneco, J. P. Theobald and J. A. Wartena, **Nuclear Data for Reactors**, Conference, Helsinki, Finland, 15-19 June 1970, Vol.I (I. A. E. A., 1970) p.437
9. C. Wagemans and A. Deruytter, **Nuclear Data for Science and Technology**, Conference, Antwerp, Belgium, 6-10 September 1982 (D. Reidel Publishing, 1983) p. 69
10. J. A. Harvey and O. D. Simpson, Oak-Ridge National Laboratory(1973), unpublished
11. T. B. Young and J. R. Smith, **WASH-1093**, p. 60 (1968) AEC Nuclear Cross Section Advisory Committee
12. A. Carlson, et al., ENDF/B-VI standard evaluation, private communication from R. W. Peele (1987)

ENDF/B-VI MOD 1 NEW EVALUATION (L. Weston, ORNL, October 1988)

See ENDF-201 Summary Documentation, 4th Edition (1991), page 446, for documentation of ENDF/B-VI evaluation.

Evaluation: **^{243}Pu Incident Neutron Sublibrary, Release 2 (MAT 9449)**
Energy Range: 10^{-5} eV to 20 MeV
Files: 1, 2, 3, 4, 5, 8, 12, 13, 14, 15
Evaluators: R. Benjamin, F. McCrosson (SRL); R. Howerton (LLNL) (assembled by R. Kinsey, BNL)

ENDF/B-VI MOD 2 REVISION 1 (NNDC, May 1993)
Added missing fission neutron angular distribution; assumed to be isotropic.

ENDF/B-VI MOD 0 (NNDC, February 1990)
ENDF/B-V MAT 8443 converted to ENDF-6 format.

ENDF/B-V EVALUATION (assembled by R. Kinsey, NNDC, February 1990)
ENDF/B-V MAT 8443 was converted to ENDF-6 format. This evaluation is, in general, a combination of the August 1975 evaluation of Benjamin and McCrosson at SRL and the ENDL evaluation of Howerton at LLNL [5]. Important changes or additions are noted.

GENERAL INFORMATION (File 1)
$\bar{\nu}$ thermal value computed from semi-empirical work of Gordeeva and Smirenkin [1] as revised by Manero and Konshin [2]. Energy dependence based on work of Howerton [3].

RESONANCE PARAMETERS (File 2)
Resolved resonance region (0 to 101.7 eV). Resonance parameters are determined by the GENRPAR code [3] based on the estimated resonance integrals and thermal cross sections from production studies [4].
Unresolved region (101.7 eV to 10 keV). Unresolved resonances are determined with average parameters by GENRPAR.

2200 m/s cross sections and resonance integrals

	σ(0.0253 eV)	I (0.5 eV - 20 MeV)
Total	289.252	
Elastic	19.752	
Fission	181.394	557.436
Capture	88.106	274.163

SMOOTH CROSS SECTIONS (File 3) (1.-5 EV TO 20 MEV)
For total, elastic, fission, and capture, zero background files up to 10 keV are joined to the Howerton evaluation.
(n,2n), (n,3n), and (n,4n), are taken from the Howerton evaluation with threshold calculated from the Q value.

ANGULAR DISTRIBUTIONS (File 4)

Elastic is taken from the Howerton evaluation, culled to 101 points per distribution and renormalized.

(n,2n), (n,3n), (n,4n), and the inelastic scattering to the continuum are dummy distributions.

SECONDARY NEUTRON ENERGY DISTRIBUTIONS (File 5)

(n,2n), (n,3n), (n,4n), and the inelastic scattering to the continuum are taken from the Howerton evaluation.

Fission is a simple fission Maxwellian with energy-dependent temperature taken from the SRL evaluation.

REFERENCES

1. L. D. Gordeeva and G. N. Smirenkin, ***Sov. At. En.*** **14**, 562 (1963); translated from ***At. En.*** **14**, 530 (1963)
2. F. Manero and V. A. Konshin, ***At. En. Rev***. **10**, 637 (1972)
3. F. J. McCrosson, **Neutron Cross Sections for Science and Technology**, Conference, 15-17 March 1971, Knoxville, TN (National Technical Information Service 1971) p.714
4. R. W. Benjamin, et al., **DP-1394** (1975) Savannah River Laboratory
5. R. J. Howerton, **UCRL 50400**, Vol 15, Part D, Rev. 1, p. 379 (1978) Lawrence Livermore National Laboratory

Evaluation: **^{241}Am Incident Neutron Data, Release 2, 3** (MAT 9543)
Energy Range: 10^{-5} eV to 30 MeV
Files: 1, 2, 3, 4, 5, 6, 8, 9, 12, 13, 14, 15, 32, 33
Evaluators: P. G. Young, D. W. Madland (LANL); Zhou Delin, Yu Baosheng, et al. (CNDC)

ENDF/B-VI MOD 3 REVISION 2 (P. G. Young, D. G. Madland, LANL, August 1994)

The cross section data file for neutron reactions with ^{241}Am has been reevaluated over the incident neutron energy range from 0.01 to 30 MeV. Details of the analysis are given in the sections that follow. Some general features of the work are:

1. The ENDF/B-VI MOD 2, resonance parameters were adopted at neutron energies below 30 keV, suitably joined with the results of the present analysis at 30 keV.
2. A coupled-channel optical model potential was developed from analyses of nearby actinides that is consistent with measurements of the neutron total cross section. This potential was used to calculate the neutron total cross section, elastic and inelastic scattering cross sections and angular distributions, and reaction cross sections and transmission coefficients for a theoretical analysis of the reaction channels. The direct cross sections from the coupled-channel analysis were combined with compound nucleus calculations at lower energies and with preequilibrium theory calculations at higher energies. Angular distributions for the first 40 excited states of ^{241}Am were obtained from the direct, compound-nucleus, and preequilibrium calculations, and energy-angle correlated distributions are provided for all continuum neutrons.
3. The evaluated fission and total cross sections were obtained by adjusting the theoretical cross sections as needed to match the available experimental data.
4. $\bar{\nu}$ and the fission neutron spectra were obtained using Madland-Nix theory.

ENDF/B-VI MOD 2 REVISION 1 (NNDC, June 1992)

Energy release per fission added from ENDF/B-V.

ENDF/B-VI MOD 2 NEW EVALUATION (P. G. Young, D. G. Madland, LANL, February 1988)

THEORETICAL ANALYSIS

The primary goal of the theoretical analysis was to provide a consistent set of data for all reactions over the energy range 30 keV to 30 MeV. In the case of n+^{241}Am, there are reasonable experimental data available for the neutron total and fission cross sections. Therefore, the function of the theoretical analysis was to provide the elastic, inelastic, (n,2n), (n,3n) and (n,4n) cross sections, as well as the angular and energy distributions of secondary neutrons. To accomplish this, a theoretical analysis was performed, adjusting the relevant parameters to match the total, fission, and (n,γ) cross sections. Additionally, a theoretical analysis was performed to obtain the average neutron multiplicity from fission and the energy spectra of fission neutrons as a function of incident energy.

Coupled-channel deformed optical model calculations were performed with the ECIS code [Ra70] over the incident neutron energy range from 0.001 to 30 MeV. Hauser-Feshbach reaction theory calculations were carried out with the LANL version of the COMNUC code [Du70] at lower energies and the GNASH statistical/preequilibrium code [Yo92] at higher energies to obtain all partial reaction cross section data. Both reaction theory codes used neutron transmission coefficients from the optical model analysis.

A. Optical Model

The optical model potential was obtained by considering several coupled-channel parameterizations developed from n+^{235,238}U and ^{239}Pu experimental data [Ma78, Yo88, Yo92a]. Parameters were adjusted until a reasonable fit to experimental data for the neutron total cross section of ^{241}Am was obtained. The lowest five members of the 5/2- ground state rotational band were included in the calculations, that is, the 7/2-, 9/2-, 11/2- and 13/2- excited states at E_x = 41, 94, 159 and 235 keV were coupled with the 5/2- ground state.

B. Reaction Theory Calculations

The Hauser-Feshbach statistical calculations were performed with the COMNUC and GNASH codes. Both codes include a double-humped fission barrier model, using uncoupled oscillators for the barrier representation in GNASH and coupled or uncoupled oscillators in COMNUC, as described by Arthur [Ar82a]. The COMNUC calculations include the possibility of width-fluctuation corrections and corrections for class II fluctuations [Ly74], which are needed at lower energies, whereas GNASH provides the preequilibrium corrections that are required at higher energies. Accordingly, COMNUC was used in the calculations below about 2 MeV, utilizing a non-resonant model and including class II fluctuations, and the GNASH code was employed at higher energies using two uncoupled oscillators in the fission calculations.

Each compound nucleus formed in the calculations is permitted to decay through the fission channel, by neutron emission, and by gamma-ray emission. Neutron transmission coefficients for the Hauser-Feshbach calculations are obtained from the coupled-channel optical model. Gamma-ray transmission coefficients are obtained from gamma-ray strength functions calculated with the generalized Lorentzian model of Kopecky and Uhl [Ko90]. Transmission coefficients for fission are calculated from the fission model summarized here and detailed in [Yo92b]. Gilbert and Cameron [Gi70] phenomenological level density functions were used to represent continuum levels at ground-state deformations, appropriately matched to available experimental structure data at lower excitation energies. Multiplicative factors were applied to the level density functions to account for enhancements in the fission transition state densities at the fission barriers due to increased asymmetry conditions, and the continuum level densities were matched to the discrete fission transition states at each barrier. The discrete fission transition state spectra were calculated from bandhead information taken from calculations and compilations by Britt [Br82] and by Nagel [Na91].

DESCRIPTION OF EVALUATED DATA BASE

A. Total Cross Section

The evaluated total cross section below 30 keV is obtained from the ENDF/B-VI MOD 2 resonance parameter evaluation, suitably matched to the results of the current analysis at 30 keV. From 30 keV to 30 MeV, the coupled-channel deformed optical model calculations described above were modified to agree with the experimental data of Phillips [Ph70].

B. Elastic Cross Section

The elastic cross section at all energies is obtained from the difference of the total and nonelastic cross sections. Below 30 keV it comes from the ENDF/B-VI MOD 2 resonance parameters and at higher energies it is mainly determined by the coupled- channel optical model calculations. Angular distributions for elastic neutrons were obtained at all energies from the coupled-channel calculations and are given as Legendre expansions.

C. Fission Cross Section

The fission cross section was obtained by adjusting the results of the theoretical analysis to optimize agreement with experimental data. At most energies the adjustment was less than a few percent. Above 8 MeV, the theoretical values were used directly. Neutrons from fission are assumed to isotropic in the laboratory system.

D. Radiative Capture Cross Section

The radiative capture cross section is calculated using the generalized Lorentzian model of Kopecky and Uhl [Ko90]. The normalization of the strength function was set by requiring the calculated (n,γ) cross section be consistent with measured values.

E. Inelastic Neutron Cross Sections

Discrete (n,n′) cross sections are included for the lowest 40 excited states. The first, second, third, and fifth excited states are members of the K = 5/2 ground-state rotational band and include coupled-channel as well as compound nucleus contributions. The remaining discrete-state cross sections through the 40th excited state are combinations of compound nucleus and preequilibrium contributions and were calculated with the GNASH code. Angular distributions for all the discrete inelastic neutrons are appropriate combinations of the compound nucleus, direct reaction, and preequilibrium contributions and are represented by Legendre expansions.

The inelastic data corresponding to excitation energies in ^{241}Am above 0.508 MeV are given as energy-angle correlated continuous spectra and were calculated with the GNASH code. The results are given in File 6 and utilize systematics by Kalbach [Ka88] for angular distribution information, parameterized in terms of preequilibrium ratios calculated in GNASH.

F. Cross Sections for ^{241}Am(n,xn) Reactions

The (n,2n), (n,3n), and (n,4n) cross sections result entirely from the theoretical analysis and GNASH calculations. Energy-angle correlated distributions are given for all the (n,xn) reactions, making use of Kalbach's systematics [Ka88] and the ENDF-6 File 6 representation.

G. $\bar{\nu}$

The evaluation of delayed $\bar{\nu}$ was carried over directly from ENDF/B-VI MOD 2. The prompt $\bar{\nu}$ evaluation was obtained using Madland-Nix theory.

H. Fission Neutron Spectra

The fission neutron spectra was determined using Madland-Nix theory and are consistent with $\bar{\nu}$.

REFERENCES

Ar82 E. D. Arthur, **Fast Neutron Scattering on Actinide Nuclei,** OECD/NEA Specialists' Meeting, Paris, France, November, 1981, **NEANDC-158** (1982) p. 145

Ba74 B. B. Back, et al., ***Phys. Rev. C*** **9**, 1924 (1974)

Br82 H. C. Britt, personal communication, 1982

Du70 C. L. Dunford, **AI-AEC-12931** (1970) Atomics International

Gi65 A. Gilbert and A. Cameron, ***Can. J. Phys.*** **43**, 1446 (1965)

Ka88 C. Kalbach, ***Phys. Rev. C*** **37**, 2350 (1988); C. Kalbach and F. M. Mann, ***Phys. Rev. C*** **23**, 112 (1981)

Ko90 J. Kopecky and M. Uhl, ***Phys. Rev. C*** **41**, 1941 (1990)

Ra70 J. Raynal, **Computing as a Language of Physics**, Conference, Vienna, Austria, 1970, (International Atomic Energy Agency, 1972), p. 281

Yo88 P. G. Young and E. D. Arthur, **Nucl. Data for Science & Technology**, Mito, Japan, 1988 (Saikon Publishing, Japan, 1988) p. 603

Yo92a P. G. Young and E. D. Arthur, **Nuclear Data for Science and Technology**, Conference, Jülich, Germany, 13-17 May 1991 (Springer-Verlag, 1992) p. 894

Yo92b P. G. Young, E. D. Arthur, and M. B. Chadwick, **LA-12343-MS** (1992) Los Alamos National Laboratory

Evaluation: **^{242}Am Incident Neutron Data, Release 1** (MAT 9546)
Energy Range: 10^{-5} eV to 20 MeV
Files: 1, 2, 3, 4, 5, 8
Evaluators: R. W. Benjamin, F. J. McCrosson (SRL)

ENDF/B-VI MOD 2 REVISION 1 (NNDC, August 1991)
Delayed fission neutron spectrum which was intended for ^{242m}Am was removed.

ENDF/B-VI MOD 0 (NNDC, February 1990)
ENDF/B-V MAT 8542 converted to ENDF-6 format.

ENDF/B-V EVALUATION (R. W. Benjamin, F. J. McCrosson, SRL, August 1975)

GENERAL INFORMATION (File 1)
$\bar{\nu}$ thermal value computed from the semi-empirical work of Gordeeva and Smirenkin [1] as revised by Manero and Konshin [2]. Energy dependence is taken from Howerton [3].
$\bar{\nu}_d$ is taken from Brady and England [4]

RESONANCE PARAMETERS (File 2)
Resolved resonance region is 0 to 101.2 eV. Resonance parameters are determined using the GENRPAR code [5] based upon the SRL data set and an average level spacing of 1.2 eV.
Unresolved resonances are determined on same basis as the resolved parameters using average resonance parameters.

	σ(0.0253 ev)	I_{res} (0.5 eV - 20 MeV)
total	2549.91	
elastic	28.95	
fission	2268.88	620.15
capture	252.08	71.88

SMOOTH CROSS SECTIONS (File 3)
The data in file 3 are given only so that the various processing codes can work. Continuity with the unresolved region is provided, but the cross sections drop immediately to zero. The elastic scattering cross section above 10 keV is the potential scattering cross section calculated with a Spherical Optical Model potential at 10 keV.

ANGULAR DISTRIBUTIONS (File 4)
Elastic distributions taken from ENDF/B-V ^{242m}Am.

SECONDARY NEUTRON ENERGY DISTRIBUTIONS
Simple fission Maxwellian with energy-dependent temperature used.

REFERENCES

1. L. D. Gordeeva and G. N. Smirenkin, ***Sov. At. En.*** **14**, 562 (1963); translated from ***At. En.*** **14**, 530 (1963)
2. F. Manero and V. A. Konshin, ***At. En. Rev*****.** **10**, 637 (1972)
3. R. J. Howerton, ***Nucl. Sci. Eng.*** **46**, 42 (1971)
4. M. C. Brady and T. R. England, ***Nucl. Sci. Eng.*** **103**, 129 (1989)
5. F. J. McCrosson, **Neutron Cross Sections for Science and Technology**, Conference, 15-17 March 1971, Knoxville, TN (National Technical Information Service 1971) p.714

Evaluation: **^{242m}Am Incident Neutron Data, Release 1 (MAT 9547)**
Energy Range: 10^{-5} eV to 20 MeV
Files: 1, 2, 3, 4, 5, 8, 9, 12, 13, 14, 15
Evaluators: F. Mann, R. Schenter (HEDL); R. Benjamin (SRL); R. Howerton (LLNL)

ENDF/B-VI MOD 2 REVISION 1 (NNDC, February 1990)
The delayed fission neutron spectrum was added.

ENDF/B-VI MOD 0 (NNDC, February 1990)
ENDF/B-V MAT 1369 converted to ENDF-6 format.

ENDF/B-V (F. Mann, R. Schenter (HEDL), R. Benjamin (SRL), R. Howerton (LLNL), August 1975)
See ENDF-102 Summary Documentation, 3rd Edition(1991), page 95-Am-242m-1, for documentation of the ENDF/B-V evaluation.

Evaluation: **^{245}Cm Incident Neutron Sublibrary, Release 2 (MAT 9640)**
Energy Range: 10^{-5} eV to 20 MeV
Files: 1, 2, 3, 4, 5, 8, 12, 13, 14, 15
Evaluators: R. W. Benjamin (SRL), R. J. Howerton (LLNL)

ENDF/B-VI MOD 2 REVISION 1 (NNDC, May 1993)
Added missing fission neutron angular distribution to file 4; assumed to be isotropic.

ENDF/B-VI MOD 0 (NNDC, February 1990)
ENDF/B-V MAT 1345 was converted to ENDF-6 format.

ENDF/B-V (R.W. Benjamin (SRL), R. J. Howerton (LLNL), January 1979)
See ENDF-102 Summary Documentation, 3rd Edition (1979), page 96-245-1, for documentation of ENDF/B-V evaluation.

Evaluation: **^{246}Cm Incident Neutron Sublibrary, Release 2 (MAT 9643)**
Energy Range: 10^{-5} eV to 20 MeV
Files: 1, 2, 3, 4, 5, 8, 12, 13, 14, 15
Evaluators: R. W. Benjamin, F. McCrosson (SRL); R. J. Howerton (LLNL) (assembled by R. Kinsey, BNL)

ENDF/B-VI MOD 2 REVISION 1 (NNDC, May 1993)
Added missing fission neutron angular distribution to file 4; assumed to be isotropic.

ENDF/B-VI MOD 0 (NNDC, February 1990)
ENDF/B-V MAT 1346 was converted to ENDF-6 format.

ENDF/B-V (R.W. Benjamin (SRL), R. J. Howerton (LLNL), January 1979)
See ENDF-102 Summary Documentation, 3rd Edition (1979), page 96-246-1, for documentation of ENDF/B-V evaluation.

Evaluation: **^{247}Cm Incident Neutron Sublibrary, Release 2 (MAT 9646)**
Energy Range: 10^{-5} eV to 20 MeV
Files: 1, 2, 3, 4, 5, 8, 12, 13, 14, 15
Evaluators: R. W. Benjamin, F. J. McCrosson (SRL); R. J. Howerton (LLNL)
(assembled by R. Kinsey, BNL)

ENDF/B-VI MOD 2 REVISION 1 (NNDC, May 1993)
Added missing fission neutron angular distribution to file 4; assumed to be isotropic.

ENDF/B-VI MOD 0 (NNDC, February 1990)
ENDF/B-V MAT 8647 was converted to ENDF-6 format.

ENDF/B-V EVALUATION (R. W. Benjamin, F. McCrosson, SRL, Assembled by R. Kinsey, NNDC, July 1976)

This evaluation is in general a combination of the August 1975 evaluation, documented here, of Benjamin and McCrosson (SRL) and the ENDL evaluation of Howerton (LLNL). Important changes or additions are noted.

GENERAL INFORMATION (File 1)

$\bar{\nu}$ thermal value is computed from the semi-empirical work of Gordeeva and Smirenkin [1] as revised by Manero and Konshin [2]. The energy dependence is based on work of Howerton [3] renormalized to the thermal value.

RESONANCE PARAMETERS (File 2)

The resolved region is 0 to 61.7 eV and includes 34 resolved resonances plus one bound level. The first 5 resolved resonances were determined by the GENRPAR code [4] to fit integral and production results [5,6]. The bound level was added. 29 additional resonances were added from the measurements of Moore and Keyworth [7].

The unresolved region is 61.7 eV to 10 keV. Unresolved resonances are determined on the same basis as the resolved, using average resonance parameters.

2200 m/s cross sections and resonance integrals

	σ(0.0253 eV)	I (0.5 eV - 20 MeV)
Total	150.010	
Elastic	8.404	
Fission	83.435	749.670
Capture	58.171	491.197

SMOOTH CROSS SECTIONS (File 3)

For total, elastic, fission, and capture, zero background files up to 10 keV were joined to the LLNL evaluation.

The inelastic (MT=4,91) are taken from the LLNL evaluation with Q calculated from threshold.

(n,2n), (n,3n), and (n,4n) are taken from the LLNL evaluation with threshold calculated from the Q value.

ANGULAR DISTRIBUTIONS (File 4)

Elastic from the LLNL evaluation culled to 101 points per distribution and renormalized.

(n,2n), (n,3n), (n,4n), and the inelastic continuum are dummy isotropic distributions.

SECONDARY NEUTRON ENERGY DISTRIBUTIONS (File 5)

(n,2n), (n,3n), (n,4n), and the inelastic continuum are taken from the LLNL evaluation.

The fission spectrum is a simple fission Maxwellian with energy dependent temperature taken from the SRL evaluation.

PHOTON PRODUCTION (Files 12,13,14,15)

The data are taken from the LLNL evaluation with ranges extended at BNL to agree with File 3.

REFERENCES

1. L. D. Gordeeva and G. N. Smirenkin, ***Sov. At. En.*** **14**, 562 (1963); translated from ***At. En.*** **14**, 530 (1963)
2. F. Manero and V. A. Konshin, ***At. En. Rev.*** **10**, 637 (1972)
3. R. J. Howerton, **UCRL 50400**, Vol 15, Part D, Rev. 1, p. 432 (1978) Lawrence Livermore National Laboratory
4. F. J. McCrosson, **Neutron Cross Sections for Science and Technology**, Conference, 15-17 March 1971, Knoxville, TN (National Technical Information Service 1971) p.714
5. R. W. Benjamin, K. W. MacMurdo, J. D. Spencer, ***Nucl. Sci. Eng.*** **47**, 203 (1972)
6. R. W. Benjamin, et al., **DP-1394** (1975) Savannah River Laboratory
7. M. S. Moore and G. A. Keyworth, ***Phys. Rev. C*** **3**, 1656 (1971)

Evaluation: **^{250}Cf Incident Neutron Sublibrary, Release 2 (MAT 9855)**
Energy Range: 10^{-5} eV to 20 MeV
Files: 1, 2, 3, 4, 5, 8, 12, 13, 14, 15
Evaluators: R. W. Benjamin, F. McCrosson (SRL); R. J. Howerton (LLNL) (assembled by R. Kinsey, BNL)

ENDF/B-VI MOD 2 REVISION 1 (NNDC, May 1993)
Added missing fission neutron angular distribution to file 4; assumed to be isotropic.

ENDF/B-VI MOD 0 (Assembled by R. Kinsey, NNDC, February 1990)
ENDF/B-V MAT 8850 was converted to ENDF-6 format.

ENDF/B-V EVALUATION (R. W. Benjamin, F. McCrosson, SRL, R. J. Howerton, LLNL, Assembled by R. Kinsey, NNDC, July 1976)

This evaluation is in general a combination of the August 1975 evaluation of Benjamin and McCrosson at SRL, documented here, and the ENDL evaluation of Howerton at LLNL [4]. Important changes or additions are noted.

GENERAL INFORMATION (File 1)
$\bar{\nu}$ taken from LLNL evaluation.

RESONANCE PARAMETERS (File 2) (0 TO 10 KEV)

The resolved region is 0 to 286.1 eV. Resonance parameters were determined by the GENRPAR code [1], based upon resonance integrals and cross sections from production measurements of Benjamin, et al. [2] and ORR irradiations of Halperin, et al. [3]. A bound level at -2.115 eV was removed from the SRL evaluation. Appropriate backgrounds were included in the total cross sections in order that the (n,γ) curve would remain the same.

The unresolved region is 286.1 eV to 10 keV. Unresolved resonances are determined on the same basis as the resolved, using average resonance parameters.

2200 m/s cross sections and resonance integrals

	σ(0.0253 eV)	I_{res} (0.5 eV - 20 MeV)
Total	1619.88	
Elastic	8.90	
Fission	0.00	10.79
Capture	1610.98	11200.1

SMOOTH CROSS SECTIONS (File 3)

The total cross section is the sum of the elastic and (n,γ) background files up to 10 keV joined to the LLNL evaluation.

The elastic background is a constant up to the first resonance which then goes rapidly to zero. The constant chosen to give a thermal cross section in combination with the resonance parameters which is equal to 90% of the Spherical Optical Model value. Above the first resonance, this background does not prevent the cross section from going negative for the next dozen or so resonances. Above 10 keV, the cross section is from the LLNL evaluation.

For fission, a zero background file up to 10 keV was joined to the LLNL evaluation.

For capture, the background was calculated to give the same curve after the bound level was deleted as was obtained with the original SRL parameters up to 10 keV; it was then joined to the LLNL evaluation.

The inelastic data are taken from the LLNL evaluation with Q calculated from the threshold.

(n,2n), (n,3n), and (n,4n) are taken from the LLNL evaluation with threshold calculated from the Q value.

ANGULAR DISTRIBUTIONS (File 4)

Elastic from LLNL evaluation are culled to 101 points per distribution and renormalized.

(n,2n), (n,3n), (n,4n), and the inelastic continuum are dummy isotropic distributions.

SECONDARY NEUTRON ENERGY DISTRIBUTIONS (File 5)

(n,2n), (n,3n), (n,4n), and the inelastic continuum are taken from LLNL evaluation.

The fission spectrum is a simple fission Maxwellian distribution with energy dependent temperature from the LLNL evaluation has been converted from a tabular representation and extended down to 10^{-5} eV.

REFERENCES

1. F. J. McCrosson, **Neutron Cross Sections for Science and Technology**, Conference, 15-17 March 1971, Knoxville, TN (National Technical Information Service 1971) p.714
2. R. W. Benjamin, et al., **DP-1394** (1975) Savannah River Laboratory
3. J. Halperin, et al., **ORNL-4706**, p. 47 (1971) Oak Ridge National Laboratory Progress Report
4. R. J. Howerton, **UCRL 50400**, Vol 15, Part D, Rev. 1, p. 456 (1978) Lawrence Livermore National Laboratory

Evaluation: **^{251}Cf Incident Neutron Sublibrary, Release 2 (MAT 9858)**
Energy Range: 10^{-5} eV to 20 MeV
Files: 1, 2, 3, 4, 5, 8, 12, 13, 14, 15
Evaluators: R. W. Benjamin, F. McCrosson (SRL); R. J. Howerton (LLNL) (assembled by R. Kinsey, BNL)

ENDF/B-VI MOD 2 REVISION 1 (NNDC, May 1993)
Added missing fission neutron angular distribution to file 4; assumed to be isotropic.

ENDF/B-VI MOD 0 (NNDC, February 1990)
ENDF/B-V MAT 8851 converted to ENDF-6 format.

ENDF/B-V EVALUATION (R. W. Benjamin, F. McCrosson, SRL, R. J. Howerton, LLNL, assembled by R. Kinsey, NNDC, July 1976)

This evaluation is in general a combination of the August 1975 evaluation of Benjamin and McCrosson at SRL, documented here, and the ENDL evaluation of Howerton at LLNL [3]. Important changes or additions are noted.

GENERAL INFORMATION (File 1)

$\bar{\nu}$ thermal value is computed from the semi-empirical work of Gordeeva and Smirenkin [1] as revised by Manero and Konshin [2]. The energy dependence is based on work of Howerton [3] renormalized to the thermal value at BNL.

$\bar{\nu}_d$ is taken from Brady and England [7].

RESONANCE PARAMETERS (File 2)

The resolved region is 0 to 163.9 eV. Resolved resonance parameters determined by the GENRPAR Code [4] based upon resonance integrals and cross sections from production measurements [5] and ORR irradiations [6]. A bound level at -2.035 eV was removed from the SRL evaluation. Appropriate backgrounds were included in File 3 in order that the capture and fission curves would remain the same.

The unresolved region is 163.9 eV to 10 keV. Unresolved resonances are determined on the same basis as the resolved, using average resonance parameters.

<u>2200 m/s cross sections and resonance integrals</u>

	σ(0.0253 eV)	I_{res} (0.5 eV - 20 MeV)
Total	8191.73	
Elastic	8.84	
Fission	5321.28	4949.63
Capture	2861.61	1629.34

SMOOTH CROSS SECTIONS (File 3)

The total is sum of the elastic, fission and capture background files up to 10 keV, joined to the LLNL evaluation.

Elastic background is a constant up to the first resonance which then goes rapidly to zero. The constant is chosen to give a thermal cross section in combination with the resonance parameters which is equal to 90% of the spherical optical model value. Above 10 keV, the cross section is from the LLNL evaluation.

The fission and capture backgrounds were calculated to give the same curve after the bound level was deleted as was obtained with the original SRL parameters up to 10 keV joined to the LLNL evaluation.

The inelastic data is taken from LLNL evaluation with Q calculated from threshold.

(n,2n), (n,3n), and (n,4n) is from LLNL evaluation with threshold calculated from the Q value.

ANGULAR DISTRIBUTIONS (File 4)

Elastic from LLNL evaluation culled to 101 points per distribution and renormalized.

(n,2n), (n,3n), (n,4n), and inelastic to the continuum are dummy isotropic distributions.

SECONDARY NEUTRON ENERGY DISTRIBUTIONS

(n,2n), (n,3n), (n,4n), and inelastic to the continuum from LLNL evaluation.

Fission is a simple fission Maxwellian distribution with energy dependent temperature taken from the SRL evaluation.

REFERENCES

1. L. D. Gordeeva and G. N. Smirenkin, ***Sov. At. En.*** **14**, 562 (1963); translated from ***At. En.*** **14**, 530 (1963)
2. F. Manero and V. A. Konshin, ***At. En. Rev.*** **10**, 637 (1972)
3. R. J. Howerton, **UCRL 50400**, Vol 15, Part D, Rev. 1, p. 462 (1978) Lawrence Livermore National Laboratory
4. F. J. McCrosson, **Neutron Cross Sections for Science and Technology**, Conference, 15-17 March 1971, Knoxville, TN (National Technical Information Service 1971) p.714
5. R. W. Benjamin, et al., **DP-1394** (1975) Savannah River Laboratory
6. J. Halperin, et al., **ORNL-4706**, p. 47 (1971) Oak Ridge National Laboratory Progress Report
7. M. C. Brady and T. R. England, ***Nucl. Sci. Eng.*** **103**, 129 (1989)

Evaluation: **^{252}Cf Incident Neutron Sublibrary, Release 1, 2 (MAT 9861)**
Energy Range: 10^{-5} eV to 20 MeV
Files: 1, 2, 3, 4, 5, 8, 12, 13, 14, 15
Evaluators: R. W. Benjamin, F. McCrosson (SRL); R. J. Howerton (LLNL) (assembled by R. Kinsey, BNL)

ENDF/B-VI MOD 3 REVISION 2 (NNDC, May 1993)
Added missing fission neutron angular distribution to file 4; assumed to be isotropic.

ENDF/B-VI MOD 2 REVISION 1 (NNDC, August 1991)
Removed delayed fission neutron spectra which were for spontaneous fission.

ENDF/B-VI MOD 0 (Assembled by R. Kinsey, NNDC, February 1990)
ENDF/B-V MAT 8851 converted to ENDF-6 format.

ENDF/B-V EVALUATION (R. W. Benjamin, F. McCrosson, SRL, R. J. Howerton, LLNL, assembled by R. Kinsey, NNDC, July 1976)

This evaluation is in general a combination of the August 1975 evaluation of Benjamin and McCrosson at SRL, documented here, and the ENDL evaluation of Howerton at LLNL [3]. Important changes or additions are noted.

GENERAL INFORMATION (File 1)

$\bar{\nu}$ thermal value is computed from the semi-empirical work of Gordeeva and Smirenkin [1] as revised by Manero and Konshin [2]. The energy dependence is based on work of Howerton [3] renormalized to the thermal value at BNL.

$\bar{\nu}_d$ is taken from Brady and England [8].

RESONANCE PARAMETERS (File 2)

The resolved region is 0 to 366.5 eV. Resolved resonance parameters determined by the GENRPAR Code [4] based upon resonance integrals and cross sections from production measurements [5] and ORR irradiations [6,7]. A bound level at -2.035 eV was removed from the SRL evaluation. Appropriate backgrounds were included in File 3 in order that the capture and fission curves would remain the same.

The unresolved region is 366.5 eV to 10 keV. Unresolved resonances are determined on the same basis as the resolved, using average resonance parameters.

2200 m/s cross sections and resonance integrals

	σ(0.0253 eV)	I_{res} (0.5 eV - 20 MeV)
Total	63.881	
Elastic	11.213	
Fission	32.174	119.198
Capture	20.493	47.292

SOOTH CROSS SECTIONS (File 3)

The total is sum of the elastic, fission and capture background files up to 10 keV joined to the LLNL evaluation.

The inelastic data is taken from LLNL evaluation with Q calculated from threshold.

(n,2n), (n,3n), and (n,4n) are taken from LLNL evaluation with threshold calculated from the Q value.

ANGULAR DISTRIBUTIONS (File 4)

The elastic is taken from LLNL evaluation, culled to 101 points per distribution, and renormalized.

The (n,2n), (n,3n), (n,4n), and inelastic to the continuum are dummy isotropic distributions.

SECONDARY NEUTRON ENERGY DISTRIBUTIONS (File 5)

The (n,2n), (n,3n), (n,4n), and inelastic to the continuum are taken from LLNL evaluation.

The fission is a simple fission Maxwellian distribution with energy dependent temperature taken from the SRL evaluation.

REFERENCES

1. L. D. Gordeeva and G. N. Smirenkin, ***Sov. At. En.*** **14**, 562 (1963); translated from ***At. En.*** **14**, 530 (1963)
2. F. Manero and V. A. Konshin, ***At. En. Rev.*** **10**, 637 (1972)
3. R. J. Howerton, **UCRL 50400**, Vol 15, Part D, Rev. 1, p. 468 (1978) Lawrence Livermore National Laboratory
4. F. J. McCrosson, **Neutron Cross Sections for Science and Technology**, Conference, 15-17 March 1971, Knoxville, TN (National Technical Information Service 1971) p.714
5. R. W. Benjamin, et al., **DP-1394** (1975) Savannah River Laboratory
6. J. Halperin, et al., **ORNL-4706**, p. 47 (1971) Oak Ridge National Laboratory Progress Report
7. M. C. Brady and T. R. England, ***Nucl. Sci. Eng.*** **103**, 129 (1989)

Evaluation: **^{253}Cf Incident Neutron Sublibrary, Release 2 (MAT 9864)**
Energy Range: 10^{-5} eV to 20 MeV
Files: 1, 2, 3, 4, 5
Evaluators: R. W. Benjamin, F. McCrosson (SRL); R. J. Howerton (LLNL) (assembled by R. Kinsey, BNL)

ENDF/B-VI MOD 2 REVISION 1 (NNDC, May 1993)
Added missing fission neutron angular distribution; assumed to be isotropic.

ENDF/B-VI MOD 0 (NNDC, February 1990)
ENDF/B-V MAT 8853 converted to ENDF-6 format.

ENDF/B-V EVALUATION (R. W. Benjamin, F. McCrosson, SRL, Assembled by R. Kinsey, NNDC, December 1995)

This evaluation is, in general, the December 1975 evaluation of Benjamin and McCrosson at SRL documented here.

GENERAL INFORMATION (File 1)

$\bar{\nu}$ thermal value is computed from the semi-empirical work of Gordeeva and Smirenkin [1] as revised by Manero and Konshin [2]. The energy dependence is based on work of Howerton [3].

RESONANCE PARAMETERS (File 2)

The resolved region is 0 to 100.4 eV. Resolved resonance parameters determined by the GENRPAR code [4] based upon resonance integrals and thermal cross sections from production [5] and integral [6,7] measurements. The effective ^{253}Cf capture-to-fission ratio, derived from the measurements of Bemis, et al. [9], is well below the range expected from nuclear systematics. In the present evaluation, alpha has been assumed to be 0.3 over the entire energy range, in accordance with the work of Prince [8].

The unresolved region 100.4 eV to 10 keV. Unresolved resonances are determined on the same basis as the resolved, giving average resonance parameters.

2200 m/s cross sections and resonance integrals

	σ(0.0253 eV)	I_{res} (0.5 eV - 20 MeV)
Total	542.22	
Elastic	64.82	
Fission	1136.12	1244.84
Capture	341.28	379.19

SMOOTH CROSS SECTIONS (File 3)

The data in File 3 are given only so that the various processing codes can work. Continuity with the unresolved region is provided, but the cross sections drop immediately to zero. The elastic cross section is the potential scattering cross section calculated with a Spherical Optical Model potential at 10 keV.

ANGULAR DISTRIBUTIONS (File 4)

Elastic distributions are taken from the ENDF/B-V evaluation for ^{251}Cf.

SECONDARY NEUTRON ENERGY DISTRIBUTIONS (File 5)

The fission is a simple fission Maxwellian distribution with energy dependent temperature.

REFERENCES

1. L. D. Gordeeva and G. N. Smirenkin, ***Sov. At. En.*** **14**, 562 (1963); translated from ***At. En.*** **14**, 530 (1963)
2. F. Manero and V. A. Konshin, ***At. En. Rev.*** **10**, 637 (1972)
3. R. J. Howerton, ***Nucl. Sci. Eng.*** **46**, 42 (1971)
4. F. J. McCrosson, **Neutron Cross Sections for Science and Technology**, Conference, 15-17 March 1971, Knoxville, TN (National Technical Information Service 1971) p.714
5. R. W. Benjamin, et al., **DP-1394** (1975) Savannah River Laboratory
6. J. F. Wild, E. K. Hulet, and R. W. Lougheed, ***J. Inorg. Nucl. Chem.*** **35**, 1063(1973)
7. C. E. Bemis, Jr., R. E. Druschel,and J. Halperin, ***Nucl. Sci. Eng.*** **41**, 146 (1970)
8. A. Prince, **Neutron Cross Sections & Technology**, Conference, Washington, DC, 4-7 March 1968, Volume II (National Bureau of Standards, 1968) p. 951