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HANDBOOK OF NUCLEAR DATA FOR SAFEGUARDS

Prepared by

A. L. Nichols, D. L. Aldama*, M. Verpelli

* División de Información

Centro de Gestión de la Información y Desarrollo de la Energía.
Agencia de Energía Nuclear y Tecnologías de Avanzada.
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Division of Physical and Chemical Sciences
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International Atomic Energy Agency
Vienna, Austria

January 2007

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Abstract

A set of recommended nuclear data have been assembled that are judged to be suitable for application with respect to nuclear materials accounting techniques. These revised data supersede the tabulations to be found within IAEA report INDC(NDS)-376, December 1997. The update is based on available evaluated nuclear databases and recently published files, books and technical reports. Every effort has been made to ensure that the recommended data are credible and correct with respect to their original sources. Section A contains decay data, thermal neutron capture cross section data, resonance integrals and neutron emission yields per fission for relevant actinides and their natural decay products; Section B includes decay and thermal neutron capture cross section data for some important fission products; Section C presents fission product yield data for selected actinides. The recommended data sets can be inspected as tables in this INDC(NDS) report, or through the adoption and use of appropriate software. Users are referred to "Interactive Chart of Nuclides" for an introduction to software that can be downloaded from the Web to undertake rapid inspections of the assembled database. The Web site is located at <http://www-nds.iaea.org/sgnucdat/>

January 2007

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1 Introduction

The aim of the present handbook is to provide evaluated and carefully selected nuclear data suitable for application with respect to nuclear materials accounting techniques. These revised data supersede the tabulations to be found within IAEA report INDC(NDS)-376, December 1997. The update is based on available evaluated nuclear databases and recently published files, books and technical reports.

Adopted definitions, symbols and notations are listed in Section 2, below. The selection rules for recommended data from the various sources are given in Section 3, while Section 4 specifies the contents of the tables. The nuclear data for safeguards are given in three sections:

Section A contains decay data, thermal neutron cross-section data, resonance integrals and neutron emission yields per fission for relevant actinides and their natural decay products;

Section B includes decay and thermal neutron cross-section data for some important fission products;

Section C presents fission product yield data for some selected actinides.

Additional remarks are given as footnotes to the corresponding tables.

Notable additions in this release were the inclusion of decay data for a number of natural decay chain products of U-238, U-235 and Th-232. Furthermore, a re-evaluation of the Th-234 gamma-ray emission probabilities was performed and Pa-234m gamma-ray data were also included.

2 Definitions, Symbols and Notations

2.1 Definitions

Nuclide: atoms characterized by atomic number Z and mass number A .

Radionuclide: radioactive nuclide.

Disintegration: spontaneous transformation of the nucleus into another nucleus that gives rise to a change in the atomic number, into two or more nuclei (fission), or a transition to a lower energy state of the same nucleus.

Emission probability: particles or quanta emitted per disintegration.

Half-life ($T_{1/2}$): time required for the initial number of atomic nuclei to decrease by a factor of two via radioactive disintegration.

Independent fission yields: number of atoms of a specific nuclide produced directly by a fission event (not via radioactive decay of the precursors).

Cumulative fission yields: total number of atoms of a specific nuclide produced directly by a fission event and via decay of precursors.

Chain fission yields: sum of the cumulative yields of the last (stable or long-lived) chain members - obtained by means of mass spectrometric measurements of long-lived or stable products of mass chains.

Mass number yields: sum of all independent yields of a particular mass chain.

2.2 Units adopted

s: second
m: minute
h: hour
d: day
y: year (1 y = 365.24219878 d = 31 556 926 s)
J: joule
eV: electronvolt (1 eV = $1.602177 \cdot 10^{-19}$ J)
barn: 10^{-24} cm²

2.3 Symbols and notations

2.3.1 Decay data

$T_{1/2}$: half-life
BF: branching fraction
 α : alpha particle
 β^- : electron from β^- decay
 β^+ : positron from β^+ decay
e: electron
 γ : gamma quantum
X: X-ray quantum
 X_k : K X-ray quantum
n: neutron
SF: spontaneous fission
EC: electron capture
IT: isomeric transition
E: energy
 P_α : α -particle emission probability
 P_γ : γ -ray emission probability
 P_x : X-ray emission probability

2.3.2 Cross-section and delayed-neutron data

σ_0 : neutron cross section at 2200 m/s
 σ : neutron cross section in a Maxwellian spectrum
 σ_r : neutron cross section measured with reactor neutrons
 σ_c : neutron cross section calculated from resonance parameters or derived from equivalent data of the natural element
 $\sigma_{(m)}$: neutron cross section leading to a metastable state of the product
 $\sigma_{(g)}$: neutron cross section leading to the ground state of the product
g Westcott factor: ratio of the Maxwellian averaged cross section σ to 2200 m/s cross section σ_0 ($g = \sigma/\sigma_0$); if the cross section varies as a function of $1/v$, $g = 1.0$
RI: infinite dilution resonance integral (including $1/v$ contribution)
 γ : subscript for radiative capture cross section
f: subscript for fission cross section
 ν_t : total neutron yield per fission
 ν_d : delayed-neutron yield per fission
 $T_{1/2i}$: half-life of delayed-neutron group i
 λ_i : mean life of delayed-neutron group i

- α_i : ratio of the average number of delayed neutrons per fission emitted in group i to the average number of all delayed neutrons per fission ($\alpha_i = \nu_{di} / \nu_d$)
- β_i : ratio of the average number of delayed neutrons per fission emitted in group i to the average number of all neutrons per fission ($\beta_i = \nu_{di} / \nu_t = \alpha_i \cdot \nu_d / \nu_t$)

3 General rules for selection of data

The following criteria were applied in the course of selecting the data:

Preference was given to evaluated data recommended by international working groups and projects, reported in recent publications, or available on the web.

If the first criterion was not applicable, data were adopted from available evaluated nuclear data libraries: ENSDF for decay data and ENDF/B-VII or JEFF-3.1 for reaction data.

If uncertainties were not available in the evaluated nuclear data source, these parameters were adopted from the original documentation related to the selected source, or they were estimated from the experimental data available in the EXFOR library, or published in recent relevant papers or reports.

4 Contents of the tables

The data are presented in three sections:

Section A: Decay data, thermal neutron cross-section data, resonance integrals, average fission neutron yields and delayed-neutron eight-group parameters for actinides and natural decay products.

Section B: Decay data, thermal neutron cross-section data and resonance integrals for fission products.

Section C: Fission product yield data for the most important actinides.

4.1 Section A – Actinides and natural decay products

Table A-1: Half-lives and branching fractions for actinides and natural decay products

Table A-2: Alpha energies and emission probabilities for actinides and natural decay products

Table A-3: Gamma-ray energies and emission probabilities for actinides and natural decay products

Table A-4: X-ray energies and intensities for actinides and natural decay products

Table A-5: Actinide data: Thermal neutron cross sections, resonance integrals and Westcott factors

Table A-6: Average number of neutrons emitted per fission

Table A-7: Delayed-neutron eight-group parameters

A brief description of the data presented in each table is given below. Additional remarks are included as footnotes to the tables.

4.1.1 Table A-1: Half-lives and branching fractions for actinides and natural decay products

Content of Table A-1:

1. Nuclide
2. Half-life with 1σ uncertainty, ($T_{1/2} \pm \Delta T_{1/2}$)
3. Units (s, m, h, d, y)
4. Decay mode (α , β^+ , β^- , EC, IT, SF)
5. Branching fraction with 1σ uncertainty, ($BF \pm \Delta BF$)
6. Source of data

Data sources are listed below in order of preference:

BIPM-5: M.-M. Bé, V. Chisté, C. Dullieu, E. Browne, V. Chechev, N. Kuzmenko, R. Helmer, A. Nichols, E. Schönfeld, R. Dersch, Monographie BIPM-5, Table of Radionuclides, Vol. 2 - A = 151 to 242, 2004.

LNHB: Laboratoire National Henri Becquerel, Decay Data Evaluation Project, http://www.nucleide.org/DDEP_WG/DDEPdata.htm, 3 October 2006.

IAEA-CRP-XG: M.-M. Bé, V.P. Chechev, R. Dersch, O.A.M. Helene, R.G. Helmer, M. Herman, S. Hlaváč, A. Marcinkowski, G.L. Molnár, A.L. Nichols, E. Schönfeld, V.R. Vanin, M.J. Woods, IAEA CRP "Update of X-ray and Gamma-ray Decay Data Standards for Detector Calibration and Other Applications", IAEA Nuclear Data Section, 2004.

ENSDF: Evaluated Nuclear Structure Data File, <http://www-nds.iaea.org/ensdf/>, 15 November 2006.

If the data in BIPM-5 and LNHB were the same for a given evaluation, BIPM-5 was quoted as the data source. Data from BIPM-5 and LNHB were adopted in preference to ENSDF data.

4.1.2 Table A-2: Alpha-particle energies and emission probabilities for actinides and natural decay products

Content of Table A-2:

1. Nuclide
2. Half-life with 1σ uncertainty, ($T_{1/2} \pm \Delta T_{1/2}$)
3. Half-life units (s, m, h, d, y)
4. α -particle energy with 1σ uncertainty, ($E_\alpha \pm \Delta E_\alpha$ in keV)
5. Emission probability P_α per 100 decays with 1σ uncertainty, ($P_\alpha \pm \Delta P_\alpha$ in % decay)
6. Source of data
7. Notes

Data sources are listed below in order of preference:

BIPM-5: M.-M. Bé, V. Chisté, C. Dullieu, E. Browne, V. Chechev, N. Kuzmenko, R. Helmer, A. Nichols, E. Schönfeld, R. Dersch, Monographie BIPM-5, Table of Radionuclides, Vol. 2 - A = 151 to 242, 2004.

LNHB: Laboratoire National Henri Becquerel, Decay Data Evaluation Project, http://www.nucleide.org/DDEP_WG/DDEPdata.htm, 3 October 2006.

ENSDF: Evaluated Nuclear Structure Data File,
<http://www-nds.iaea.org/ensdf/>, 15 November 2006.

Same comments about preference are applicable as stated for Table A-1. Alpha particles with energies below 40 keV were normally omitted, as they are judged to be unsuitable for non-destructive assay.

4.1.3 Table A-3: Gamma-ray energies and emission probabilities for actinides and natural decay products

Content of Table A-3:

1. Nuclide
2. Half-life with 1σ uncertainty, ($T_{1/2} \pm \Delta T_{1/2}$)
3. Half-life units (s, m, h, d, y).
4. γ -ray energy with 1σ uncertainty, ($E_\gamma \pm \Delta E_\gamma$ in keV)
5. Emission probability P_γ per 100 decays with 1σ uncertainty, ($P_\gamma \pm \Delta P_\gamma$ in % decay)
6. Source of data
7. Notes

Data sources are listed below in order of preference:

ADS-98: I. Adsley, J.S. Backhouse, A.L. Nichols, J. Toole, U-238 Decay Chain: Resolution of Observed Anomalies in the Measured Secular Equilibrium Between Th-234 and Daughter Pa-234m, *Appl. Radiat. Isot.* **49** (1998) 1337.

BIPM-5: M.-M. Bé, V. Chisté, C. Dulieu, E. Browne, V. Chechev, N. Kuzmenko, R. Helmer, A. Nichols, E. Schönfeld, R. Dersch, Monographie BIPM-5, Table of Radionuclides, Vol. 2 - A = 151 to 242, 2004.

LNHB: Laboratoire National Henri Becquerel, Decay Data Evaluation Project,
http://www.nucleide.org/DDEP_WG/DDEPdata.htm, 3 October 2006.

IAEA-CRP-XG: M.-M. Bé, V.P. Chechev, R. Dersch, O.A.M. Helene, R.G. Helmer, M. Herman, S. Hlaváč, A. Marcinkowski, G.L. Molnár, A.L. Nichols, E. Schönfeld, V.R. Vanin, M.J. Woods, IAEA CRP "Update of X-ray and Gamma-ray Decay Data Standards for Detector Calibration and Other Applications", IAEA Nuclear Data Section, 2004.

ENSDF: Evaluated Nuclear Structure Data File,
<http://www-nds.iaea.org/ensdf/>, 15 November 2006.

Same comments about preference are applicable as stated for Table A-1. Gamma rays with energies below 40 keV were normally omitted, as they are judged to be unsuitable for non-destructive assay.

4.1.4 Table A-4: K X-ray energies and intensities for actinides and natural decay products

Content of Table A-4:

1. Nuclide
2. Half-life with 1σ uncertainty, ($T_{1/2} \pm \Delta T_{1/2}$)
3. Half-life units (s, m, h, d, y)
4. Decay mode (α , β^+ , β^- , EC)

5. Origin of K X-rays - element of origin is specified, and the X-rays are defined on the basis of the Siegbahn notation. K X-rays associated with the following shell transitions are listed in the table:

$K\alpha_2$	K-L2	
$K\alpha_1$	K-L3	
$K'\beta_1$	$K\beta_3$	K-M2
	$K\beta_1$	K-M3
	$K\beta_5$	K-M5M4
$K'\beta_2$	$K\beta_2$	K-N3N2
	$K\beta_4$	K-N5N4
	KO	K-O23
	KP	K-P23

6. X-ray energy (E_x) or energy group in keV
 7. Emission probability P_x per 100 decays with 1σ uncertainty, ($P_x \pm \Delta P_x$ in % decay)
 8. Source of data

Data sources are listed below in order of preference:

- PTB: E. Schönfeld, G. Rodloff, Energies and relative emission probabilities of K X-rays for elements with atomic number in the range from $Z = 5$ to $Z = 100$, Report PTB-6.11-1999-1, 1999.
- BIPM-5: M.-M. Bé, V. Chisté, C. Dulieu, E. Browne, V. Chechev, N. Kuzmenko, R. Helmer, A. Nichols, E. Schönfeld, R. Dersch, Monographie BIPM-5, Table of Radionuclides, Vol. 2 - A = 151 to 242, 2004.
- LNHB: Laboratoire National Henri Becquerel, Decay Data Evaluation Project, http://www.nucleide.org/DDEP_WG/DDEPdata.htm, 3 October 2006.
- IAEA-CRP-XG: M.-M. Bé, V.P. Chechev, R. Dersch, O.A.M. Helene, R.G. Helmer, M. Herman, S. Hlaváč, A. Marcinkowski, G.L. Molnár, A.L. Nichols, E. Schönfeld, V.R. Vanin, M.J. Woods, IAEA CRP "Update of X-ray and Gamma-ray Decay Data Standards for Detector Calibration and Other Applications", IAEA Nuclear Data Section, 2004.
- ENSDF: Evaluated Nuclear Structure Data File, <http://www-nds.iaea.org/ensdf/>, 15 November 2006.

K X-ray energies were always adopted from PTB. If the data in BIPM-5 and LNHB were the same for a given evaluation, BIPM-5 was quoted as the data source. Data from BIPM-5 and LNHB were adopted in preference to ENSDF data.

When ENSDF was selected as the source of data, only the emission probability for the $K\alpha_1$ transition was adopted from this evaluated nuclear database. The emission probabilities for $K\alpha_2$, $K'\beta_1$ and $K'\beta_2$ were calculated using the relative emission probabilities listed in PTB.

4.1.5 Table A-5: Actinide data: Thermal neutron cross sections, resonance integrals and Westcott factors

Content of Table A-5:

1. Nuclide
2. Type of thermal cross section (σ_0 , σ , σ_r , σ_c , $\sigma_{(m)}$, $\sigma_{(g)}$)
3. Thermal cross section with 1σ uncertainty in barns, ($\sigma \pm \Delta\sigma$)
4. Westcott factor, ($g \pm \Delta g$)
5. Resonance integral with 1σ uncertainty in barns, ($RI \pm \Delta RI$)
6. Source of data

Data sources are listed below:

TRK-05: A. Trkov, G.L. Molnár, Zs. Révay, S.F. Mughabghab, R.B. Firestone, V.G. Pronyaev, A.L. Nichols, M.C. Moxon, Revisiting the ^{238}U Thermal Capture Cross Section and Gamma-ray Emission Probabilities from ^{239}Np Decay, *Nucl. Sci. Eng.* **150** (2005) 336.

ANR: S.F. Mughabghab, Atlas of Neutron Resonances, Resonance Parameters and Thermal Cross Sections, $Z = 1 - 100$, 5th Edition, Elsevier, Amsterdam, 2006.

ENDF/B-VII: US Evaluated Nuclear Data Library ENDF/B-VII $\beta 3$, Incident neutron data, <http://www.nndc.bnl.gov/exfor4/endl00.htm>, 2 October 2006; see also M.B. Chadwick *et al.*, ENDF/B-VII.0: Next Generation Evaluated Nuclear Data Library for Nuclear Science and Technology, *Nucl. Data Sheets*, **107** (2006) 2931.

JEFF-3.1: Joint Evaluated Fission and Fusion File, Incident neutron data, <http://www-nds.iaea.org/exfor/endl00.htm>, 2 October 2006; see also A. Koning, R. Forrest, M. Kellett, R. Mills, H. Henriksson, Y. Rugama, The JEFF-3.1 Nuclear Data Library, JEFF Report 21, OECD/NEA, Paris, France, 2006, ISBN 92-64-02314-3.

Cross sections, Westcott factors and resonance integrals were adopted from ANR, whereas the U-238 thermal neutron capture cross section was taken from TRK-05. When ANR data were incomplete or judged to be inadequate, the ENDF/B-VII and the JEFF-3.1 evaluated nuclear data libraries were used as data sources. Additional remarks are included as footnotes to the table.

4.1.6 Table A-6: Average number of neutrons emitted per fission

Content of Table A-6:

1. Nuclide (fissionable isotope)
2. Type of incident neutron spectrum (fast, thermal, spontaneous fission)
3. Total neutron yield per fission (ν_t) and associated 1σ uncertainty, ($\nu_t \pm \Delta\nu_t$)
4. Source of data for ν_t
5. Total delayed-neutron yield per fission (ν_d) and associated 1σ uncertainty, ($\nu_d \pm \Delta\nu_d$)
6. Source of data for ν_d

Data sources are listed below:

IAEA-CRP-STD: S.A. Badikov, A.D. Carlson, E.V. Gai, G.M. Hale, H.M. Hofmann, T. Kawano, N.M. Larson, Sy. Oh, V.G. Pronyaev, S. Tagesen, H.K. Vonach,

C. Zhenpeng, IAEA-CRP "Improvement of the standard cross sections for light elements", IAEA Nuclear Data Section, November 2004, <http://www-nds.iaea.org/standards/lastresults.html>.

NEA/WPEC-6: G. Rudstam, Ph. Finck, A. Filip, A. D'Angelo, R.D. McKnight, Delayed Neutron Data for the Major Actinides, NEA/WPEC-6, Volume 6, NEA/OECD, Paris, France, 2002.

JEFF-3.1: Joint Evaluated Fission and Fusion File, Incident neutron and radioactive decay data files, <http://www.nea.fr/html/dbdata/JEFF/>, 26 February 2006; see also A. Koning, R. Forrest, M. Kellett, R. Mills, H. Henriksson, Y. Rugama, The JEFF-3.1 Nuclear Data Library, JEFF Report 21, OECD/NEA, Paris, France, 2006, ISBN 92-64-02314-3.

ENDF/B-VII: US Evaluated Nuclear Data Library ENDF/B-VII β 3, Incident neutron data, <http://www.nndc.bnl.gov/exfor4/endl00.htm>, 2 October 2006; see also M.B. Chadwick *et al.*, ENDF/B-VII.0: Next Generation Evaluated Nuclear Data Library for Nuclear Science and Technology, *Nucl. Data Sheets*, **107** (2006) 2931.

P&I(1998): V.M. Piksaikin, S.G. Isaev, Correlation properties of delayed neutrons from fast neutron induced fission, pp. 1-13 in INDC(CCP)-415, October 1998, IAEA, Vienna, Austria.

Mills(1995): R.W. Mills, Fission product yield evaluation, PhD thesis, University of Birmingham, UK, March 1995.

Tuttle(1979): R.J. Tuttle, Delayed-neutron yields in nuclear fission, pp. 29-67 in Proc. Consultants' Meeting on Delayed Neutron Properties, 26-30 March 1979, INDC(NDS)-107 (1979) 29, IAEA, Vienna, Austria.

EXFOR: Experimental Nuclear Reaction Data, <http://www-nds.iaea.org/exfor/exfor00.htm>, 27 March 2006.

Total fission neutron yields reported in IAEA-CRP-STD were preferred. Otherwise, JEFF-3.1 data were recommended, with the exceptions of Th-232 and U-238 for which ENDF/B-VII data were chosen.

Delayed-neutron yields were usually adopted from the JEFF-3.1 library; exceptions were U-238 and the delayed-neutron yields from spontaneous fission. ENDF/B-VII data were selected for U-238, and values reported by Mills or Tuttle were adopted in the case of spontaneous fission.

Data adopted from the JEFF-3.1 or ENDF/B-VII evaluated nuclear data libraries were processed using the NJOY-99 code. A thermal or a fast reactor spectrum was used to average the corresponding thermal or fast neutron yield (GROUPR input option IWT= - 4 and - 8, respectively). If available, covariance file MF=31 was also processed to estimate uncertainties.

When the chosen data source did not include uncertainties, they were estimated from the experimental data to be found in the EXFOR library or reported by P&I (1998). The uncertainty was calculated on the basis of the following expression:

$$\sigma_v = [(v - v_{\text{exp}})^2 + \sigma_{v,\text{exp}}^2]^{1/2},$$

where σ_v is the standard deviation of v (total or delayed-neutron yield),
 v is the recommended value of v given in Table A-6,

v_{exp} is the weighted average value of v calculated from the selected experimental data - weights were the inverse of the squares of the individual measured uncertainties, and
 $\sigma_{v,\text{exp}}$ is the standard deviation of v_{exp} .

4.1.7 Table A-7: Delayed-neutron eight-group parameters

Content of Table A-7:

1. Nuclide
2. Type of incident neutron spectrum (fast, thermal, spontaneous fission)
3. Delayed-neutron group
4. Half-life in seconds ($T_{1/2i}$)
5. Decay constant in s^{-1} (λ_i)
6. Fraction $\alpha_i = v_{di}/v_d$ and associated 1σ uncertainty
7. Delayed neutron ratio $\beta_i = v_{di}/v_t$ [%] and associated 1σ uncertainty in percent
8. Notes

Sources of data:

NEA/WPEC-6: G. Rudstam, Ph. Finck, A. Filip, A. D'Angelo, R.D. McKnight, Delayed Neutron Data for the Major Actinides, NEA/WPEC-6, Volume 6, NEA/OECD, Paris, France, 2002.

JEFF-3.1: Joint Evaluated Fission and Fusion File, Incident neutron and radioactive decay data files, <http://www.nea.fr/html/dbdata/JEFF/>, 26 February 2006;
see also A. Koning, R. Forrest, M. Kellett, R. Mills, H. Henriksson, Y. Rugama, The JEFF-3.1 Nuclear Data Library, JEFF Report 21, OECD/NEA, Paris, France, 2006, ISBN 92-64-02314-3.

Recommended data were adopted from the JEFF-3.1 library and documentation. The eight-group delayed-neutron structure is discussed in NEA/WPEC-6.

4.2 Section B – Fission products

Table B-1: Half-lives and branching fractions for fission products

Table B-2: Gamma-ray energies and emission probabilities for fission products

Table B-3: Fission product data: Thermal neutron cross sections, resonance integrals and Westcott factors

A brief description of the data presented in each table is given below. Additional remarks are included as footnotes to the tables.

4.2.1 Table B-1: Half-lives and branching fractions for fission products

Content of Table B-1:

1. Nuclide
2. Half-life with 1σ uncertainty, ($T_{1/2} \pm \Delta T_{1/2}$)
3. Units (s, m, h, d, y)

4. Decay mode (β^- , EC, IT)
5. Branching fraction with 1σ uncertainty, ($BF \pm \Delta BF$)
6. Source of data

Data sources are listed below in order of preference:

BIPM-5: M.-M. Bé, V. Chisté, C. Duiieu, E. Browne, V. Chechev, N. Kuzmenko, R. Helmer, A. Nichols, E. Schönfeld, R. Dersch, Monographie BIPM-5, Table of Radionuclides, Vol. 2 - A = 151 to 242, 2004.

LNHB: Laboratoire National Henri Becquerel, Decay Data Evaluation Project, http://www.nucleide.org/DDEP_WG/DDEPdata.htm, 3 October 2006.

IAEA-CRP-XG: M.-M. Bé, V.P. Chechev, R. Dersch, O.A.M. Helene, R.G. Helmer, M. Herman, S. Hlaváč, A. Marcinkowski, G.L. Molnár, A.L. Nichols, E. Schönfeld, V.R. Vanin, M.J. Woods, IAEA CRP "Update of X-ray and Gamma-ray Decay Data Standards for Detector Calibration and Other Applications", IAEA Nuclear Data Section, 2004.

ENSDF: Evaluated Nuclear Structure Data File, <http://www-nds.iaea.org/ensdf/>, 15 November 2006.

If the data in BIPM-5 and LNHB were the same for a given evaluation, BIPM-5 was quoted as the data source. Data from BIPM-5 and LNHB were adopted in preference to ENSDF data.

4.2.2 Table B-2: Gamma-ray energies and emission probabilities for fission products

Content of Table B-2:

1. Nuclide
2. Half-life with 1σ uncertainty, ($T_{1/2} \pm \Delta T_{1/2}$)
3. Half-life units (s, m, h, d, y)
4. γ -ray energy with 1σ uncertainty, ($E_\gamma \pm \Delta E_\gamma$ in keV)
5. Emission probability P_γ per 100 decays with 1σ uncertainty, ($P_\gamma \pm \Delta P_\gamma$ in % decay)
6. Source of data
7. Notes

Data sources are listed below in order of preference:

BIPM-5: M.-M. Bé, V. Chisté, C. Duiieu, E. Browne, V. Chechev, N. Kuzmenko, R. Helmer, A. Nichols, E. Schönfeld, R. Dersch, Monographie BIPM-5, Table of Radionuclides, Vol. 2 - A = 151 to 242, 2004.

LNHB: Laboratoire National Henri Becquerel, Decay Data Evaluation Project, http://www.nucleide.org/DDEP_WG/DDEPdata.htm, 3 October 2006.

IAEA-CRP-XG: M.-M. Bé, V.P. Chechev, R. Dersch, O.A.M. Helene, R.G. Helmer, M. Herman, S. Hlaváč, A. Marcinkowski, G.L. Molnár, A.L. Nichols, E. Schönfeld, V.R. Vanin, M.J. Woods, IAEA CRP "Update of X-ray and Gamma-ray Decay Data Standards for Detector Calibration and Other Applications", IAEA Nuclear Data Section, 2004.

ENSDF: Evaluated Nuclear Structure Data File, <http://www-nds.iaea.org/ensdf/>, 15 November 2006.

Same comments about preference are applicable as noted for Table B-1. Gamma rays with energies below 40 keV were normally omitted, as they are judged to be unsuitable for non-destructive assay.

4.2.3 Table B-3: Fission product data: Thermal neutron cross sections, resonance integrals and Westcott factors

Content of Table B-3:

1. Nuclide
2. Type of thermal cross section (σ_0 , σ , σ_r , σ_c , $\sigma_{(m)}$, $\sigma_{(g)}$)
3. Thermal cross section with 1σ uncertainty in barns, ($\sigma \pm \Delta\sigma$)
4. Westcott factor, ($g \pm \Delta g$)
5. Resonance integral with 1σ uncertainty in barns, ($RI \pm \Delta RI$)
6. Source of data

Data sources are listed below:

ANR: S.F. Mughabghab, Atlas of Neutron Resonances, Resonance Parameters and Thermal Cross Sections, Z = 1 - 100, 5th Edition, Elsevier, Amsterdam, 2006.

ENDF/B-VII: US Evaluated Nuclear Data Library ENDF/B-VII β_3 , Incident neutron data, <http://www.nndc.bnl.gov/exfor4/endlf00.htm>, 2 October 2006; see also M.B. Chadwick *et al.*, ENDF/B-VII.0: Next Generation Evaluated Nuclear Data Library for Nuclear Science and Technology, *Nucl. Data Sheets*, **107** (2006) 2931.

JENDL-3.3: Japanese Evaluated Nuclear Data Library, Incident neutron data, <http://www-nds.iaea.org/exfor/endlf00.htm>, 2 October 2006.

HAR-91: H. Harada *et al.*, Proceedings of 1990 Symposium on Nuclear Data, Japan Atomic Energy Research Institute Report JAERI-M 91-032 (1991) 199.

GRY-87: G. Gryntakis *et al.*, Handbook on Nuclear Activation Data, IAEA Technical Reports Series No. 273 (1987) 199.

SEK-87: T. Sekine *et al.*, Triple Neutron Capture of ^{153}Eu in a Reactor: the Cross Sections of ^{154}Eu and ^{155}Eu , *Appl. Radiat. Isot.* **38** (1987) 513.

Cross sections, Westcott factors and resonance integrals were adopted from ANR. When ANR data were incomplete or judged to be inadequate, the ENDF/B-VII evaluated nuclear data library was used as the data source. Furthermore, specific resonance integrals and cross sections were compared with equivalent data in the JENDL-3.3 library or other well known publications – any notable observations are included as footnotes to the table.

4.3 Section C – Fission yields

Table C-1.1: Th-232 chain fission yields

Table C-1.2: U-233 chain fission yields

Table C-1.3: U-235 chain fission yields

Table C-1.4: U-238 chain fission yields

Table C-1.5: Pu-239 chain fission yields

Table C-1.6: Pu-241 chain fission yields

Table C-2.1: Th-232 fast fission yields for selected fission products

- Table C-2.2: U-233 thermal fission yields for selected fission products
 Table C-2.3: U-235 thermal fission yields for selected fission products
 Table C-2.4: U-238 fast fission yields for selected fission products
 Table C-2.5: Pu-239 thermal fission yields for selected fission products
 Table C-2.6: Pu-241 thermal fission yields for selected fission products

Tables C-1.1 to C-1.6 list the chain yields and associated 1σ uncertainties for all mass chains at different energies. A maximum of three neutron energies are given: thermal, fast and 14 MeV. The units are percent per fission; only chain fission yields greater than $10^{-6}\%$ per fission are shown.

Tables C-2.1 to C-2.6 contain the independent and cumulative fission yields for 51 selected fission products. Fission yields are given for the thermal neutron fission of U-233, U-235, Pu-239 and Pu-241 and for the fast neutron fission of Th-232 and U-238. The units are percent per fission; independent fission yields below $10^{-9}\%$ were not included.

Data source for all tables in Section C:

JEFF-3.1: Joint Evaluated Fission and Fusion File, Neutron-induced fission yield library, <http://www-nds.iaea.org/exfor/endl00.htm>, 2 October 2006;
 see also A. Koning, R. Forrest, M. Kellett, R. Mills, H. Henriksson, Y. Rugama, The JEFF-3.1 Nuclear Data Library, JEFF Report 21, OECD/NEA, Paris, France, 2006, ISBN 92-64-02314-3.

The contents of the tables are described below.

4.3.1 Table C-1.1: Th-232 chain fission yields

1. FPA: mass number of the chain.
2. Fast fission yields and uncertainties as % per fission.
3. 14-MeV fission yields and uncertainties as % per fission.

4.3.2 Table C-1.2: U-233 chain fission yields

1. FPA: mass number of the chain.
2. Thermal fission yields and uncertainties as % per fission.
3. Fast fission yields and uncertainties as % per fission.
4. 14-MeV fission yields and uncertainties as % per fission.

4.3.3 Table C-1.3: U-235 chain fission yields

1. FPA: mass number of the chain.
2. Thermal fission yields and uncertainties as % per fission.
3. Fast fission yields and uncertainties as % per fission.
4. 14-MeV fission yields and uncertainties as % per fission.

4.3.4 Table C-1.4: U-238 chain fission yields

1. FPA: mass number of the chain.
2. Fast fission yields and uncertainties as % per fission.
3. 14-MeV fission yields and uncertainties as % per fission.

4.3.5 Table C-1.5: Pu-239 chain fission yields

1. FPA: mass number of the chain.
2. Thermal fission yields and uncertainties as % per fission.
3. Fast fission yields and uncertainties as % per fission.

4.3.6 Table C-1.6: Pu-241 chain fission yields

1. FPA: mass number of the chain.
2. Thermal fission yields and uncertainties as % per fission.
3. Fast fission yields and uncertainties as % per fission.

4.3.7 Table C-2.1: Th-232 fast fission yields for selected fission products

1. Fission product.
2. Independent fast fission product yields and uncertainties as % per fission.
3. Cumulative fast fission product yields and uncertainties as % per fission.

4.3.8 Table C-2.2: U-233 thermal fission yields for selected fission products

1. Fission product.
2. Independent thermal fission product yields and uncertainties as % per fission.
3. Cumulative thermal fission product yields and uncertainties as % per fission.

4.3.9 Table C-2.3: U-235 thermal fission yields for selected fission products

1. Fission product.
2. Independent thermal fission product yields and uncertainties as % per fission.
3. Cumulative thermal fission product yields and uncertainties as % per fission.

4.3.10 Table C-2.4: U-238 fast fission yields for selected fission products

1. Fission product.
2. Independent fast fission product yields and uncertainties as % per fission.
3. Cumulative fast fission product yields and uncertainties as % per fission.

4.3.11 Table C-2.5: Pu-239 thermal fission yields for selected fission products

1. Fission product.
2. Independent thermal fission product yields and uncertainties as % per fission.
3. Cumulative thermal fission product yields and uncertainties as % per fission.

4.3.12 Table C-2.6: Pu-241 thermal fission yields for selected fission products

1. Fission product.
2. Independent thermal fission product yields and uncertainties as % per fission.
3. Cumulative thermal fission product yields and uncertainties as % per fission.

5 Concluding Remarks

The most respected nuclear databases have been assessed in detail during the course of an extensive exercise that took place in 2006 to review and improve the contents of a recommended set of data files maintained by the International Atomic Energy Agency and entitled "Nuclear Data for Safeguards". An earlier version of these data files was used to specify the parameters to be included in the new tabulations, along with additional guidance

on their contents from analytical specialists associated with the non-destructive assay of nuclear materials.

The recommended data sets can be inspected in tabulated form, or through the adoption and use of appropriate software. Users are referred to the next section (Interactive Chart of Nuclides) for an introduction to software that can be downloaded from the Web and used to undertake rapid inspections of the assembled database. An appropriate Web site has been established for access to the recommended database, and is located at <http://www-nds.iaea.org/sgnucdat/>

Every effort has been made to ensure that the recommended data are credible and correct with respect to their original sources. Despite these best endeavours, absolute correctness can not be fully guaranteed – any errors detected by data users should be communicated to the International Atomic Energy Agency, Nuclear Data Section, to ensure their elimination and correction (e-mail: online@iaeand.iaea.org).

INTERACTIVE CHART OF NUCLIDES

The interactive chart of nuclides represents a complementary means of browsing the information contained in the database of Nuclear Data for Safeguards. The following notes can be used as an aid in using this application.

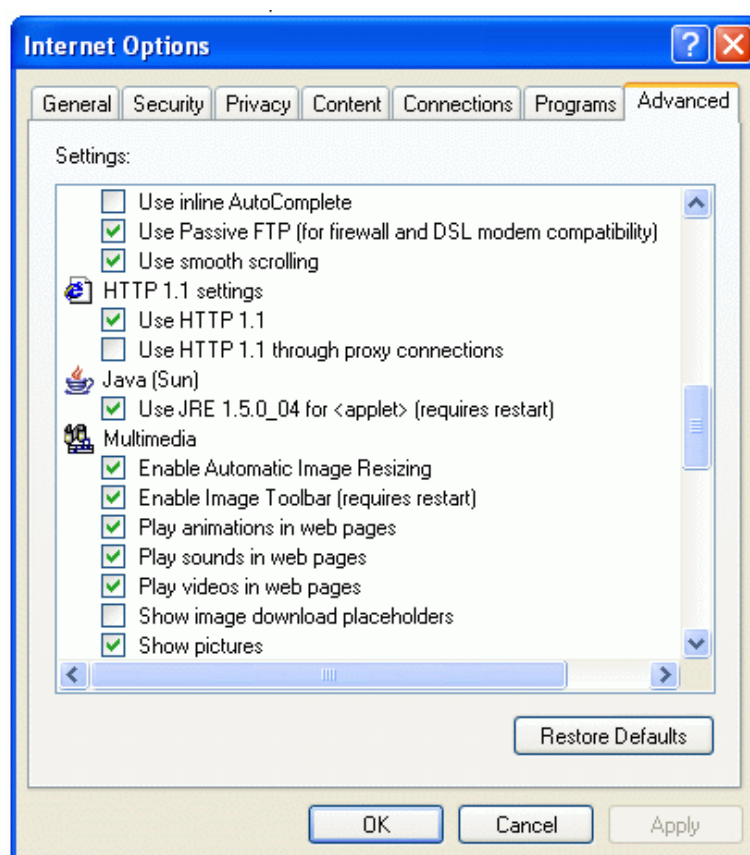
BROWSER SETTINGS

Check that the correct Internet browser settings have been enabled:

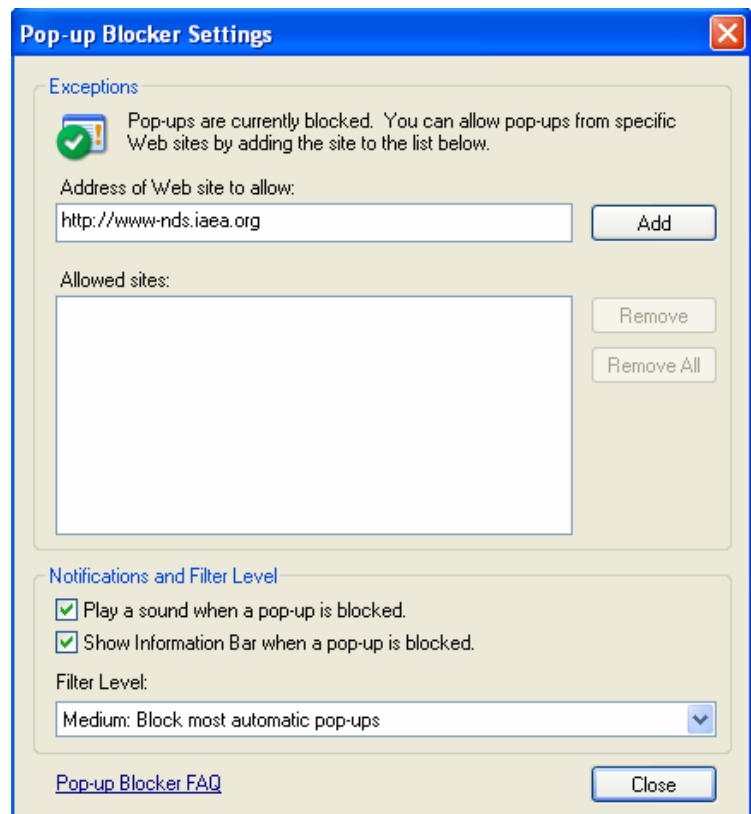
Internet Explorer:

1) go to menu

Tools → Internet Options. Java (Sun) checkbox should be defined as shown in the picture.



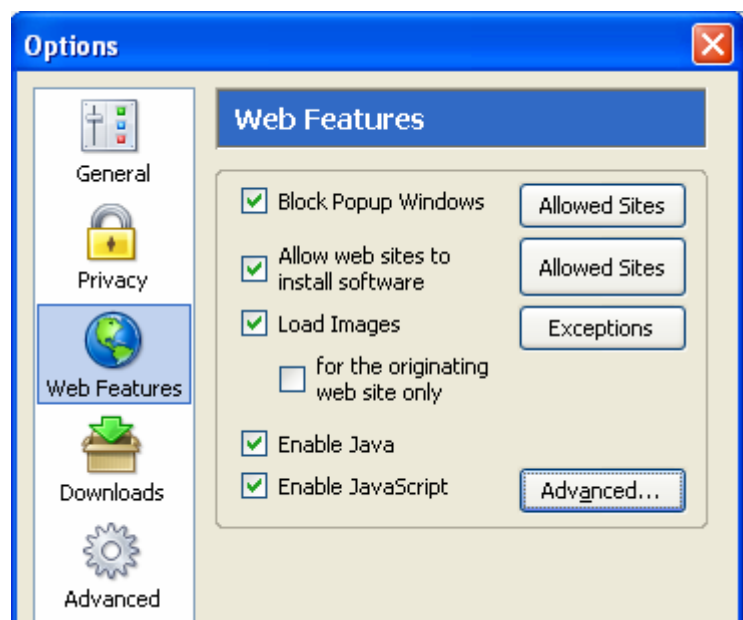
2) go to menu **Tools** → **Pop-up Blocker** → **Pop-up Blocker Settings** and then type in <http://www-nds.iaea.org>, before clicking the **add** button



Firefox:

go to menu **Tools** → **Options** → **Web Features**. **Enable Java**, and then **Block Popup Windows** checkboxes should be checked as shown in the picture.

Click on the first **Allowed Sites** button and type <http://www-nds.iaea.org> in the text field.

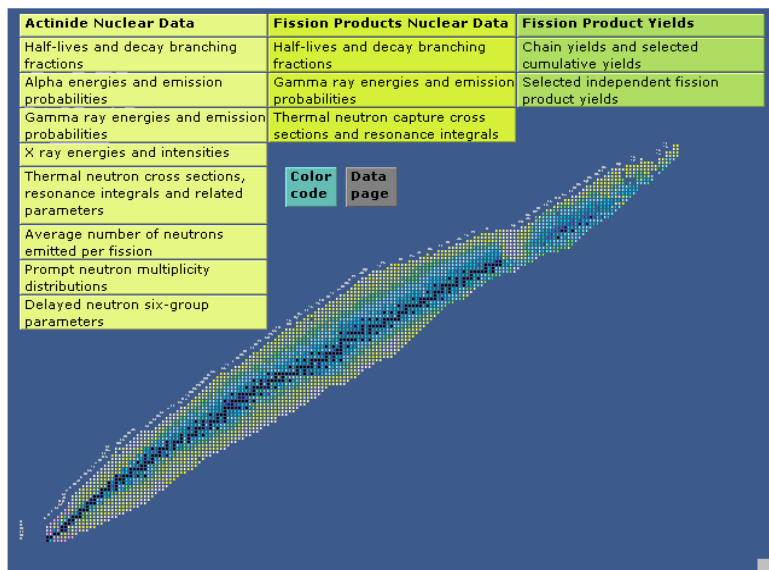


ACTIVATION

The loading panel will initially show the loading progression:



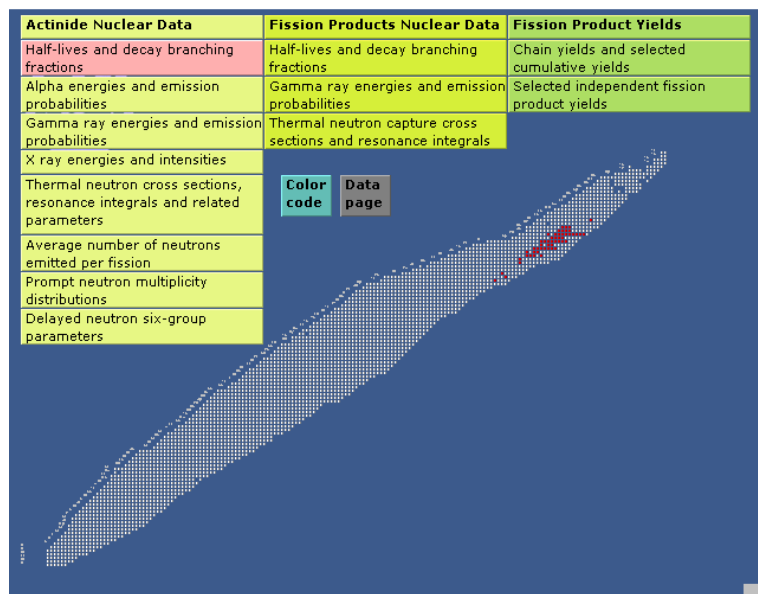
When the software is ready and the full image is shown, click on the blue area to activate the software.



USE

If the image is bigger than the screen dimension, either the image resolution can be maintained using the browser scroll bar to move the image, or the image dimensions can be changed by dragging the lower-right grey corner to the desired dimension.

When the mouse is rolled on a menu-label, the relevant nuclides are shown in red.

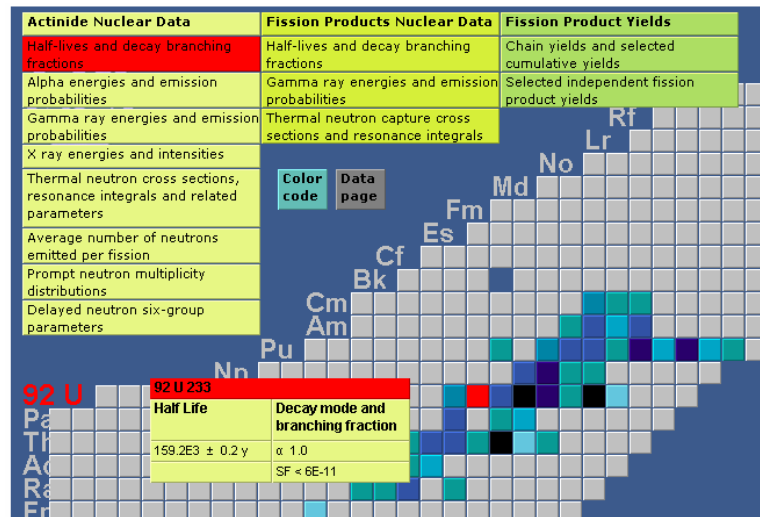


When a menu-label is clicked, the map zooms into the area of interest, and the data can be browsed by rolling the mouse over a nuclide.

Clicking on a nuclide will maintain selection and fix the data panel. Click a second time on the red-selected nuclide to restore the mouse-moving mode.

When a nuclide is selected the **Data page** button is activated; clicking on this button will open a new frame to reveal html-formatted data that can be saved.

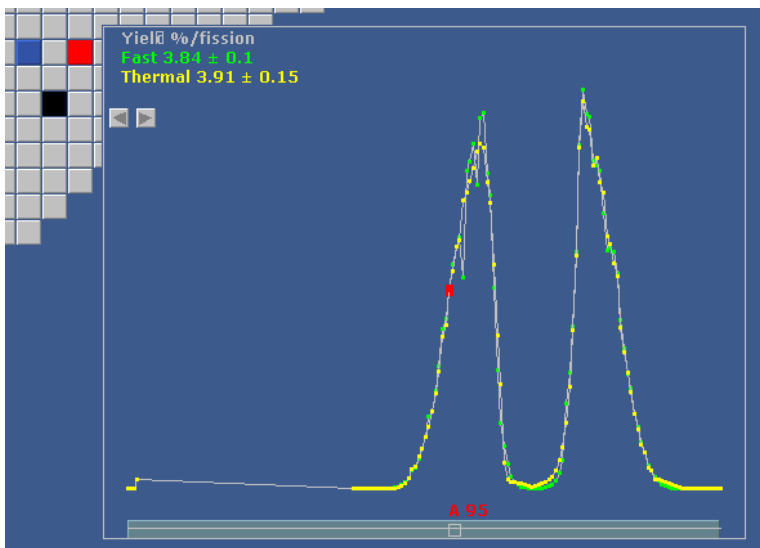
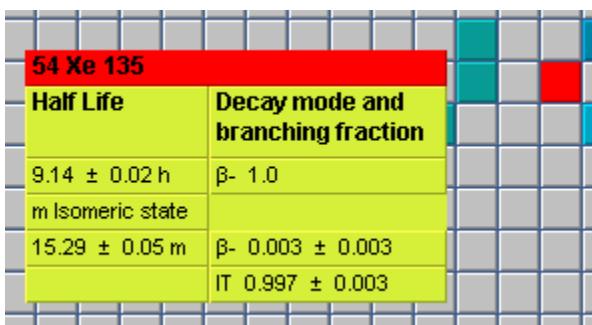
When a nuclide has isomeric states, the data panel shows the isomers.



The **fission product yields** data are shown graphically.

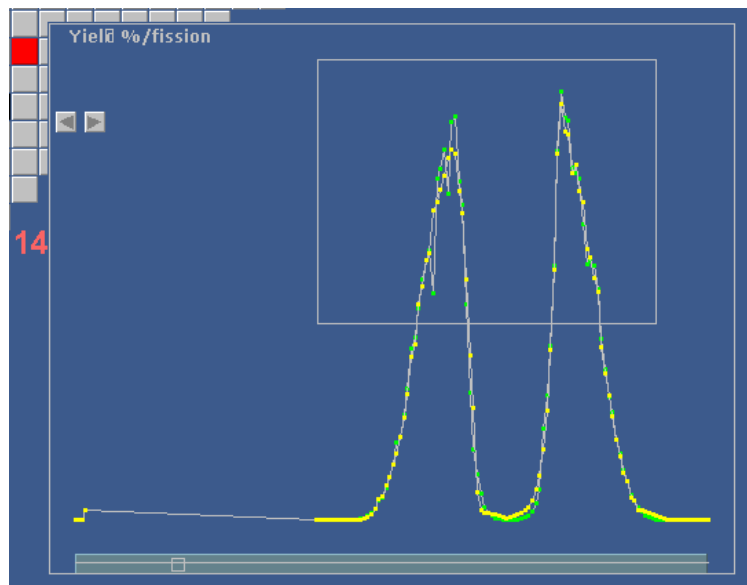
Values can be browsed by means of the following methods:

- move the mouse on the bottom slide bar,
- click on a point,
- use the buttons above the graph panel.



Click with the mouse and drag a rectangle to produce a detailed view of a particular area.

When the mouse is released, the selected area expands by means of the zoom function. Just click the nuclide chart on the selected nuclide to restore to the original size.



DATA TABLES

- A-1: Half-lives and branching fractions for actinides and natural decay products.
- A-2: Alpha-particle energies and emission probabilities for actinides and natural decay products.
- A-3: Gamma-ray energies and emission probabilities for actinides and natural decay products.
- A-4: K X-ray energies and intensities for actinides and natural decay products.
- A-5: Actinide data: Thermal neutron cross sections, resonance integrals and Westcott factors.
- A-6: Average number of neutrons emitted per fission.
- A-7: Delayed-neutron eight-group parameters.
- B-1: Half-lives and branching fractions for fission products.
- B-2: Gamma-ray energies and emission probabilities for fission products.
- B-3: Fission product data: Thermal neutron cross sections, resonance integrals and Westcott factors.
- C-1: Chain fission yields for selected actinides.
- C-2: Selected independent and cumulative fission product yields.

A-1. Half-lives and branching fractions for actinides and natural decay products.

References

LNHB: Laboratoire National Henri Becquerel, Recommended Data,
http://www.nucleide.org/DDEP_WG/DDEPdata.htm, 3 October 2006.

BIPM-5: M.-M. Bé, V. Chisté, C. Dulieu, E. Browne, V. Chechev, N. Kuzmenko,
 R. Helmer, A. Nichols, E. Schönfeld, R. Dersch, Monographie BIPM-5,
 Table of Radionuclides, Vol. 2 - A = 151 to 242, 2004.

ENSDF: Evaluated Nuclear Structure Data File,
<http://www-nds.iaea.org/ensdf/>, 15 November 2006.

IAEA-CRP-XG: M.-M. Bé, V.P. Chechev, R. Dersch, O.A.M. Helene, R.G. Helmer, M. Herman,
 S. Hlaváč, A. Marcinkowski, G.L. Molnár, A.L. Nichols, E. Schönfeld, V.R. Vanin,
 M.J. Woods, IAEA CRP "Update of X-ray and Gamma-ray Decay Data Standards
 for Detector Calibration and Other Applications", IAEA Nuclear Data Section, 2004.

Table A-1. Half-lives and branching fractions for actinides and natural decay products.

Nuclide	Half-life $T_{1/2}$	Units	Decay mode	Branching Fraction		Source
81-Tl-206	4.202 ± 0.011	m	β-	1.0		LNHB
81-Tl-208	3.060 ± 0.008	m	β-	1.0		BIPM-5
82-Pb-210	22.20 ± 0.22	y	β- α	1.0 (1.9 ± 0.4) × 10 ⁻⁸		ENSDF
82-Pb-211	36.1 ± 0.2	m	β-	1.0		ENSDF
82-Pb-212	10.64 ± 0.01	h	β-	1.0		BIPM-5
82-Pb-214	26.8 ± 0.9	m	β-	1.0		ENSDF
83-Bi-211	2.14 ± 0.02	m	α β-	0.99724 ± 0.00004 0.00276 ± 0.00004		ENSDF
83-Bi-212	60.54 ± 0.06	m	α β-	0.3593 ± 0.0007 0.6407 ± 0.0007		BIPM-5
83-Bi-214	19.9 ± 0.4	m	β- α	0.99979 ± 0.00001 0.00021 ± 0.00001		ENSDF
84-Po-210	138.376 ± 0.002	d	α	1.0		ENSDF
86-Rn-219	3.96 ± 0.01	s	α	1.0		ENSDF
86-Rn-220	55.8 ± 0.3	s	α	1.0		BIPM-5
87-Fr-221	4.9 ± 0.2	m	α β-	0.99995 ± 0.00003 0.00005 ± 0.00003		ENSDF

Table A-1. Half-lives and branching fractions for actinides and natural decay products.

Nuclide	Half-life $T_{1/2}$	Units	Decay mode	Branching Fraction		Source
88-Ra-223	11.43 ± 0.05	d	α ^{14}C	1.0 (8.9 ± 0.4) × 10 ⁻¹⁰		ENSDF
88-Ra-224	3.627 ± 0.007	d	α	1.0		BIPM-5
88-Ra-225	14.9 ± 0.2	d	β^-	1.0		ENSDF
88-Ra-226	(1.600 ± 0.007) × 10 ³	y	α	1.0		BIPM-5
88-Ra-228	5.75 ± 0.03	y	β^-	1.0		ENSDF
89-Ac-224	2.78 ± 0.17	h	EC	0.909	+ 0.014 - 0.020	ENSDF
			α	0.091	+ 0.020 - 0.014	
89-Ac-225	10.0 ± 0.1	d	α	1.0		ENSDF
89-Ac-227	21.772 ± 0.003	y	α	0.01380	± 0.00004	ENSDF
			β^-	0.98620	± 0.00004	
89-Ac-228	6.15 ± 0.02	h	β^-	1.0		ENSDF
90-Th-227	18.718 ± 0.005	d	α	1.0		BIPM-5
90-Th-228	698.60 ± 0.23	d	α	1.0		BIPM-5
90-Th-229	(7.34 ± 0.16) × 10 ³	y	α	1.0		ENSDF
90-Th-230	(7.538 ± 0.030) × 10 ⁴	y	α	1.0		ENSDF
			SF	≤ 4. × 10 ⁻¹³		
90-Th-231	25.52 ± 0.01	h	β^-	1.0		ENSDF
			α	~ 4. × 10 ⁻¹³		
90-Th-232	(1.405 ± 0.006) × 10 ¹⁰	y	α	1.0		ENSDF
			SF	(1.1 ± 0.4) × 10 ⁻¹¹		
90-Th-233	22.15 ± 0.15	m	β^-	1.0		LNHB
90-Th-234	24.10 ± 0.03	d	β^-	1.0		ENSDF
91-Pa-231	(3.276 ± 0.011) × 10 ⁴	y	α	1.0		ENSDF
			SF	≤ 3. × 10 ⁻¹²		
91-Pa-232	1.32 ± 0.02	d	β^-	0.99997	± 0.00001	ENSDF
			EC	0.00003	± 0.00001	
91-Pa-233	26.98 ± 0.02	d	β^-	1.0		LNHB

Table A-1. Half-lives and branching fractions for actinides and natural decay products.

Nuclide	Half-life $T_{1/2}$	Units	Decay mode	Branching Fraction		Source
91-Pa-234	6.70 ± 0.05	h	β-	1.0		ENSDF
91-Pa-234m	1.159 ± 0.016	m	β- IT	0.9984 ± 0.0002 0.0016 ± 0.0002		IAEA-CRP-XG
92-U-232	68.9 ± 0.4	y	α SF	1.0 < 1. × 10 ⁻¹⁴		ENSDF
92-U-233	(1.592 ± 0.002) × 10 ⁵	y	α SF	1.0 < 6. × 10 ⁻¹¹		ENSDF
92-U-234	(2.455 ± 0.006) × 10 ⁵	y	α SF	1.0 (1.6 ± 0.2) × 10 ⁻¹¹		LNHB
92-U-235	(7.038 ± 0.005) × 10 ⁸	y	α SF	1.0 (7. ± 2.) × 10 ⁻¹¹		ENSDF
92-U-235m	26. ± 1.	m	IT	1.0		ENSDF
92-U-236	(2.342 ± 0.004) × 10 ⁷	y	α SF	1.0 (9.4 ± 0.4) × 10 ⁻¹⁰		ENSDF
92-U-237	6.749 ± 0.016	d	β-	1.0		LNHB
92-U-238	(4.468 ± 0.005) × 10 ⁹	y	α SF	1.0 (5.45 ± 0.04) × 10 ⁻⁷		LNHB
92-U-239	23.45 ± 0.02	m	β-	1.0		ENSDF
93-Np-236	(1.55 ± 0.08) × 10 ⁵	y	β- α EC	0.120 ± 0.006 0.0016 ± 0.0006 0.878 ± 0.006		LNHB
93-Np-236m	22.5 ± 0.4	h	β- EC	0.47 ± 0.01 0.53 ± 0.01		LNHB
93-Np-237	(2.144 ± 0.007) × 10 ⁶	y	α SF	1.0 < 2. × 10 ⁻¹²		ENSDF
93-Np-238	2.117 ± 0.002	d	β-	1.0		ENSDF
93-Np-239	2.356 ± 0.003	d	β-	1.0		ENSDF
94-Pu-236	2.858 ± 0.008	y	α SF	1.0 (1.9 ± 0.4) × 10 ⁻⁹		ENSDF
94-Pu-238	87.74 ± 0.03	y	α SF	1.0 (1.85 ± 0.05) × 10 ⁻⁹		BIPM-5

Table A-1. Half-lives and branching fractions for actinides and natural decay products.

Nuclide	Half-life $T_{1/2}$	Units	Decay mode	Branching Fraction		Source
94-Pu-239	$(2.411 \pm 0.003) \times 10^4$	y	α SF	1.0 $(3.1 \pm 0.6) \times 10^{-12}$		ENSDF
94-Pu-240	$(6.561 \pm 0.007) \times 10^3$	y	α SF	1.0 $(5.7 \pm 0.2) \times 10^{-8}$		BIPM-5
94-Pu-241	14.290 ± 0.006	y	α β -	0.0000245 ± 0.0000002 0.9999755 ± 0.0000002		ENSDF
94-Pu-242	$(3.73 \pm 0.03) \times 10^5$	y	α SF	1.0 $(5.49 \pm 0.09) \times 10^{-6}$		BIPM-5
94-Pu-243	4.956 ± 0.003	h	β -	1.0		ENSDF
94-Pu-244	$(8.00 \pm 0.09) \times 10^7$	y	α SF	0.99879 ± 0.00004 0.00121 ± 0.00004		ENSDF
94-Pu-245	10.5 ± 0.1	h	β -	1.0		ENSDF
94-Pu-246	10.84 ± 0.02	d	β -	1.0		ENSDF
95-Am-240	50.8 ± 0.3	h	EC α	0.9999981 ± 0.0000007 0.0000019 ± 0.0000007		ENSDF
95-Am-241	432.6 ± 0.6	y	α SF	1.0 $(4.3 \pm 1.8) \times 10^{-12}$		BIPM-5
95-Am-242	16.02 ± 0.02	h	β - EC	0.827 ± 0.003 0.173 ± 0.003		ENSDF
95-Am-242m	$141. \pm 2.$	y	IT α SF	0.9955 ± 0.0002 0.0045 ± 0.0002 $< 4.7 \times 10^{-11}$		ENSDF
95-Am-243	$(7.370 \pm 0.017) \times 10^3$	y	α SF	1.0 $(3.8 \pm 0.7) \times 10^{-11}$		LNHB
96-Cm-242	162.86 ± 0.08	d	α SF	1.0 $(6.36 \pm 0.14) \times 10^{-8}$		LNHB
96-Cm-243	29.1 ± 0.1	y	α EC SF	0.9971 ± 0.0003 0.0029 ± 0.0003 $(5.3 \pm 0.9) \times 10^{-11}$		ENSDF
96-Cm-244	18.11 ± 0.03	y	α SF	1.0 $(1.36 \pm 0.01) \times 10^{-6}$		LNHB
98-Cf-252	2.645 ± 0.008	y	α SF	0.96908 ± 0.00008 0.03092 ± 0.00008		ENSDF

1 y = 1 year = 365.24219878 days

A-2. Alpha-particle energies and emission probabilities for actinides and natural decay products.

References

- ENSDF: Evaluated Nuclear Structure Data File,
<http://www-nds.iaea.org/ensdf/>, 15 November 2006.
- LNHB: Laboratoire National Henri Becquerel, Recommended Data,
http://www.nucleide.org/DDEP_WG/DDEPdata.htm, 3 October 2006.
- BIPM-5: M.-M. Bé, V. Chisté, C. Dulieu, E. Browne, V. Chechev, N. Kuzmenko,
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Table A-2. Alpha-particle energies and emission probabilities for actinides and natural decay products.

Nuclide	Half-life $T_{1/2}$	Units	α particles				Source	Notes
			Energy [keV]		Emission probability P_{α} [% decay]			
83-Bi-211	2.14 \pm 0.02	m	6278.2	\pm 0.7	16.19	\pm 0.14	ENSDF	
			6622.9	\pm 0.6	83.54	\pm 0.14		
83-Bi-212	60.54 \pm 0.06	m	5606.63	\pm 0.14	0.43	\pm 0.04	LNHB	
			5768.27	\pm 0.10	0.63	\pm 0.03		
			6050.92	\pm 0.04	25.1	\pm 0.1		
			6090.02	\pm 0.04	9.7	\pm 0.1		
84-Po-210	138.376 \pm 0.002	d	5304.33	\pm 0.07	100.		ENSDF	
86-Rn-219	3.96 \pm 0.01	s	6425.	\pm 1.	7.5	\pm 0.6	ENSDF	
			6552.6	\pm 1.0	12.9	\pm 0.6		
			6819.1	\pm 0.3	79.4	\pm 1.0		
86-Rn-220	55.8 \pm 0.3	s	5748.46	\pm 0.14	0.118	\pm 0.015	LNHB	
			6288.22	\pm 0.10	99.882	\pm 0.015		
88-Ra-223	11.43 \pm 0.05	d	5433.6	\pm 0.5	2.22	\pm 0.20	ENSDF	
			5539.8	\pm 0.9	9.0	\pm 0.2		
			5606.73	\pm 0.30	25.2	\pm 0.5		
			5716.23	\pm 0.29	51.6	\pm 1.3		
			5747.0	\pm 0.4	9.0	\pm 0.2		
			5871.3	\pm 1.0	1.0	\pm 0.2		
88-Ra-224	3.627 \pm 0.007	d	5448.81	\pm 0.16	5.26	\pm 0.07	LNHB	
			5685.50	\pm 0.15	94.72	\pm 0.07		
88-Ra-226	(1.600 \pm 0.007) $\times 10^3$	y	4601.	\pm 1.	5.96	\pm 0.08	LNHB	
			4784.34	\pm 0.25	94.03	\pm 0.08		
90-Th-227	18.718 \pm 0.005	d	5668.0	\pm 1.5	2.06	\pm 0.12	LNHB	
			5693.0	\pm 1.6	1.5	\pm 0.1		
			5700.8	\pm 1.6	3.63	\pm 0.20		
			5708.8	\pm 1.6	8.3	\pm 0.3		
			5713.2	\pm 1.6	4.89	\pm 0.20		
			5756.87	\pm 0.15	20.4	\pm 0.9		
			5807.5	\pm 1.5	1.27	\pm 0.02		
			5866.6	\pm 1.5	2.42	\pm 0.10		
			5959.7	\pm 1.5	3.00	\pm 0.15		
			5977.72	\pm 0.10	23.5	\pm 0.9		
			6008.8	\pm 1.5	2.90	\pm 0.15		
			6038.01	\pm 0.15	24.2	\pm 0.9		

Table A-2. Alpha-particle energies and emission probabilities for actinides and natural decay products.

Nuclide	Half-life $T_{1/2}$	Units	α particles					Source	Notes
			Energy [keV]		Emission probability P_α [% decay]				
90-Th-228	698.60 \pm 0.23	d	5340.38	\pm 0.22	26.2	\pm 0.2	BIPM-5		
			5423.28	\pm 0.22	73.2	\pm 0.2			
90-Th-229	(7.34 \pm 0.16) $\times 10^3$	y	4797.8	\pm 1.2	1.5	\pm 0.2	ENSDF		
			4814.6	\pm 1.2	9.30	\pm 0.08			
			4838.	\pm 2.	5.0	\pm 0.2			
			4845.3	\pm 1.2	56.2	\pm 0.2			
			4901.0	\pm 1.2	10.20	\pm 0.08			
			4967.5	\pm 1.2	5.97	\pm 0.06			
			4978.5	\pm 1.2	3.17	\pm 0.04			
5053.	\pm 2.	6.6	\pm 0.1						
90-Th-230	(7.538 \pm 0.030) $\times 10^4$	y	4620.5	\pm 1.5	23.4	\pm 0.1	ENSDF		
			4687.0	\pm 1.5	76.3	\pm 0.3			
90-Th-232	(1.405 \pm 0.006) $\times 10^{10}$	y	3947.2	\pm 2.0	21.7	\pm 1.3	ENSDF		
			4012.3	\pm 1.4	78.2	\pm 1.3			
91-Pa-231	(3.276 \pm 0.011) $\times 10^4$	y	4681.	\pm 2.	1.5	\pm 0.6	ENSDF	[1]	
			4736.0	\pm 0.8	8.4	\pm 1.2			
			4853.	\pm 2.	1.4	\pm 0.4			
			4934.	\pm 2.	3.0	\pm 0.3			
			4951.3	\pm 1.4	22.8	\pm 5.8			
			4986.	\pm 2.	1.4	\pm 0.4			
			5013.8	\pm 1.4	25.4	\pm 14.1			
			5028.4	\pm 1.0	20.0	\pm 4.2			
5058.6	\pm 1.5	11.0	\pm 2.0						
92-U -232	68.9 \pm 0.4	y	5263.36	\pm 0.09	31.55	\pm 0.23	ENSDF		
			5320.12	\pm 0.14	68.15	\pm 0.23			
92-U -233	(1.592 \pm 0.002) $\times 10^5$	y	4729.	\pm 1.	1.61	\pm 0.17	ENSDF	[2]	
			4783.5	\pm 1.2	13.2	\pm 0.2			
			4824.2	\pm 1.2	84.4	\pm 0.5			
92-U -234	(2.455 \pm 0.006) $\times 10^5$	y	4722.4	\pm 0.7	28.42	\pm 0.02	LNHB		
			4774.6	\pm 0.7	71.37	\pm 0.02			
92-U -235	(7.038 \pm 0.005) $\times 10^8$	y	4150.	\pm 5.	0.9	\pm 0.2	ENSDF		
			4214.7	\pm 1.9	5.7	\pm 0.6			
			4366.1	\pm 2.0	17.	\pm 2.			
			4397.8	\pm 1.3	55.	\pm 3.			
			4414.	\pm 4.	2.1	\pm 0.2			
			4502.	\pm 2.	1.7	\pm 0.2			
			4556.	\pm 2.	4.2	\pm 0.3			
4596.4	\pm 1.3	5.0	\pm 0.5						
92-U -236	(2.342 \pm 0.004) $\times 10^7$	y	4445.	\pm 5.	25.9	\pm 4.0	ENSDF		
			4494.	\pm 3.	73.8	\pm 4.0			
92-U -238	(4.468 \pm 0.005) $\times 10^9$	y	4151.	\pm 5.	22.33	\pm 0.50	LNHB		
			4198.	\pm 3.	77.54	\pm 0.50			

Table A-2. Alpha-particle energies and emission probabilities for actinides and natural decay products.

Nuclide	Half-life $T_{1/2}$	Units	α particles				Source	Notes
			Energy [keV]		Emission probability P_{α} [% decay]			
93-Np-237	$(2.144 \pm 0.007) \times 10^6$	y	4640.0	± 1.0	6.43	± 0.03	ENSDF	
			4665.0	± 0.9	3.478	± 0.024		
			4766.5	± 0.8	9.3	± 0.3		
			4771.4	± 0.8	23.2	± 0.3		
			4788.0	± 0.9	47.64	± 0.06		
			4803.5	± 1.0	2.014	± 0.017		
			4816.8	± 1.0	2.430	± 0.017		
94-Pu-236	2.858 ± 0.008	y	5721.00	± 0.10	30.6	± 0.5	ENSDF	
			5767.66	± 0.08	69.3	± 0.5		
94-Pu-238	87.74 ± 0.03	y	5456.26	± 0.20	28.25	± 0.06	BIPM-5	
			5499.03	± 0.20	71.04	± 0.06		
94-Pu-239	$(2.411 \pm 0.003) \times 10^4$	y	5105.5	± 0.8	11.94	± 0.07	ENSDF	
			5144.3	± 0.8	17.11	± 0.14		
			5156.59	± 0.14	70.77	± 0.14		
94-Pu-240	$(6.561 \pm 0.007) \times 10^3$	y	5123.64	± 0.15	27.16	± 0.11	BIPM-5	
			5168.13	± 0.15	72.74	± 0.11		
94-Pu-241	14.290 ± 0.006	y	4853.0	± 1.1	0.000299	± 0.000006	ENSDF	[3]
			4896.3	± 1.1	0.00204	± 0.00003		
94-Pu-242	$(3.73 \pm 0.03) \times 10^5$	y	4858.1	± 0.9	23.49	± 0.18	BIPM-5	
			4902.2	± 0.9	76.48	± 0.18		
95-Am-241	432.6 ± 0.6	y	5388.26	± 0.13	1.66	± 0.03	BIPM-5	
			5442.86	± 0.12	13.23	± 0.10		
			5485.56	± 0.12	84.45	± 0.10		
95-Am-242m	$141. \pm 2.$	y	5143.0	± 1.3	0.0257	± 0.0012	ENSDF	[4]
			5207.06	± 0.25	0.409	± 0.012		
95-Am-243	$(7.370 \pm 0.017) \times 10^3$	y	5181.	$\pm 1.$	1.383	± 0.007	LNHB	
			5233.3	± 1.0	11.46	± 0.05		
			5275.3	± 1.0	86.74	± 0.05		
			5321.	$\pm 1.$	0.192	± 0.003		
			5349.4	± 2.3	0.240	± 0.003		
96-Cm-242	162.86 ± 0.08	d	6069.37	± 0.09	25.94	± 0.07	LNHB	
			6112.72	± 0.08	74.06	± 0.07		
96-Cm-243	29.1 ± 0.1	y	5686.	$\pm 3.$	1.6	± 0.2	ENSDF	[5]
			5742.1	± 0.9	11.5	± 0.5		
			5785.2	± 0.9	73.0	± 2.3		
			5991.8	± 1.5	5.7	± 0.2		
			6010.	$\pm 3.$	1.1	± 0.1		
			6058.	$\pm 1.$	4.7	± 0.3		
			6066.2	± 1.7	1.5	± 0.2		
96-Cm-244	18.11 ± 0.03	y	5762.65	± 0.05	23.3	± 0.4	LNHB	
			5804.77	± 0.05	76.7	± 0.4		
98-Cf -252	2.645 ± 0.008	y	6075.64	± 0.11	15.2	± 0.3	ENSDF	
			6118.10	± 0.04	81.6	± 0.3		

Table A-2. Alpha-particle energies and emission probabilities for actinides and natural decay products.

[1] No uncertainties available for the experimental emission probabilities reported in ENSDF, but the evaluators deduced the following emission data from the γ -ray transition balance:

Energy [keV]		P_{α}^{cal} [% decay]		
4681.	$\pm 2.$	2.06	± 0.18	
4736.0	± 0.8	9.3	± 0.7	
4853.	$\pm 2.$	1.5	± 0.3	
4934.	$\pm 2.$	3.0	± 0.3	
4951.3	± 1.4	27.	$\pm 4.$	
4986.	$\pm 2.$	1.2	± 0.3	
5013.8	± 1.4	27.	$\pm 14.$	
5028.4	± 1.0	19.	$\pm 4.$	
5058.6	± 1.5	$\sim 9.$		

the adopted 1σ uncertainties were estimated from $\Delta P_{\alpha}^2 = (P_{\alpha} - P_{\alpha}^{\text{cal}})^2 + (\Delta P_{\alpha}^{\text{cal}})^2$.

[2] No uncertainties reported for the 4729-keV alpha-particle emission in ENSDF; an uncertainty of 1 keV was adopted for the energy, and approximately 10% relative uncertainty was recommended for the corresponding emission probability.

[3] Only low intensity emissions.

[4] Low intensity emissions included.

[5] No uncertainties reported for the 5686- and 6010-keV alpha-particle emissions; a value of 3 keV was adopted from R.B. Firestone and V.S. Shirley (editor), Table of Isotopes, 8th ed., Volume II: A = 151 - 272, John Wiley & Sons, New York, 1996; approximately 10% relative uncertainty is recommended for the corresponding emission probabilities.

A-3. Gamma-ray energies and emission probabilities for actinides and natural decay products.

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Table A-3. Gamma-ray energies and emission probabilities for actinides and natural decay products.

Nuclide	Half-life $T_{1/2}$	Units	Energy [keV]	γ rays		Source	Notes
				Emission probability [% decay]			
81-Tl-208	3.060 ± 0.008	m	277.37 ± 0.03	6.6	± 0.3	BIPM-5	[1]
			583.187 ± 0.002	85.0	± 0.3		
			860.56 ± 0.03	12.5	± 0.1		
			2614.511 ± 0.010	99.79	± 0.01		
82-Pb-210	22.20 ± 0.22	y	46.539 ± 0.001	4.25	± 0.04	ENSDF	
82-Pb-211	36.1 ± 0.2	m	404.853 ± 0.010	3.78	± 0.06	ENSDF	
			427.088 ± 0.010	1.76	± 0.04		
			704.64 ± 0.03	0.46	± 0.01		
			766.51 ± 0.03	0.62	± 0.02		
			832.01 ± 0.03	3.52	± 0.06		
82-Pb-212	10.64 ± 0.01	h	115.183 ± 0.005	0.623	± 0.022	BIPM-5	
			238.632 ± 0.002	43.6	± 0.3		
			300.09 ± 0.01	3.18	± 0.13		
82-Pb-214	26.8 ± 0.9	m	53.2275 ± 0.0021	1.066	± 0.014	IAEA-CRP-XG	
			241.997 ± 0.003	7.19	± 0.06		
			295.224 ± 0.002	18.28	± 0.14		
			351.932 ± 0.002	35.34	± 0.27		
83-Bi-211	2.14 ± 0.02	m	351.06 ± 0.04	12.91	± 0.11	ENSDF	
83-Bi-212	60.54 ± 0.06	m	727.33 ± 0.01	6.74	± 0.12	BIPM-5	
			785.37 ± 0.09	1.11	± 0.01		
			1078.63 ± 0.11	0.55	± 0.02		
			1620.74 ± 0.01	1.51	± 0.03		

Table A-3. Gamma-ray energies and emission probabilities for actinides and natural decay products.

Nuclide	Half-life $T_{1/2}$	Units	Energy [keV]	γ rays		Source	Notes
				Emission probability [% decay]			
83-Bi-214	19.9 \pm 0.4	m	609.316 \pm 0.003	45.16	\pm 0.33	IAEA-CRP-XG	
			665.453 \pm 0.022	1.521	\pm 0.011		
			768.367 \pm 0.011	4.850	\pm 0.038		
			806.185 \pm 0.011	1.255	\pm 0.011		
			934.061 \pm 0.012	3.074	\pm 0.025		
			1120.287 \pm 0.010	14.78	\pm 0.11		
			1155.19 \pm 0.02	1.624	\pm 0.014		
			1238.110 \pm 0.012	5.785	\pm 0.045		
			1280.96 \pm 0.02	1.425	\pm 0.012		
			1377.669 \pm 0.012	3.954	\pm 0.033		
			1401.516 \pm 0.014	1.324	\pm 0.011		
			1407.993 \pm 0.007	2.369	\pm 0.019		
			1509.217 \pm 0.008	2.108	\pm 0.021		
			1661.316 \pm 0.013	1.037	\pm 0.010		
			1729.640 \pm 0.012	2.817	\pm 0.023		
			1764.539 \pm 0.015	15.17	\pm 0.12		
			1847.420 \pm 0.025	2.000	\pm 0.018		
			2118.536 \pm 0.008	1.148	\pm 0.011		
2204.071 \pm 0.021	4.89	\pm 0.10					
2447.673 \pm 0.010	1.536	\pm 0.015					
86-Rn-219	3.96 \pm 0.01	s	271.23 \pm 0.01	10.8	\pm 0.6	ENSDF	
			401.81 \pm 0.01	6.6	\pm 0.4		
86-Rn-220	55.8 \pm 0.3	s	549.76 \pm 0.04	0.115	\pm 0.015	BIPM-5	
88-Ra-223	11.43 \pm 0.05	d	122.319 \pm 0.010	1.21	\pm 0.02	ENSDF	
			144.235 \pm 0.010	3.27	\pm 0.08		
			154.208 \pm 0.010	5.70	\pm 0.16		
			269.463 \pm 0.010	13.9	\pm 0.3		
			323.871 \pm 0.010	3.99	\pm 0.09		
			338.282 \pm 0.010	2.84	\pm 0.07		
445.033 \pm 0.012	1.29	\pm 0.05					
88-Ra-224	3.627 \pm 0.007	d	240.986 \pm 0.006	4.12	\pm 0.04	BIPM-5	
88-Ra-226	(1.600 \pm 0.007) \times 10 ³	y	186.211 \pm 0.013	3.533	\pm 0.028	IAEA-CRP-XG	
90-Th-227	18.718 \pm 0.005	d	50.13 \pm 0.01	8.2	\pm 0.5*	LNHB	[2]
			79.69 \pm 0.02	1.90	\pm 0.11		
			93.88 \pm 0.05	1.48	\pm 0.08		
			210.62 \pm 0.05	1.22	\pm 0.11		
			235.96 \pm 0.02	12.6	\pm 0.6		
			256.23 \pm 0.02	6.8	\pm 0.4		
			286.09 \pm 0.02	1.70	\pm 0.17*		
			289.59 \pm 0.10	1.9	\pm 0.4*		
			299.98 \pm 0.03	2.16	\pm 0.12*		
			304.50 \pm 0.02	1.12	\pm 0.14		
			329.85 \pm 0.02	2.9	\pm 0.2		
			334.37 \pm 0.02	1.11	\pm 0.09		
			90-Th-228	698.60 \pm 0.23	d		
131.612 \pm 0.004	0.124	\pm 0.006					
166.410 \pm 0.004	0.094	\pm 0.007					
215.985 \pm 0.004	0.226	\pm 0.020					
90-Th-229	(7.34 \pm 0.16) \times 10 ³	y	107.108 \pm 0.008	0.81	\pm 0.05	ENSDF	
			136.99 \pm 0.04	1.18	\pm 0.04		
			148.15 \pm 0.04	0.88	\pm 0.07		
			156.409 \pm 0.009	1.19	\pm 0.04		
			193.509 \pm 0.004	4.41	\pm 0.07		
			210.853 \pm 0.003	2.8	\pm 0.4		

Table A-3. Gamma-ray energies and emission probabilities for actinides and natural decay products.

Nuclide	Half-life $T_{1/2}$	Units	Energy [keV]	γ rays		Source	Notes
				Emission probability [% decay]			
90-Th-230	$(7.538 \pm 0.030) \times 10^4$	y	67.672 \pm 0.002	0.38	\pm 0.04	ENSDF	
			143.872 \pm 0.004	0.049	\pm 0.004		
			253.729 \pm 0.010	0.0111	\pm 0.0009		
90-Th-231	25.52 \pm 0.01	h	58.5700 \pm 0.0024	0.46	\pm 0.03	ENSDF	
			81.2280 \pm 0.0014	0.90	\pm 0.06		
			82.0870 \pm 0.0014	0.42	\pm 0.03		
			84.2140 \pm 0.0013	6.6	\pm 0.4		
			89.95 \pm 0.02	1.00	\pm 0.06		
			102.2700 \pm 0.0013	0.44	\pm 0.03		
90-Th-232	$(1.405 \pm 0.006) \times 10^{10}$	y	63.81 \pm 0.01	0.263	\pm 0.013	ENSDF	
			140.88 \pm 0.01	0.021	\pm 0.004		
90-Th-233	22.15 \pm 0.15	m	29.373 \pm 0.010	2.5	\pm 0.4	LNHB	[3]
			86.477 \pm 0.010	2.7	\pm 0.4		
			94.65 \pm 0.05	0.8	\pm 0.1		
			169.159 \pm 0.010	0.34	\pm 0.05		
			459.222 \pm 0.007	1.4	\pm 0.3		
			669.902 \pm 0.016	0.68	\pm 0.14		
90-Th-234	24.10 \pm 0.03	d	63.29 \pm 0.02	3.70	\pm 0.06	ADS-98	[4]
			92.38 \pm 0.01	2.62	\pm 0.06		
			92.80 \pm 0.02	2.59	\pm 0.06		
			112.81 \pm 0.05	0.244	\pm 0.015		
91-Pa-231	$(3.276 \pm 0.011) \times 10^4$	y	260.19 \pm 0.06	0.188	\pm 0.012	ENSDF	
			283.69 \pm 0.01	1.7	\pm 0.1		
			300.07 \pm 0.01	2.5	\pm 0.2		
			302.65 \pm 0.05	2.2	\pm 0.4		
			330.06 \pm 0.01	1.40	\pm 0.09		
			340.74 \pm 0.05	0.181	\pm 0.011		
			357.12 \pm 0.09	0.175	\pm 0.013		
			91-Pa-233	26.98 \pm 0.02	d		
86.595 \pm 0.010	1.99	\pm 0.11					
103.86 \pm 0.01	0.853	\pm 0.006					
271.555 \pm 0.010	0.323	\pm 0.003					
300.129 \pm 0.005	6.60	\pm 0.21					
311.904 \pm 0.005	38.25	\pm 0.23					
340.476 \pm 0.005	4.47	\pm 0.03					
375.404 \pm 0.005	0.684	\pm 0.007					
398.492 \pm 0.005	1.408	\pm 0.014					
415.764 \pm 0.005	1.747	\pm 0.007					
91-Pa-234m	1.159 \pm 0.016	m	258.24 \pm 0.07	0.0726	\pm 0.0009	IAEA-CRP-XG	
			742.814 \pm 0.022	0.096	\pm 0.003		
			766.358 \pm 0.020	0.318	\pm 0.005		
			786.272 \pm 0.022	0.054	\pm 0.001		
			1001.025 \pm 0.022	0.832	\pm 0.010		
92-U-232	68.9 \pm 0.4	y	57.78 \pm 0.05	0.200	\pm 0.002	ENSDF	[5]
			129.08 \pm 0.05	0.0682	\pm 0.0004		
			270.2 \pm 0.2	0.00316	\pm 0.00005		
			327.9 \pm 0.2	0.00283	\pm 0.00006		

Table A-3. Gamma-ray energies and emission probabilities for actinides and natural decay products.

Nuclide	Half-life $T_{1/2}$	Units	Energy [keV]	γ rays		Source	Notes
				Emission probability [% decay]			
92-U-233	$(1.592 \pm 0.002) \times 10^5$	y	54.699 \pm 0.001	0.0182	\pm 0.0003	ENSDF	[5]
			118.968 \pm 0.002	0.00406	\pm 0.00004		
			120.816 \pm 0.001	0.00332	\pm 0.00003		
			135.36 \pm 0.03	0.00232	\pm 0.00002		
			146.345 \pm 0.002	0.00657	\pm 0.00006		
			164.522 \pm 0.002	0.00623	\pm 0.00005		
			208.171 \pm 0.002	0.00229	\pm 0.00003		
			245.345 \pm 0.002	0.00362	\pm 0.00003		
			291.354 \pm 0.004	0.00537	\pm 0.00005		
			317.16 \pm 0.01	0.00776	\pm 0.00007		
320.541 \pm 0.005	0.00290	\pm 0.00003					
92-U-234	$(2.455 \pm 0.006) \times 10^5$	y	53.20 \pm 0.02	0.1253	\pm 0.0040	LNHB	[5]
			120.90 \pm 0.04	0.0386	\pm 0.0032		
92-U-235	$(7.038 \pm 0.005) \times 10^8$	y	109.16 \pm 0.02	1.54	\pm 0.06	ENSDF	
			140.76 \pm 0.04	0.22	\pm 0.03		
			143.76 \pm 0.02	10.96	\pm 0.14		
			163.33 \pm 0.02	5.08	\pm 0.07		
			182.61 \pm 0.05	0.34	\pm 0.03		
			185.715 \pm 0.005	57.2	\pm 0.8		
			194.94 \pm 0.01	0.63	\pm 0.02		
			202.11 \pm 0.02	1.08	\pm 0.03		
			205.311 \pm 0.010	5.01	\pm 0.06		
			221.38 \pm 0.02	0.12	\pm 0.02		
92-U-236	$(2.342 \pm 0.004) \times 10^7$	y	49.369 \pm 0.009	0.078	\pm 0.012	ENSDF	
			112.750 \pm 0.015	0.019	\pm 0.003		
92-U-237	6.749 \pm 0.016	d	59.5409 \pm 0.0001	34.1	\pm 0.8	LNHB	
			64.83 \pm 0.02	1.286	\pm 0.017		
			164.61 \pm 0.02	1.86	\pm 0.03		
			208.00 \pm 0.01	21.3	\pm 0.3		
			332.36 \pm 0.04	1.199	\pm 0.016		
92-U-238	$(4.468 \pm 0.005) \times 10^9$	y	49.55 \pm 0.06	0.0697	\pm 0.0026	LNHB	
			113.5 \pm 0.1	0.0174	\pm 0.0047		
92-U-239	23.45 \pm 0.02	m	43.533 \pm 0.001	4.07	\pm 0.13	ENSDF	
			74.664 \pm 0.001	49.2	\pm 1.2		
			662.24 \pm 0.03	0.182	\pm 0.005		
			819.22 \pm 0.04	0.148	\pm 0.004		
			844.10 \pm 0.04	0.162	\pm 0.004		
93-Np-236m	22.5 \pm 0.4	h	538.11 \pm 0.10	0.0125	\pm 0.0015	LNHB	
			642.35 \pm 0.09	1.08	\pm 0.06		
			687.60 \pm 0.05	0.292	\pm 0.021		
93-Np-237	$(2.144 \pm 0.007) \times 10^6$	y	57.104 \pm 0.020	0.354	\pm 0.008	ENSDF	
			86.477 \pm 0.010	12.4	\pm 0.3		
			87.99 \pm 0.03	0.167	\pm 0.004		
			117.702 \pm 0.020	0.169	\pm 0.004		
			143.249 \pm 0.020	0.443	\pm 0.008		
			151.414 \pm 0.020	0.23	\pm 0.02		
			194.95 \pm 0.03	0.177	\pm 0.005		
			212.29 \pm 0.05	0.151	\pm 0.003		

Table A-3. Gamma-ray energies and emission probabilities for actinides and natural decay products.

Nuclide	Half-life $T_{1/2}$	Units	γ rays				Source	Notes
			Energy [keV]		Emission probability [% decay]			
93-Np-238	2.117 ± 0.002	d	101.90	± 0.03	0.251	± 0.007	ENSDF	
			882.63	± 0.03	0.811	± 0.011		
			918.69	± 0.04	0.532	± 0.007		
			923.98	± 0.02	2.62	± 0.04		
			936.61	± 0.06	0.368	± 0.006		
			941.38	± 0.05	0.514	± 0.007		
			962.77	± 0.03	0.645	± 0.008		
			984.45	± 0.02	25.19	± 0.21		
			1025.87	± 0.02	8.72	± 0.15		
		1028.54	± 0.02	18.3	± 0.3			
93-Np-239	2.356 ± 0.003	d	61.460	± 0.002	1.30	± 0.02	ENSDF	
			106.123	± 0.002	26.3	± 1.0		
			209.753	± 0.002	3.42	± 0.03		
			226.38	± 0.02	0.259	± 0.016		
			228.183	± 0.001	11.14	± 0.11		
			277.599	± 0.001	14.44	± 0.10		
			315.880	± 0.003	1.60	± 0.02		
334.310	± 0.002	2.06	± 0.02					
94-Pu-236	2.858 ± 0.008	y	47.57	± 0.01	0.066	± 0.020	ENSDF	[6]
			109.00	± 0.01	0.012	± 0.004		
			165.0	± 0.5	0.00066	± 0.00020		
			645.	$\pm 2.$	0.00024	± 0.00008		
94-Pu-238	87.74 ± 0.03	y	43.498	± 0.001	0.0397	± 0.0008	BIPM-5	[7]
			99.852	± 0.003	0.00735	± 0.00008		
			152.719	± 0.002	0.000930	± 0.000007		
94-Pu-239	$(2.411 \pm 0.003) \times 10^4$	y	51.624	± 0.001	0.02722	± 0.00003	ENSDF	[7]
			56.828	± 0.003	0.001152	± 0.000013		
			129.296	± 0.001	0.00631	± 0.00004		
			144.201	± 0.003	0.000283	± 0.000006		
			146.094	± 0.006	0.000119	± 0.000003		
			161.450	± 0.015	0.000123	± 0.000002		
			171.393	± 0.006	0.000110	± 0.000002		
			195.679	± 0.008	0.000107	± 0.000001		
			203.550	± 0.005	0.000569	± 0.000003		
			332.845	± 0.005	0.000494	± 0.000003		
			345.013	± 0.004	0.000556	± 0.000005		
			375.054	± 0.003	0.001554	± 0.000009		
			380.191	± 0.006	0.000305	± 0.000006		
			382.75	± 0.05	0.000259	± 0.000005		
			392.53	± 0.03	0.000205	± 0.000020		
			413.713	± 0.005	0.001466	± 0.000011		
422.598	± 0.019	0.000122	± 0.000002					
451.481	± 0.010	0.0001894	± 0.0000016					
645.94	± 0.04	0.0000152	± 0.0000003					
652.05	± 0.02	0.0000066	± 0.0000002					
658.86	± 0.06	0.0000097	± 0.0000002					
94-Pu-240	$(6.561 \pm 0.007) \times 10^3$	y	45.242	± 0.003	0.0450	± 0.0009	BIPM-5	[7]
			104.234	± 0.006	0.00714	± 0.00007		
			160.307	± 0.003	0.0004045	± 0.0000022		
94-Pu-241	14.290 ± 0.006	y	77.10	± 0.10	0.0000211	± 0.0000008	ENSDF	[7]
			103.680	± 0.005	0.000102	± 0.000002		
			148.567	± 0.010	0.000185	± 0.000003		

Table A-3. Gamma-ray energies and emission probabilities for actinides and natural decay products.

Nuclide	Half-life $T_{1/2}$	Units	Energy [keV]	γ rays		Source	Notes
				Emission probability [% decay]			
94-Pu-242	$(3.73 \pm 0.03) \times 10^5$	y	44.915 \pm 0.013	0.0376 \pm 0.0008	BIPM-5	[7]	
			103.50 \pm 0.04	0.00251 \pm 0.00011			
			158.80 \pm 0.08	0.000298 \pm 0.000020			
95-Am-241	432.6 \pm 0.6	y	26.3446 \pm 0.0002	2.40 \pm 0.03	BIPM-5	[8]	
			33.1963 \pm 0.0003	0.121 \pm 0.003			
			59.5409 \pm 0.0001	35.78 \pm 0.09			
			98.95 \pm 0.01	0.0203 \pm 0.0004			
			102.97 \pm 0.01	0.0195 \pm 0.0004			
			123.02 \pm 0.02	0.00100 \pm 0.00004			
			125.29 \pm 0.01	0.0041 \pm 0.0002			
			146.57 \pm 0.01	0.00046 \pm 0.00001			
			169.55 \pm 0.02	0.00017 \pm 0.00001			
			208.00 \pm 0.02	0.000786 \pm 0.000005			
			322.53 \pm 0.03	0.000151 \pm 0.000003			
			335.40 \pm 0.03	0.000496 \pm 0.000005			
			368.63 \pm 0.03	0.000214 \pm 0.000004			
662.41 \pm 0.02	0.000367 \pm 0.000005						
95-Am-242m	141. \pm 2.	y	49.35 \pm 0.02	0.13 \pm 0.01	ENSDF	[9]	
			60.13 \pm 0.06	0.005 \pm 0.001			
			66.89 \pm 0.02	0.015 \pm 0.001			
			73.66 \pm 0.02	0.008 \pm 0.001			
			86.65 \pm 0.02	0.023 \pm 0.001			
			135.19 \pm 0.02	0.007 \pm 0.001			
			136.03 \pm 0.02	0.009 \pm 0.001			
95-Am-243	$(7.370 \pm 0.017) \times 10^3$	y	43.53 \pm 0.02	5.89 \pm 0.10	LNHB		
			74.66 \pm 0.02	67.2 \pm 1.2			
			86.71 \pm 0.02	0.346 \pm 0.009			
			141.90 \pm 0.06	0.115 \pm 0.008			
96-Cm-242	162.86 \pm 0.08	d	44.08 \pm 0.03	0.0330 \pm 0.0007	LNHB	[7]	
			101.92 \pm 0.04	0.00251 \pm 0.00014			
			157.42 \pm 0.09	0.00145 \pm 0.00016			
96-Cm-243	29.1 \pm 0.1	y	209.753 \pm 0.002	3.29 \pm 0.1	ENSDF		
			228.183 \pm 0.002	10.6 \pm 0.3			
			277.599 \pm 0.002	14.0 \pm 0.4			
			285.460 \pm 0.002	0.73 \pm 0.02			
96-Cm-244	18.11 \pm 0.03	y	42.824 \pm 0.008	0.0258 \pm 0.0007	LNHB	[7]	
			98.860 \pm 0.013	0.00136 \pm 0.00009			
			152.63 \pm 0.02	0.00102 \pm 0.00005			
98-Cf-252	2.645 \pm 0.008	y	43.399 \pm 0.025	0.0148 \pm 0.0009	ENSDF	[7]	
			100.2 \pm 0.4	0.013 \pm 0.006			

[1] 510.7-keV emission probability of $22.6 \pm 0.2\%$ has been set aside as too close in energy to any annihilation radiation.

[2] Possible minor interference from other gamma-ray emissions of comparable energy (*).

[3] Doubly-placed transitions were not considered. Uncertainties of the emission probabilities are adopted from E. Browne, R.B. Firestone and V.S. Shirley, Table of Radioactive Isotopes, John Wiley & Sons, New York, 1986.

[4] Measurement of the emission probability of the 63.29-keV gamma ray by Abousahl et al., Nucl. Instrum. Meth. Phys. Res. A517 (2004) 211, has been incorporated into an earlier evaluation (Adsley et al., Appl. Radiat. Isot. 49 (1998) 1337) to give a recommended value of $(3.70 \pm 0.06)\%$; all other emissions probabilities and uncertainties were adjusted accordingly.

[5] Low intensity emissions.

[6] Energy uncertainties are adopted from E. Browne, R.B. Firestone and V.S. Shirley, Table of Radioactive Isotopes, John Wiley & Sons, New York, 1986.

[7] Low intensity emissions (no alternative).

[8] Low intensity emissions included.

[9] Low intensity emissions included; doubly-placed transitions were not considered.

A-4. K X-ray energies and intensities for actinides and natural decay products.

References

- PTB: E. Schönfeld, G. Rodloff, Energies and relative emission probabilities of K X-rays for elements with atomic number in the range from $Z = 5$ to $Z = 100$, Report PTB-6.11-1999-1, 1999.
- LNHB: Laboratoire National Henri Becquerel, Recommended Data, http://www.nucleide.org/DDEP_WG/DDEPdata.htm, 3 October 2006.
- BIPM-5: M.-M. Bé, V. Chisté, C. Duiieu, E. Browne, V. Chechev, N. Kuzmenko, R. Helmer, A. Nichols, E. Schönfeld, R. Dersch, Monographie BIPM-5, Table of Radionuclides, Vol. 2 - $A = 151$ to 242 , 2004.
- ENSDF: Evaluated Nuclear Structure Data File, <http://www-nds.iaea.org/ensdf/>, 25 October 2006; see also NuDat2, <http://www.nndc.bnl.gov/nudat2>, 25 October 2006.

Table A-4. K X-ray energies and intensities for actinides and natural decay products.

Nuclide	Half-life $T_{1/2}$	Units	Decay mode	Origin	Energy [keV]	Emission probability P_x [% decay]		Source
81-Tl-206	4.202 ± 0.011	m	β-	Pb Kα ₂	72.8049	0.026	± 0.003	[1]
				Pb Kα ₁	74.9700	0.044	± 0.005	
				Pb K'β ₁	84.451 – 85.470	0.0150	± 0.0017	
				Pb K'β ₂	87.238 – 88.003	0.0045	± 0.0006	
81-Tl-208	3.060 ± 0.008	m	β-	Pb Kα ₂	72.8049	2.15	± 0.06	[1]
				Pb Kα ₁	74.9700	3.61	± 0.09	
				Pb K'β ₁	84.451 - 85.470	1.23	± 0.04	
				Pb K'β ₂	87.238 - 88.003	0.373	± 0.013	
82-Pb-212	10.64 ± 0.01	h	β-	Bi Kα ₂	74.8157	10.7	± 0.3	[2]
				Bi Kα ₁	77.1088	17.9	± 0.5	
				Bi K'β ₁	86.835 - 87.862	6.12	± 0.20	
				Bi K'β ₂	89.732 - 90.522	1.87	± 0.07	
83-Bi -212	60.54 ± 0.06	m	α	Tl Kα ₂	70.8325	0.0563	± 0.0027	[2]
				Tl Kα ₁	72.8725	0.095	± 0.005	
				Tl K'β ₁	82.118 - 83.115	0.0323	± 0.0016	
				Tl K'β ₂	84.838 - 85.530	0.0096	± 0.0005	
83-Bi -212	60.54 ± 0.06	m	β-	Po Kα ₂	76.864	0.0404	± 0.0010	[2]
				Po Kα ₁	79.293	0.0672	± 0.0017	
				Po K'β ₁	89.256 - 90.363	0.0231	± 0.0007	
				Po K'β ₂	92.263 - 93.095	0.00720	± 0.00024	
88-Ra-224	3.627 ± 0.007	d	α	Rn Kα ₂	81.07	0.130	± 0.004	[2]
				Rn Kα ₁	83.78	0.215	± 0.007	
				Rn K'β ₁	94.247 - 95.449	0.0744	± 0.0024	
				Rn K'β ₂	97.48 - 98.389	0.0238	± 0.0009	
88-Ra-226	(1.600 ± 0.007) × 10 ³	y	α	Rn Kα ₂	81.07	0.191	± 0.007	[2]
				Rn Kα ₁	83.78	0.315	± 0.011	
				Rn K'β ₁	94.247 – 95.449	0.109	± 0.004	
				Rn K'β ₂	97.48 – 98.389	0.0349	± 0.0014	
89-Ac-224	2.78 ± 0.17	h	EC	Ra Kα ₂	85.43	22.2	± 0.8	[3]
				Ra Kα ₁	88.47	36.2	± 1.2	
				Ra K'β ₁	99.432 - 100.738	12.8	± 0.5	
				Ra K'β ₂	102.89 - 103.899	4.22	± 0.16	
89-Ac-224	2.78 ± 0.17	h	α	Fr Kα ₂	83.231	0.150	± 0.015	[3]
				Fr Kα ₁	86.105	0.247	± 0.023	
				Fr K'β ₁	96.815 - 98.069	0.087	± 0.009	
				Fr K'β ₂	100.16 - 101.118	0.028	± 0.003	

Table A-4. K X-ray energies and intensities for actinides and natural decay products.

Nuclide	Half-life $T_{1/2}$	Decay Units mode	Origin	Energy [keV]	Emission probability P_x [% decay]	Source
89-Ac-228	6.15 ± 0.02	h β-	Th $K\alpha_2$	89.954	1.92 ± 0.19	[3]
			Th $K\alpha_1$	93.351	± 0.3	
			Th $K'\beta_1$	104.819 - 106.239	1.11 ± 0.11	
			Th $K'\beta_2$	108.509 - 109.630	0.37 ± 0.04	
90-Th-227	18.718 ± 0.005	d α	Ra $K\alpha_2$	85.43	1.81 ± 0.06	[2]
			Ra $K\alpha_1$	88.47	± 0.10	
			Ra $K'\beta_1$	99.432 - 100.738	1.04 ± 0.04	
			Ra $K'\beta_2$	102.89 - 103.899	0.340 ± 0.013	
90-Th-228	698.60 ± 0.23	d α	Ra $K\alpha_2$	85.43	0.0172 ± 0.0008	[2]
			Ra $K\alpha_1$	88.47	0.0281 ± 0.0012	
			Ra $K'\beta_1$	99.432 - 100.738	0.0098 ± 0.0005	
			Ra $K'\beta_2$	102.89 - 103.899	0.00323 ± 0.00016	
90-Th-231	25.52 ± 0.01	h β-	Pa $K\alpha_2$	92.288	0.37 ± 0.05	[3]
			Pa $K\alpha_1$	95.869	± 0.07	
			Pa $K'\beta_1$	107.595 - 109.072	0.216 ± 0.026	
			Pa $K'\beta_2$	111.405 - 112.575	0.073 ± 0.009	
90-Th-233	22.15 ± 0.15	m β-	Pa $K\alpha_2$	92.288	0.48 ± 0.05	[4]
			Pa $K\alpha_1$	95.869	± 0.08	
			Pa $K'\beta_1$	107.595 - 109.072	0.28 ± 0.03	
			Pa $K'\beta_2$	111.405 - 112.575	0.095 ± 0.010	
91-Pa-231	$(3.276 \pm 0.011) \times 10^4$	y α	Ac $K\alpha_2$	87.768	0.75 ± 0.04	[3]
			Ac $K\alpha_1$	90.885	± 0.06	
			Ac $K'\beta_1$	102.101 - 103.462	0.435 ± 0.022	
			Ac $K'\beta_2$	105.679 - 106.738	0.145 ± 0.008	
91-Pa-232	1.32 ± 0.02	d β-	U $K\alpha_2$	94.666	1.06 ± 0.04	[3]
			U $K\alpha_1$	98.440	± 0.06	
			U $K'\beta_1$	110.421 - 111.964	0.613 ± 0.023	
			U $K'\beta_2$	114.407 - 115.580	0.210 ± 0.009	
91-Pa-233	26.98 ± 0.02	d β-	U $K\alpha_2$	94.666	9.09 ± 0.25	[1]
			U $K\alpha_1$	98.440	14.6 ± 0.4	
			U $K'\beta_1$	110.421 - 111.964	5.25 ± 0.21	
			U $K'\beta_2$	114.407 - 115.580	1.80 ± 0.08	

Table A-4. K X-ray energies and intensities for actinides and natural decay products.

Nuclide	Half-life $T_{1/2}$	Units	Decay mode	Origin	Energy [keV]	Emission probability P_x [% decay]		Source
91-Pa-234	6.75 ± 0.05	h	β-	U $K\alpha_2$	94.666	12.3	± 0.8	[3]
				U $K\alpha_1$	98.440	19.7	± 1.2	
				U $K'\beta_1$	110.421 - 111.964	7.1	± 0.5	
				U $K'\beta_2$	114.407 - 115.580	2.43	± 0.16	
92-U -233	$(1.592 \pm 0.002) \times 10^5$	y	α	Th $K\alpha_2$	89.954	0.00810	± 0.00022	[3]
				Th $K\alpha_1$	93.351	0.0131	± 0.0003	
				Th $K'\beta_1$	104.819 - 106.239	0.00469	± 0.00012	
				Th $K'\beta_2$	108.509 - 109.630	0.00158	± 0.00005	
92-U -235	$(7.038 \pm 0.005) \times 10^8$	y	α	Th $K\alpha_2$	89.954	3.46	± 0.09	[3]
				Th $K\alpha_1$	93.351	5.60	± 0.12	
				Th $K'\beta_1$	104.819 - 106.239	2.00	± 0.05	
				Th $K'\beta_2$	108.509 - 109.630	0.675	± 0.018	
92-U -237	6.749 ± 0.016	d	β-	Np $K\alpha_2$	97.069	14.7	± 0.4	[1]
				Np $K\alpha_1$	101.059	23.4	± 0.6	
				Np $K'\beta_1$	113.303 - 114.912	8.50	± 0.27	
				Np $K'\beta_2$	117.463 - 118.646	2.92	± 0.10	
93-Np-236	$(1.55 \pm 0.08) \times 10^5$	y	EC	U $K\alpha_2$	94.666	20.2	± 0.3	[1]
				U $K\alpha_1$	98.440	32.4	± 0.5	
				U $K'\beta_1$	110.421 - 111.964	11.68	± 0.25	
				U $K'\beta_2$	114.407 - 115.580	3.99	± 0.11	
93-Np-237	$(2.144 \pm 0.007) \times 10^6$	y	α	Pa $K\alpha_2$	92.288	1.67	± 0.10	[3]
				Pa $K\alpha_1$	95.869	2.68	± 0.14	
				Pa $K'\beta_1$	107.595 - 109.072	0.96	± 0.06	
				Pa $K'\beta_2$	111.405 - 112.575	0.327	± 0.018	
93-Np-238	2.117 ± 0.002	d	β-	Pu $K\alpha_2$	99.525	0.172	± 0.009	[5]
				Pu $K\alpha_1$	103.734	0.272	± 0.013	
				Pu $K'\beta_1$	116.244 - 117.918	0.099	± 0.005	
				Pu $K'\beta_2$	120.540 - 121.768	0.034	± 0.002	
93-Np-239	2.356 ± 0.003	d	β-	Pu $K\alpha_2$	99.525	14.0	± 0.6	[3]
				Pu $K\alpha_1$	103.734	22.2	± 0.8	
				Pu $K'\beta_1$	116.244 - 117.918	8.1	± 0.4	
				Pu $K'\beta_2$	120.540 - 121.768	2.80	± 0.11	

Table A-4. K X-ray energies and intensities for actinides and natural decay products.

Nuclide	Half-life $T_{1/2}$	Units	Decay mode	Origin	Energy [keV]	Emission probability P_x [% decay]		Source
94-Pu-239	$(2.411 \pm 0.003) \times 10^4$	y	α	U $K\alpha_2$	94.666	0.0036	± 0.0004	[3]
				U $K\alpha_1$	98.440	0.0058	± 0.0005	
				U $K'\beta_1$	110.421 - 111.964	0.00209	± 0.00019	
				U $K'\beta_2$	114.407 - 115.580	0.00072	± 0.00007	
94-Pu-241	14.290 \pm 0.006	y	α	U $K\alpha_2$	94.666	0.000312	± 0.000011	[3]
				U $K\alpha_1$	98.440	0.000499	± 0.000017	
				U $K'\beta_1$	110.421 - 111.964	0.000180	± 0.000007	
				U $K'\beta_2$	114.407 - 115.580	0.0000615	± 0.0000023	
95-Am-241	432.6 \pm 0.6	y	β^-	Np $K\alpha_2$	97.069	0.00116	± 0.00002	[2]
				Np $K\alpha_1$	101.059	0.00185	± 0.00004	
				Np $K'\beta_1$	113.303 - 114.912	0.000670	± 0.000014	
				Np $K'\beta_2$	117.463 - 118.646	0.000231	± 0.000005	
95-Am-242	16.02 \pm 0.02	h	EC	Pu $K\alpha_2$	99.525	3.6	± 0.3	[3]
				Pu $K\alpha_1$	103.734	5.7	± 0.4	
				Pu $K'\beta_1$	116.244 - 117.918	2.07	± 0.15	
				Pu $K'\beta_2$	120.540 - 121.768	0.72	± 0.06	
96-Cm-243	29.1 \pm 0.1	y	α	Pu $K\alpha_2$	99.525	13.2	± 0.6	[3]
				Pu $K\alpha_1$	103.734	20.9	± 0.8	
				Pu $K'\beta_1$	116.244 - 117.918	7.6	± 0.4	
				Pu $K'\beta_2$	120.540 - 121.768	2.64	± 0.11	

[1] X-ray energies adopted from PTB. Emission probabilities adopted from LNHB; the values listed in LNHB are consistent with the relative X-ray emission probabilities reported in PTB.

[2] X-ray energies adopted from PTB. Emission probabilities adopted from BIPM-5 - the values listed in BIPM-5 are consistent with the relative X-ray emission probabilities reported in PTB.

[3] X-ray energies adopted from PTB. Emission probabilities are calculated from the relative X-ray emission probabilities listed in PTB and the absolute $K\alpha_1$ -emission probability given in the ENSDF database.

[4] X-ray energies adopted from PTB. Emission probabilities reported without uncertainties were adopted from LNHB. There are no precise measurements of P_x available in the literature for Th-233 and known experimental data without uncertainties are based on unpublished work; under these circumstances an uncertainty of ~10% was adopted for P_x values.

[5] X-ray energies adopted from PTB. Emission probabilities are not listed by NuDat2; therefore, the $K\alpha_1$ -emission probability was directly taken from the ENSDF file. The remaining X-ray emission probabilities were calculated from the relative X-ray emission probabilities listed in PTB and the absolute $K\alpha_1$ -emission probability extracted from the ENSDF database.

A-5 Actinide data: Thermal neutron cross sections, resonance integrals and Westcott factors.

References

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σ_0	Neutron cross section at 2200 m/s.
σ	Neutron cross section measured in a Maxwellian spectrum.
σ_r	Neutron cross section measured with reactor neutrons.
σ_c	Neutron cross section calculated from resonance parameters or derived from equivalent data of the natural element.
$\sigma_{(m)}$	Neutron cross section leading to a metastable state of the product.
$\sigma_{(g)}$	Neutron cross section leading to the ground state of the product.
g	Westcott factor: ratio of the Maxwellian averaged cross section σ to 2200 m/s cross section σ_0 ($g = \sigma/\sigma_0$). If the cross section varies as a function of $1/v$, $g = 1.0$.
RI	Infinite dilution resonance integral (including the $1/v$ contribution).
γ	Subscript for radiative capture cross section.
f	Subscript for fission cross section.

Table A-5: Actinide data: Thermal neutron cross sections, resonance integrals and Westcott factors.

Nuclide	Type	Thermal Cross Section		Westcott Factor	Resonance Integral		Source
		σ_x [barn]			RI [barn]		
90-Th-232	σ_{0Y}	7.35	± 0.03	0.9982	83.3	± 1.5	[1]
92-U -233	σ_{0Y}	45.5	± 0.7	1.0495 ± 0.0223	138.	$\pm 6.$	[2]
	σ_{0f}	529.1	± 1.2	0.9955 ± 0.0015	775.	$\pm 17.$	
92-U -234	σ_{0Y}	99.8	± 1.3	0.9903	640.	$\pm 20.$	[1]
92-U -235	σ_{0Y}	98.8	± 0.8	0.9956 ± 0.0016	146.	$\pm 6.$	[3]
	σ_{0f}	582.6	± 1.1	0.9771 ± 0.0008	275.	$\pm 5.$	
92-U -236	σ_{0Y}	5.09	± 0.10	1.0027	345.	$\pm 15.$	[4]
92-U -237	σ_Y	443.	$\pm 167.$	0.9767	1200.	$\pm 200.$	[5]
92-U -238	σ_{0Y}	2.683	± 0.012	1.0009	277.	$\pm 3.$	[6]
93-Np-237	σ_{0Y}	175.9	± 2.9	0.982	652.	$\pm 24.$	[1]
93-Np-239	σ_{rY}	68.	$\pm 10.$	1.0005	455.		[7]
94-Pu-238	σ_{0Y}	540.	$\pm 7.$	0.9563	162.	$\pm 15.$	[1]
	σ_{0f}	17.9	± 0.4	0.9562	33.	$\pm 5.$	
94-Pu-239	σ_{0Y}	269.3	± 2.9	1.1369 ± 0.0119	180.	$\pm 20.$	[2]
	σ_{0f}	748.1	± 2.0	1.0553 ± 0.0013	303.	$\pm 10.$	
94-Pu-240	σ_{0Y}	289.5	± 1.4	1.0264	8452.	$\pm 200.$	[1]
94-Pu-241	σ_{0Y}	362.1	± 5.1	1.038	162.	$\pm 8.$	[8]
	σ_{0f}	1011.1	± 6.2	1.046 ± 0.006	570.	$\pm 15.$	
94-Pu-242	σ_{0Y}	18.5	± 0.5	1.0096	1115.	$\pm 40.$	[1]
95-Am-241	σ_{0Y}	587.	$\pm 12.$	1.051	1425.	$\pm 100.$	[1]
	σ_{0f}	3.20	± 0.09	0.996	14.4	± 1.0	
	$\sigma_{0Y(g)}$	533.	$\pm 13.$		1230.	$\pm 100.$	
	$\sigma_{0Y(m)}$	54.	$\pm 5.$		195.	$\pm 20.$	
95-Am-242	σ_Y	330.	$\pm 50.$	1.0471	186.		[7]
	σ_f	2100.	$\pm 200.$	1.0502	986.		
95-Am-242m	σ_Y	1290.	$\pm 300.$	1.100	211.		[9]
	σ_{0f}	6200.	$\pm 200.$	1.104	1570.	$\pm 80.$	

Table A-5: Actinide data: Thermal neutron cross sections, resonance integrals and Westcott factors.

Nuclide	Type	Thermal Cross Section		Westcott Factor	Resonance Integral	Source
		σ_x [barn]		g	RI [barn]	
95-Am-243	$\sigma_{0\gamma}$	75.1	± 1.8	1.014	1820. $\pm 70.$	[10]
	σ_f	0.1983 ± 0.0043		1.012	8.5 ± 0.5	
96-Cm-242	σ_γ	16.	$\pm 5.$	0.9939	110. $\pm 20.$	[11]
	σ_f	< 5.		0.9964	12.9 ± 0.7	
96-Cm-243	$\sigma_{0\gamma}$	130.	$\pm 10.$	1.005	215. $\pm 20.$	[1]
	σ_{of}	617.	$\pm 20.$	1.0054	1570. $\pm 100.$	
96-Cm-244	$\sigma_{0\gamma}$	15.2	± 1.2	0.999	655. $\pm 30.$	[1]
	σ_{of}	1.04	± 0.20	0.989	12.5 ± 2.5	
[1]	Data adopted from ANR; no uncertainty available for Westcott factors.					
[2]	Data adopted from ANR; g_γ factor was calculated from fission and absorption cross-section data.					
[3]	All data adopted from ANR.					
[4]	Cross-section data and resonance integral adopted from ANR; Westcott factors without uncertainties calculated from the ENDF/B-VII library.					
[5]	Cross-section data and resonance integral adopted from ANR; Westcott factor without uncertainty calculated from the JEFF-3.1 library; RI = 296 barns in the ENDF/B-VII library.					
[6]	Thermal cross-section data adopted from TRK-05 (value of 2.680 ± 0.019 barns reported in ANR), and g_γ and resonance integral take from ANR; no uncertainty available for Westcott factor.					
[7]	Cross-section data adopted from ANR; Westcott factors without uncertainties and resonance integrals calculated from the ENDF/B-VII library; a relative uncertainty of 20% is recommended.					
[8]	Data adopted from ANR; no uncertainty available for the g_γ factor.					
[9]	Data adopted from ANR; g_γ factor without uncertainty was calculated from the ENDF/B-VII library; resonance integral for radiative capture reported in ANR without uncertainty; a relative uncertainty of 20% is recommended.					
[10]	Data adopted from ANR; g_f factor without uncertainty was calculated from the ENDF/B-VII library.					
[11]	σ_γ and resonance integrals adopted from ANR; $\sigma_f < 5$ barns is reported in ANR; values of 3 and 5 barns are given in the ENDF/B-VII and the JEFF-3.1 libraries, respectively; Westcott factors without uncertainties were calculated from the JEFF-3.1 library.					

A-6: Average number of neutrons emitted per fission.

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Table A-6: Average number of neutrons emitted per fission.

Nuclide	Type	Total neutron yield		Delayed-neutron yield	
		ν_t	Source	ν_d	Source
90-Th-232	fast	2.456 ± 0.018	ENDF/B-VII	0.0499 ± 0.0019	ENDF/B-VII ⁽¹⁾
92-U -233	thermal	2.4968 ± 0.0036	IAEA-CRP-STD	0.0067 ± 0.0003	JEFF-3.1 ⁽²⁾
92-U -235	thermal	2.4355 ± 0.0023	IAEA-CRP-STD	0.0162 ± 0.0005	JEFF-3.1 ⁽³⁾
92-U -238	fast	2.819 ± 0.020	ENDF/B-VII ⁽⁴⁾	0.0465 ± 0.0024	JEFF-3.1 ⁽³⁾
92-Pu-238	fast	3.00 ± 0.14	JEFF-3.1 ⁽²⁾	0.0047 ± 0.0005	JEFF-3.1 ⁽¹⁾
94-Pu-239	thermal	2.8836 ± 0.0047	IAEA-CRP-STD	0.0065 ± 0.0003	JEFF-3.1 ⁽³⁾
94-Pu-240	fast	3.086 ± 0.025	JEFF-3.1 ⁽²⁾	0.0090 ± 0.0004	JEFF-3.1 ⁽¹⁾
94-Pu-241	thermal	2.9479 ± 0.0055	IAEA-CRP-STD	0.0160 ± 0.0008	JEFF-3.1 ⁽²⁾
94-Pu-242	fast	3.189 ± 0.035	JEFF-3.1 ⁽²⁾	0.0183 ± 0.0010	JEFF-3.1 ⁽¹⁾
95-Am-241	thermal	3.239 ± 0.024	JEFF-3.1 ⁽²⁾	0.0043 ± 0.0006	JEFF-3.1 ⁽²⁾
96-Cm-242	sf	2.529 ± 0.017	JEFF-3.1 ⁽⁵⁾	0.0013 ± 0.0003	Mills(1995)
96-Cm-243	thermal	3.433 ± 0.047	JEFF-3.1 ⁽²⁾	0.0030 ± 0.0003	JEFF-3.1 ⁽²⁾
96-Cm-244	sf	2.691 ± 0.012	JEFF-3.1 ⁽⁵⁾	0.0033 ± 0.0010	Mills(1995)
96-Cm-245	thermal	3.60 ± 0.13	JEFF-3.1 ⁽²⁾	0.0064 ± 0.0014	JEFF-3.1 ⁽²⁾
98-Cf -252	sf	3.7692 ± 0.0047	IAEA-CRP-STD	0.0086 ± 0.0010	Tuttle(1979)

fast = fast spectrum, thermal = thermal spectrum, sf = spontaneous fission.

- (1) Uncertainties estimated from selected experimental data reported by P&I (1998).
- (2) Uncertainties estimated from selected experimental data available in EXFOR.
- (3) Delayed-neutron data adopted from NEA/WPEC-6.
- (4) Prompt-neutron yield adopted from ENDF/B-VII β 3; uncertainty in prompt-neutron yield estimated from the U-238 covariance files included in the ENDF/B-VII β 1 library (modification flag 5E for material 9237); total neutron yield calculated as the sum of prompt- and delayed-neutron yields.
- (5) Prompt-neutron yield adopted from the JEFF-3.1 radioactive decay data library; uncertainty in prompt-neutron yield estimated from selected experimental data available in EXFOR; total spontaneous neutron yield calculated as the sum of prompt- and delayed-neutron yields.

A-7: Delayed-neutron eight-group parameters.

References

JEFF-3.1: Joint Evaluated Fission and Fusion File, Incident neutron and radioactive decay data files, <http://www.nea.fr/html/dbdata/JEFF/>, 26 February 2006;
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A-7: Delayed-neutron eight-group parameters.

Nuclide	Type	Group	$T_{1/2}$ [s]	λ_i [s^{-1}]	$\alpha_i = \nu_i / \nu_d$	$\beta_i = \nu_i / \nu_t$ [%]	Notes
90-Th-232	fast	1	55.6	0.012467	0.0334 ± 0.0025	0.0680 ± 0.0058	[1]
		2	24.5	0.028292	0.0733 ± 0.0053	0.149 ± 0.013	
		3	16.3	0.042524	0.0931 ± 0.0019	0.1892 ± 0.0084	
		4	5.21	0.133042	0.136 ± 0.024	0.276 ± 0.050	
		5	2.37	0.292467	0.3815 ± 0.0076	0.775 ± 0.034	
		6	1.04	0.666488	0.1402 ± 0.0082	0.285 ± 0.021	
		7	0.424	1.634781	0.114 ± 0.013	0.232 ± 0.028	
		8	0.195	3.554600	0.0281 ± 0.0006	0.0572 ± 0.0026	
		Total	6.985	0.099229	1.000 ± 0.030	2.032 ± 0.079	
92-U-233	thermal	1	55.6	0.012467	0.0797 ± 0.0036	0.0214 ± 0.0015	[1]
		2	24.5	0.028292	0.1670 ± 0.0035	0.0448 ± 0.0024	
		3	16.3	0.042524	0.1500 ± 0.0030	0.0402 ± 0.0022	
		4	5.21	0.133042	0.200 ± 0.040	0.054 ± 0.012	
		5	2.37	0.292467	0.298 ± 0.022	0.0799 ± 0.0071	
		6	1.04	0.666488	0.0388 ± 0.0008	0.01040 ± 0.00055	
		7	0.424	1.634781	0.056 ± 0.025	0.015 ± 0.0068	
		8	0.195	3.554600	0.0105 ± 0.0002	0.00281 ± 0.00015	
		Total	12.782	0.054228	1.000 ± 0.053	0.268 ± 0.013	
92-U-235	thermal	1	55.6	0.012467	0.0328 ± 0.0042	0.0218 ± 0.0029	[1]
		2	24.5	0.028292	0.1539 ± 0.0068	0.1023 ± 0.0056	
		3	16.3	0.042524	0.091 ± 0.009	0.0605 ± 0.0063	
		4	5.21	0.133042	0.197 ± 0.023	0.131 ± 0.016	
		5	2.37	0.292467	0.3308 ± 0.0066	0.2200 ± 0.0083	
		6	1.04	0.666488	0.0902 ± 0.0045	0.0600 ± 0.0036	
		7	0.424	1.634781	0.0812 ± 0.0016	0.0540 ± 0.0021	
		8	0.195	3.554600	0.0229 ± 0.0095	0.0152 ± 0.0064	
		Total	9.020	0.076849	1.000 ± 0.029	0.665 ± 0.021	

A-7: Delayed-neutron eight-group parameters.

Nuclide	Type	Group	$T_{1/2}$ [s]	λ_i [s^{-1}]	$\alpha_i = \nu_i / \nu_d$		$\beta_i = \nu_i / \nu_t$ [%]		Notes
92-U-238	fast	1	55.6	0.012467	0.0084	± 0.0013	0.0139	± 0.0023	[1]
		2	24.5	0.028292	0.1040	± 0.0022	0.1716	± 0.0097	
		3	16.3	0.042524	0.0375	± 0.0008	0.0619	± 0.0035	
		4	5.21	0.133042	0.137	± 0.020	0.226	± 0.036	
		5	2.37	0.292467	0.294	± 0.012	0.485	± 0.033	
		6	1.04	0.666488	0.1980	± 0.0023	0.327	± 0.018	
		7	0.424	1.634781	0.128	± 0.013	0.211	± 0.025	
		8	0.195	3.554600	0.0931	± 0.0034	0.1536	± 0.0098	
		Total	5.315	0.130409	1.000	± 0.027	1.650	± 0.086	
94-Pu-238	fast	1	55.6	0.012467	0.045	± 0.009	0.0071	± 0.0017	[2]
		2	24.5	0.028292	0.250	± 0.018	0.0393	± 0.0056	
		3	16.3	0.042524	0.052	± 0.001	0.0082	± 0.0011	
		4	5.21	0.133042	0.256	± 0.014	0.0402	± 0.0054	
		5	2.37	0.292467	0.251	± 0.035	0.0394	± 0.0073	
		6	1.04	0.666488	0.119	± 0.012	0.0187	± 0.0030	
		7	0.424	1.634781	0.027	± 0.016	0.0042	± 0.0026	
		8	0.195	3.554600					
		Total	11.538	0.060073	1.000	± 0.048	0.157	± 0.019	
94-Pu-239	thermal	1	55.6	0.012467	0.032	± 0.012	0.0072	± 0.0028	[1]
		2	24.5	0.028292	0.237	± 0.034	0.0533	± 0.0081	
		3	16.3	0.042524	0.0826	± 0.0016	0.01859	± 0.00098	
		4	5.21	0.133042	0.182	± 0.052	0.041	± 0.012	
		5	2.37	0.292467	0.294	± 0.029	0.0662	± 0.0073	
		6	1.04	0.666488	0.0816	± 0.0016	0.01836	± 0.00097	
		7	0.424	1.634781	0.072	± 0.031	0.0162	± 0.0071	
		8	0.195	3.554600	0.0185	± 0.0004	0.00416	± 0.00023	
		Total	10.698	0.064794	1.000	± 0.077	0.225	± 0.011	
94-Pu-240	fast	1	55.6	0.012467	0.0220	± 0.0033	0.0064	± 0.0011	[1]
		2	24.5	0.028292	0.2069	± 0.0048	0.0604	± 0.0033	
		3	16.3	0.042524	0.0795	± 0.0016	0.0232	± 0.0013	
		4	5.21	0.133042	0.161	± 0.055	0.047	± 0.017	
		5	2.37	0.292467	0.3139	± 0.0088	0.0917	± 0.0051	
		6	1.04	0.666488	0.1050	± 0.0098	0.0307	± 0.0033	
		7	0.424	1.634781	0.079	± 0.017	0.0231	± 0.0051	
		8	0.195	3.554600	0.0325	± 0.0030	0.00949	± 0.00099	
		Total	9.320	0.074374	1.000	± 0.060	0.292	± 0.014	
94-Pu-241	thermal	1	55.6	0.012467	0.016	± 0.003	0.0087	± 0.0017	[1]
		2	24.5	0.028292	0.175	± 0.019	0.095	± 0.012	
		3	16.3	0.042524	0.055	± 0.012	0.0299	± 0.0067	
		4	5.21	0.133042	0.170	± 0.018	0.092	± 0.011	
		5	2.37	0.292467	0.280	± 0.035	0.152	± 0.021	
		6	1.04	0.666488	0.166	± 0.033	0.090	± 0.019	
		7	0.424	1.634781	0.113	± 0.035	0.061	± 0.020	
		8	0.195	3.554600	0.0245	± 0.0063	0.0133	± 0.0035	
		Total	7.848	0.088319	1.000	± 0.067	0.543	± 0.028	

A-7: Delayed-neutron eight-group parameters.

Nuclide	Type	Group	$T_{1/2}$ [s]	λ_i [s^{-1}]	$\alpha_i = \nu_i / \nu_d$		$\beta_i = \nu_i / \nu_t$ [%]		Notes
94-Pu-242	fast	1	55.6	0.012467	0.0138	\pm 0.0003	0.00792	\pm 0.00048	[1]
		2	24.5	0.028292	0.095	\pm 0.051	0.055	\pm 0.030	
		3	16.3	0.042524	0.134	\pm 0.015	0.0769	\pm 0.0097	
		4	5.21	0.133042	0.033	\pm 0.020	0.019	\pm 0.012	
		5	2.37	0.292467	0.4038	\pm 0.0081	0.232	\pm 0.014	
		6	1.04	0.666488	0.001	\pm 0.060	0.001	\pm 0.035	
		7	0.424	1.634781	0.258	\pm 0.046	0.148	\pm 0.028	
		8	0.195	3.554600	0.062	\pm 0.052	0.036	\pm 0.030	
		Total	6.530	0.106145	1.00	\pm 0.11	0.574	\pm 0.032	
95-Am-241	thermal	1	55.6	0.012467	0.0340	\pm 0.0031	0.00448	\pm 0.00073	[1]
		2	24.5	0.028292	0.238	\pm 0.033	0.03137	\pm 0.00603	
		3	16.3	0.042524	0.061	\pm 0.012	0.00804	\pm 0.00191	
		4	5.21	0.133042	0.182	\pm 0.033	0.02399	\pm 0.00540	
		5	2.37	0.292467	0.305	\pm 0.035	0.04021	\pm 0.00707	
		6	1.04	0.666488	0.1060	\pm 0.0021	0.01397	\pm 0.00188	
		7	0.424	1.634781	0.038	\pm 0.066	0.00501	\pm 0.00873	
		8	0.195	3.554600	0.036	\pm 0.072	0.00475	\pm 0.00952	
		Total	10.518	0.065899	1.00	\pm 0.12	0.13183	\pm 0.01752	
96-Cm-245	thermal	1	55.6	0.012467	0.016	\pm 0.005	0.0028	\pm 0.0011	[2]
		2	24.5	0.028292	0.269	\pm 0.020	0.048	\pm 0.012	
		3	16.3	0.042524	0.045	\pm 0.001	0.0080	\pm 0.0018	
		4	5.21	0.133042	0.204	\pm 0.046	0.036	\pm 0.012	
		5	2.37	0.292467	0.255	\pm 0.040	0.045	\pm 0.013	
		6	1.04	0.666488	0.178	\pm 0.050	0.032	\pm 0.012	
		7	0.424	1.634781	0.033	\pm 0.084	0.006	\pm 0.016	
		8	0.195	3.554600					
		Total	10.080	0.068765	1.00	\pm 0.12	0.178	\pm 0.039	
98-Cf-252	sf	1	55.6	0.012467	0.014	\pm 0.007	0.0032	\pm 0.0017	[2]
		2	24.5	0.028292	0.318	\pm 0.007	0.0725	\pm 0.0088	
		3	16.3	0.042524	0.001	\pm 0.024	0.0002	\pm 0.0055	
		4	5.21	0.133042	0.209	\pm 0.018	0.0477	\pm 0.0070	
		5	2.37	0.292467	0.200	\pm 0.004	0.0456	\pm 0.0055	
		6	1.04	0.666488	0.144	\pm 0.031	0.0328	\pm 0.0081	
		7	0.424	1.634781	0.114	\pm 0.044	0.026	\pm 0.011	
		8	0.195	3.554600					
		Total	10.347	0.066992	1.000	\pm 0.063	0.228	\pm 0.027	

fast = fast spectrum, thermal = thermal spectrum, sf = spontaneous fission.

[1] Values of $T_{1/2}$, λ_i and α_i adopted from the JEFF-3.1 library; uncertainties in α_i adopted from NEA/WPEC-6.

[2] Data adopted from NEA/WPEC-6.

B-1. Half-lives and branching fractions for fission products.

References

BIPM-5: M.-M. Bé, V. Chisté, C. Dulieu, E. Browne, V. Chechev, N. Kuzmenko, R. Helmer, A. Nichols, E. Schönfeld, R. Dersch, Monographie BIPM-5, Table of Radionuclides, Vol. 1 - A = 1 to 150 and Vol. 2 - A = 151 to 242, 2004.

LNHB: Laboratoire National Henri Becquerel, Recommended Data, http://www.nucleide.org/DDEP_WG/DDEPdata.htm, 16 January 2006.

IAEA-CRP-XG: M.-M. Bé, V.P. Chechev, R. Dersch, O.A.M. Helene, R.G. Helmer, M. Herman, S. Hlaváč, A. Marcinkowski, G.L. Molnár, A.L. Nichols, E. Schönfeld, V.R. Vanin, M.J. Woods, IAEA CRP "Update of X-ray and Gamma-ray Decay Data Standards for Detector Calibration and Other Applications", IAEA Nuclear Data Section, 2004.

ENSDF: Evaluated Nuclear Structure Data File, <http://www-nds.iaea.org/ensdf/>, 26 January 2006.

Table B-1. Half-lives and branching fractions for fission products.

Nuclide	Half-life		Units	Decay mode	Branching Fraction		Source	Notes
	$T_{1/2}$							
36-Kr- 85	10.752	± 0.023	y	β-	1.0		BIPM-5	
40-Zr- 95	64.032	± 0.006	d	β-	1.0		LNHB	
41-Nb- 95	34.991	± 0.006	d	β-	1.0		LNHB	
41-Nb- 95m	3.61	± 0.03	d	IT β-	0.975 0.025	± 0.001 ± 0.001	LNHB	[1]
44-Ru-103	39.247	± 0.013	d	β-	1.0		IAEA-CRP-XG	
44-Ru-106	1.018	± 0.005	y	β-	1.0		IAEA-CRP-XG	
45-Rh-106	30.1	± 0.3	s	β-	1.0		IAEA-CRP-XG	
51-Sb-125	2.7584	± 0.0006	y	β-	1.0		IAEA-CRP-XG	
53- I -131	8.0233	± 0.0019	d	β-	1.0		BIPM-5	
53- I -135	6.57	± 0.02	h	β-	1.0		ENSDF	
54-Xe-131m	11.930	± 0.016	d	IT	1.0		BIPM-5	
54-Xe-133	5.243	± 0.001	d	β-	1.0		ENSDF	
54-Xe-133m	2.19	± 0.01	d	IT	1.0		ENSDF	
54-Xe-135	9.14	± 0.02	h	β-	1.0		ENSDF	
54-Xe-135m	15.29	± 0.05	m	IT β-	0.997 0.003	± 0.003 ± 0.003	ENSDF	[2]

Table B-1. Half-lives and branching fractions for fission products.

Nuclide	Half-life $T_{1/2}$		Units	Decay mode	Branching Fraction		Source	Notes
55-Cs-134	2.063	± 0.003	y	β - EC	0.999997 \pm 0.000001 0.000003 \pm 0.000001		IAEA-CRP-XG	[3]
55-Cs-137	30.05	± 0.08	y	β -	1.0		LNHB	
56-Ba-140	12.753	± 0.004	d	β -	1.0		BIPM-5	
57-La-140	1.67850 \pm 0.00017		d	β -	1.0		BIPM-5	
58-Ce-141	32.508	± 0.010	d	β -	1.0		LNHB	
58-Ce-144	285.1	± 0.6	d	β -	1.0		IAEA-CRP-XG	
59-Pr-144	17.28	± 0.05	m	β -	1.0		ENSDF	
60-Nd-147	10.98	± 0.01	d	β -	1.0		ENSDF	
61-Pm-147	2.6234	± 0.0002	y	β -	1.0		ENSDF	
61-Pm-148	5.368	± 0.002	d	β -	1.0		ENSDF	
61-Pm-148m	41.29	± 0.11	d	β - IT	0.958 \pm 0.007 0.042 \pm 0.007		ENSDF	
61-Pm-149	2.2117	± 0.0021	d	β -	1.0		ENSDF	
61-Pm-151	1.1833	± 0.0017	d	β -	1.0		ENSDF	
62-Sm-151	90.	$\pm 8.$	y	β -	1.0		ENSDF	
62-Sm-153	1.92855 \pm 0.00005		d	β -	1.0		LNHB	
63-Eu-154	8.592	± 0.004	y	β - EC	0.99980 \pm 0.00010 0.00020 \pm 0.00010		IAEA-CRP-XG	[3]
63-Eu-155	4.753	± 0.016	y	β -	1.0		IAEA-CRP-XG	

1 y = 1 year = 365.24219878 days

[1] ENSDF branching fractions: 0.944 \pm 0.007 for IT and 0.056 \pm 0.007 for β -.

[2] Branching fractions were averaged from ENSDF database.

[3] Branching fractions were adopted from ENSDF database.

B-2. Gamma-ray energies and emission probabilities for fission products.

References

BIPM-5: M.-M. Bé, V. Chisté, C. Dulieu, E. Browne, V. Chechev, N. Kuzmenko, R. Helmer, A. Nichols, E. Schönfeld, R. Dersch, Monographie BIPM-5, Table of Radionuclides, Vol. 1 - A = 1 to 150 and Vol. 2 - A = 151 to 242,

LNHB: Laboratoire National Henri Becquerel, Recommended Data, http://www.nucleide.org/DDEP_WG/DDEPdata.htm, 3 October 2006.

AEA-CRP-XG: M.-M. Bé, V.P. Chechev, R. Dersch, O.A.M. Helene, R.G. Helmer, M. Herman, S. Hlaváč, A. Marcinkowski, G.L. Molnár, A.L. Nichols, E. Schönfeld, V.R. Vanin, M.J. Woods, IAEA CRP "Update of X-ray and Gamma-ray Decay Data Standards for Detector Calibration and Other Applications", IAEA Nuclear Data Section, 2004 .

ENSDF: Evaluated Nuclear Structure Data File, <http://www-nds.iaea.org/ensdf/>, 15 November 2006.

Table B-2. Gamma-ray energies and emission probabilities for fission products.

Nuclide	Half-life		Units	Energy		Emission probability		Source	Notes
	$T_{1/2}$			[keV]		[% decay]			
36-Kr- 85	10.752	± 0.023	y	513.997	± 0.005	0.435	± 0.010	BIPM-5	
40-Zr- 95	64.032	± 0.006	d	235.69	± 0.02	0.27	± 0.02	LNHB	
				724.193	± 0.003	44.27	± 0.22		
				756.729	± 0.012	54.38	± 0.22		
41-Nb- 95	34.991	± 0.006	d	765.803	± 0.006	99.808	± 0.007	LNHB	
41-Nb- 95m	3.61	± 0.03	d	235.69	± 0.02	25.1	± 0.3	LNHB	
44-Ru-103	39.247	± 0.013	d	39.760	± 0.010	0.071	± 0.003	IAEA-CRP-XG	
				53.275	± 0.010	0.384	± 0.006		
				294.98	± 0.02	0.289	± 0.006		
				443.80	± 0.02	0.344	± 0.003		
				497.08	± 0.02	91.31	± 0.07		
				557.04	± 0.02	0.855	± 0.005		
45-Rh-106	30.1	± 0.3	s	610.33	± 0.02	5.78	± 0.03	IAEA-CRP-XG	[1]
				511.8534	± 0.0023	20.50	± 0.21		
				616.22	± 0.09	0.724	± 0.013		
				621.93	± 0.06	9.86	± 0.11		
				873.49	± 0.05	0.435	± 0.008		
				1050.41	± 0.06	1.488	± 0.022		
51-Sb-125	2.7584	± 0.0006	y	1128.07	± 0.05	0.399	± 0.006	IAEA-CRP-XG	
				176.314	± 0.002	6.82	± 0.07		
				380.452	± 0.008	1.520	± 0.015		
				427.874	± 0.004	29.55	± 0.24		
				463.365	± 0.004	10.48	± 0.09		
				600.597	± 0.002	17.76	± 0.18		
				606.713	± 0.003	5.02	± 0.05		
				635.950	± 0.003	11.32	± 0.10		
671.441	± 0.006	1.783	± 0.016						

Table B-2. Gamma-ray energies and emission probabilities for fission products.

Nuclide	Half-life		Units	γ rays		Source	Notes	
	$T_{1/2}$			Energy [keV]	Emission probability [% decay]			
53-I-131	8.0233	± 0.0019	d	80.1850	± 0.0019	2.607	± 0.027	BIPM-5
				284.305	± 0.005	6.06	± 0.06	
				364.489	± 0.005	81.2	± 0.8	
				636.989	± 0.004	7.26	± 0.08	
				722.911	± 0.005	1.796	± 0.020	
54-Xe-131m	11.930	± 0.016	d	163.930	± 0.008	1.98	± 0.06	BIPM-5
54-Xe-133	5.243	± 0.001	d	80.997	± 0.003	38.0	± 0.7	ENSDF
55-Cs-134	2.063	± 0.003	y	563.243	± 0.003	8.37	± 0.03	IAEA-CRP-XG
				569.327	± 0.003	15.38	± 0.04	
				604.720	± 0.003	97.650	± 0.018	
				795.83	± 0.03	85.5	± 0.3	
				801.945	± 0.004	8.70	± 0.03	
1365.186	± 0.004	3.017	± 0.012					
55-Cs-137	30.05	± 0.08	y	661.657	± 0.003	84.99	± 0.20	LNHB
56-Ba-140	12.753	± 0.004	d	29.9656	± 0.0015	14.32	± 0.25	BIPM-5
				132.6972	± 0.0025	0.201	± 0.004	
				162.6628	± 0.0024	6.26	± 0.09	
				304.872	± 0.004	4.30	± 0.04	
				423.721	± 0.004	3.11	± 0.03	
				437.569	± 0.003	1.927	± 0.019	
537.303	± 0.006	24.39	± 0.22					
57-La-140	1.67850	± 0.00017	d	328.761	± 0.004	20.8	± 0.3	BIPM-5
				432.513	± 0.008	2.995	± 0.016	
				487.022	± 0.006	46.1	± 0.4	
				751.653	± 0.007	4.392	± 0.024	
				815.781	± 0.006	23.72	± 0.12	
				867.839	± 0.016	5.58	± 0.03	
				919.533	± 0.010	2.730	± 0.023	
				925.198	± 0.007	7.04	± 0.04	
				950.988	± 0.020	0.531	± 0.005	
				1596.203	± 0.013	95.40	± 0.08	
				2347.847	± 0.014	0.845	± 0.007	
2521.390	± 0.014	3.412	± 0.024					
58-Ce-141	32.508	± 0.010	d	145.4433	± 0.0014	48.29	± 0.20	LNHB
58-Ce-144	285.1	± 0.6	d	33.568	± 0.010	0.235	± 0.012	IAEA-CRP-XG
				40.98	± 0.10	0.41	± 0.25	
				80.12	± 0.05	1.52	± 0.10	
				133.515	± 0.004	11.09	± 0.16	
59-Pr-144	17.28	± 0.05	m	696.505	± 0.004	1.342	± 0.014	IAEA-CRP-XG [2]
				1489.148	± 0.003	0.296	± 0.005	
				2185.645	± 0.005	0.680	± 0.018	

Table B-2. Gamma-ray energies and emission probabilities for fission products.

Nuclide	Half-life		Units	Energy		γ rays		Source	Notes
	$T_{1/2}$			[keV]		Emission probability			
						[% decay]			
60-Nd-147	10.98	± 0.01	d	91.105	± 0.002	27.9	± 1.1	ENSDF	
				275.374	± 0.015	0.80	± 0.06		
				319.411	± 0.018	1.95	± 0.14		
				398.155	± 0.020	0.87	± 0.07		
				439.895	± 0.022	1.20	± 0.10		
				531.016	± 0.022	13.1	± 0.9		
685.90	± 0.04	0.81	± 0.06						
61-Pm-147	2.6234	± 0.0002	y	121.220	± 0.017	0.00285	± 0.00011	ENSDF	[3]
61-Pm-148	5.368	± 0.002	d	550.27	± 0.03	22.0	± 0.5	ENSDF	
				611.26	± 0.03	1.02	± 0.03		
				896.42	± 0.03	0.98	± 0.02		
				914.85	± 0.03	11.5	± 0.3		
				1465.12	± 0.03	22.2	± 0.5		
61-Pm-148m	41.29	± 0.11	d	98.48	± 0.03	2.47	± 0.05	ENSDF	
				189.63	± 0.03	1.10	± 0.03		
				288.11	± 0.03	12.56	± 0.16		
				311.63	± 0.03	3.92	± 0.06		
				414.07	± 0.03	18.66	± 0.24		
				432.78	± 0.03	5.35	± 0.08		
				501.26	± 0.03	6.75	± 0.10		
				550.27	± 0.03	94.9	± 1.2		
				599.74	± 0.03	12.54	± 0.17		
				611.26	± 0.03	5.48	± 0.10		
				629.97	± 0.03	89.0	± 0.9		
				725.70	± 0.03	32.8	± 0.5		
				915.33	± 0.03	17.17	± 0.25		
1013.81	± 0.03	20.3	± 0.3						
63-Eu-154	8.592	± 0.004	y	123.0706	± 0.0009	40.4	± 0.5	IAEA-CRP-XG	
				247.9288	± 0.0007	6.89	± 0.07		
				591.755	± 0.003	4.95	± 0.05		
				692.4205	± 0.0018	1.79	± 0.03		
				723.3014	± 0.0022	20.05	± 0.21		
				756.8020	± 0.0023	4.53	± 0.05		
				873.1834	± 0.0023	12.17	± 0.12		
				996.262	± 0.006	10.50	± 0.10		
				1004.725	± 0.007	17.85	± 0.17		
				1246.121	± 0.004	0.862	± 0.008		
				1274.429	± 0.004	34.9	± 0.3		
1596.4804	± 0.0028	1.783	± 0.017						
63-Eu-155	4.753	± 0.016	y	45.2990	± 0.0010	1.31	± 0.05	IAEA-CRP-XG	
				60.0086	± 0.0010	1.22	± 0.05		
				86.0591	± 0.0010	0.154	± 0.017		
				86.5479	± 0.0010	30.7	± 0.3		
				105.3083	± 0.0010	21.1	± 0.6		

[1] 511.8534-keV emission is extremely close in energy to any annihilation radiation.

[2] Half-life adopted from ENSDF; gamma-ray data taken from IAEA-CRP-XG.

[3] Only low intensity emission (no alternative).

B-3 Fission product data: Thermal neutron cross sections, resonance integrals and Westcott factors.

References

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- SEK-87: T. Sekine et al., Triple Neutron Capture of ^{153}Eu in a Reactor: the Cross Sections of ^{154}Eu and ^{155}Eu , Appl. Radiat. Isot. 38 (1987) 513.

- σ_0 Neutron cross section at 2200 m/s.
 σ Neutron cross section measured in a Maxwellian spectrum.
 σ_r Neutron cross section measured with reactor neutrons.
 σ_c Neutron cross section calculated from resonance parameters or derived from equivalent data of the natural element.
 $\sigma_{(m)}$ Neutron cross section leading to a metastable state of the product.
 $\sigma_{(g)}$ Neutron cross section leading to the ground state of the product.
 g Westcott factor: ratio of the Maxwellian averaged cross section σ to 2200 m/s cross section σ_0 ($g = \sigma/\sigma_0$). If the cross section varies as a function of $1/v$, $g = 1.0$.
 RI Infinite dilution resonance integral (including the $1/v$ contribution).
 γ Subscript for radiative capture cross section.
 f Subscript for fission cross section.

Table B-3: Fission product data: Thermal neutron cross sections, resonance integrals and Westcott factors.

Nuclide	Type	Thermal Cross Section		Westcott Factor g	Resonance Integral		Source
		σ_x [barn]			RI [barn]		
36-Kr- 82	σ_γ	19.	\pm 4.	1.0004	156.	\pm 20.	[1]
36-Kr- 83	σ_γ	197.	\pm 10.	0.9979	157.	\pm 25.	[1]
36-Kr- 84	σ_γ	0.110	\pm 0.015	1.0004	2.43	\pm 0.20	[1]
	$\sigma_{\gamma(g)}$	0.042	\pm 0.004				
	$\sigma_{\gamma(m)}$	0.090	\pm 0.013				
36-Kr- 85	σ_γ	1.66	\pm 0.20	0.9996	1.8	\pm 1.0	[1]
40-Zr- 90	σ_γ	0.077	\pm 0.016	1.0003	0.17	\pm 0.02	[1]
40-Zr- 91	σ_γ	0.83	\pm 0.08	1.0003	5.76	\pm 0.40	[1]
40-Zr- 92	σ_γ	0.26	\pm 0.08	1.0004	0.64	\pm 0.11	[2]
40-Zr- 93	σ_γ	0.696		1.0007	17.8		[3]

Table B-3: Fission product data: Thermal neutron cross sections, resonance integrals and Westcott factors.

Nuclide	Type	Thermal Cross Section		Westcott Factor g	Resonance Integral RI [barn]		Source
		σ_x [barn]					
40-Zr- 94	σ_Y	0.0494 ±	0.0017	1.0004	0.280 ±	0.010	[1]
40-Zr- 95	σ_{0Y}	1.2		1.0004	7.79		[4]
40-Zr- 96	σ_Y	0.0229 ±	0.0010	1.0006	5.28 ±	0.11	[1]
42-Mo- 95	σ_Y	13.4 ±	0.3	1.0000	118. ±	7.	[1]
42-Mo- 96	σ_Y	0.5 ±	0.2	1.0006	17. ±	3.	[1]
42-Mo- 97	σ_Y	2.2 ±	0.2	1.0001	14.4 ±	3.0	[1]
42-Mo- 98	σ_{0Y}	0.130 ±	0.006	1.0008	6.7 ±	0.3	[1]
42-Mo-100	σ_Y	0.199 ±	0.003	1.0003	3.76 ±	0.15	[1]
44-Ru-100	σ_{0Y}	5.8 ±	0.4	1.0003	11.2 ±	1.1	[1]
44-Ru-101	σ_{0Y}	5.2 ±	0.3	1.0011	102. ±	10.	[1]
44-Ru-102	σ_{0Y}	1.27 ±	0.04	1.0003	4.9 ±	0.3	[1]
44-Ru-103	σ_Y	1.2		1.0017	47.		[5]
44-Ru-104	σ_{0Y}	0.491 ±	0.010	1.0004	6.3 ±	0.2	[1]
44-Ru-106	σ_{0Y}	0.146 ±	0.045	1.0004	2.0 ±	0.6	[1]
54-Xe-130	σ_{0Y}	4.8 ±	1.2	0.9984	4.8		[6]
	$\sigma_{0Y(m)}$	0.45 ±	0.10				
54-Xe-131	σ_{0Y}	87. ±	10.	1.0015	890. ±	50.	[1]
54-Xe-132	σ_{0Y}	0.45 ±	0.06	1.0004	5.0 ±	0.6	[1]
	$\sigma_{0Y(m)}$	0.05 ±	0.01		0.9 ±	0.2	
54-Xe-133	σ_{rY}	190. ±	90.	1.0004	90.		[7]
54-Xe-135	σ_{0Y}	2650000. ±	110000.	1.1594	7600. ±	500.	[1]
54-Xe-136	σ_{0Y}	0.26 ±	0.02	1.0007	0.74 ±	0.21	[8]
55-Cs-133	σ_{0Y}	30.3 ±	1.1	1.0029	437. ±	26.	[1]
	$\sigma_{0Y(m)}$	2.6 ±	0.1		29.0 ±	1.1	
55-Cs-134	σ_{rY}	140. ±	12.	0.9985	105.		[9]
55-Cs-135	σ_Y	8.3 ±	0.3	0.9977	37.9 ±	2.7	[10]
55-Cs-137	σ_{rY}	0.27 ±	0.03	1.0005	0.35		[11]

Table B-3: Fission product data: Thermal neutron cross sections, resonance integrals and Westcott factors.

Nuclide	Type	Thermal Cross Section			Westcott Factor g	Resonance Integral RI [barn]			Source
		σ_x	[barn]						
58-Ce-144	σ_Y	1.0	±	0.1	1.0005	2.6	±	0.3	[1]
59-Pr-141	σ_{0Y}	11.5	±	0.3	0.9996	17.4	±	2.0	[1]
	$\sigma_{0Y(m)}$	3.9	±	0.3					
59-Pr-143	σ_{0Y}	90.	±	10.	0.9998	190.	±	25.	[1]
60-Nd-142	σ_Y	18.7	±	0.7	0.9990	6.2			[12]
60-Nd-143	σ_{0Y}	325.	±	10.	0.9967	129.	±	30.	[1]
60-Nd-144	σ_Y	3.6	±	0.3	1.0004	4.2	±	0.5	[1]
60-Nd-145	σ_{0Y}	50.0	±	1.0	1.0001	230.	±	35.	[1]
60-Nd-146	σ_{0Y}	1.49	±	0.06	1.0004	2.57	±	0.14	[1]
60-Nd-147	σ_Y	440.	±	150.	0.9957	539.8			[13]
60-Nd-148	σ_{0Y}	2.58	±	0.07	1.0005	15.5	±	1.5	[1]
60-Nd-150	σ_{0Y}	1.04	±	0.04	1.0003	15.2	±	0.8	[1]
61-Pm-147	σ_{0Y}	168.4	±	3.5	0.9971	2064.	±	100.	[1]
	$\sigma_{0Y(g)}$	96.0	±	1.8		1274.	±	66.	
	$\sigma_{0Y(m)}$	72.4	±	3.0		790.	±	100.	
61-Pm-148	σ_{TY}	2000.	±	1000.	1.0005	2515.			[14]
61-Pm-148m	σ_{0Y}	10600.	±	1000.	1.4863	3600.	±	2400.	[1]
61-Pm-149	σ_Y	1400.	±	300.	1.0005	1577.			[14]
61-Pm-151	σ_{0Y}	150.			1.0068	2977.			[15]
62-Sm-147	σ_{0Y}	57.	±	3.	0.9965	777.	±	30.	[1]
62-Sm-148	σ_Y	2.4	±	0.6	0.9995	27.	±	14.	[1]
62-Sm-149	σ_{0Y}	40140.	±	600.	1.7102	3390.			[16]
62-Sm-150	σ_{0Y}	100.	±	4.	0.9985	358.	±	50.	[17]
62-Sm-151	σ_{0Y}	15170.	±	300.	0.9274	3765.	±	160.	[17]
62-Sm-152	σ_{0Y}	206.	±	6.	1.0036	2970.	±	100.	[1]
62-Sm-153	σ_{0Y}	420.	±	180.	0.9999	4872.			[18]
62-Sm-154	σ_Y	8.3	±	0.5	0.9994	36.	±	4.	[1]

Table B-3: Fission product data: Thermal neutron cross sections, resonance integrals and Westcott factors.

Nuclide	Type	Thermal Cross Section		Westcott Factor		Resonance Integral		Source
		σ_x [barn]		g		RI [barn]		
63-Eu-151	$\sigma_{0\gamma}$	9200.	\pm 100.	0.8940		3300.	\pm 300.	[19]
	$\sigma_{0\gamma(g)}$	5900.	\pm 200.			1510.	\pm 330.	
	$\sigma_{0\gamma(m1)}$	3300.	\pm 200.			1790.	\pm 140.	
	$\sigma_{r\gamma(m2)}$	4.0	\pm 2.0					
63-Eu-152	$\sigma_{0\gamma}$	12800.	\pm 600.	0.967	\pm 0.058	2310.		[20]
63-Eu-153	$\sigma_{0\gamma}$	312.	\pm 7.	0.9860		1420.	\pm 100.	[17]
63-Eu-154	$\sigma_{0\gamma}$	1340.	\pm 130.	1.2290		1300.		[21]
63-Eu-155	σ_{γ}	3950.	\pm 125.	1.0219		15528.		[22]

- [1] Cross-section data and resonance integral adopted from ANR; Westcott factor calculated from the ENDF/B-VII library.
- [2] Cross-section data adopted from ANR; value of the resonance integral adopted from ANR; RI uncertainty adopted from GRY-87; Westcott factor calculated from the ENDF/B-VII library.
- [3] Data adopted from ENDF/B-VII; $\sigma_{\gamma} < 4$ barns and RI = 17.5 barns are reported in ANR; $\sigma_{\gamma} = 2.24$ barns and RI = 18.2 barns are reported in JENDL-3.3.
- [4] Data adopted from the ENDF/B-VII library; ENDF/B-VII data were adopted from JENDL-3.3; no data available in ANR.
- [5] Data adopted from the ENDF/B-VII library; values in ANR are 1.2 and 5 barns for the thermal cross section and resonance integral, respectively; no uncertainty was reported.
- [6] Cross-section data and resonance integral adopted from ANR; RI uncertainty not available; Westcott factor calculated from the ENDF/B-VII library.
- [7] Cross-section data adopted from ANR; resonance integral and Westcott factor calculated from the ENDF/B-VII library; resonance integral not reported in ANR.
- [8] Cross-section data and resonance integral adopted from ANR; Westcott factor calculated from the ENDF/B-VII library; RI = 0.14 ± 0.01 barns from resolved resonance parameters.
- [9] Cross-section data adopted from ANR; resonance integral and Westcott factor calculated from the ENDF/B-VII library; RI = 76 barns is reported in ANR from the resolved resonance parameters.
- [10] Cross-section data and resonance integral adopted from ANR; Westcott factor calculated from the ENDF/B-VII library; RI = 50.9 barns in the ENDF/B-VII library.
- [11] Cross-section data adopted from ANR; resonance integral and Westcott factor calculated from the ENDF/B-VII library; measured RI = 0.35 ± 0.07 barns reported by HAR-91.
- [12] Cross-section data adopted from ANR; resonance integral and Westcott factor calculated from the ENDF/B-VII library; values of 34 ± 11 and 8.8 ± 0.5 barns are also reported in ANR - the first is an experimental value and the second was calculated from the resolved resonance parameters; the ENDF/B-VII evaluation is in good agreement with recent measurements of the capture cross section in the energy range between 3 and 225 keV.
- [13] Cross-section data adopted from ANR; resonance integral and Westcott factor calculated from the ENDF/B-VII library; a resonance integral of 430 barns was calculated from the resolved resonance parameters, and is reported in ANR.
- [14] Cross-section data adopted from ANR; resonance integral and Westcott factor calculated from the ENDF/B-VII library; resonance integrals are not reported in ANR.
- [15] Data adopted from the ENDF/B-VII library; an upper limit of 700 barns is reported for σ_{γ} in ANR.
- [16] Data adopted from ANR; resonance integral calculated from resolved resonance parameters; a resonance integral of 3700 ± 400 barns is reported by GRY-87.
- [17] All data adopted from ANR.
- [18] Cross-section data adopted from ANR; Westcott factor and resonance integral calculated from the ENDF/B-VII library; a resonance integral of 3700 ± 2000 barns is reported by GRY-87.
- [19] All data adopted from ANR; resonance integral is not available for the Eu-151(n, γ)Eu-152m₂ reaction.
- [20] Cross-section data and Westcott factor taken from ANR; resonance integral calculated from the ENDF/B-VII library; a value of 2170 barns is reported in JENDL-3.3 for the resonance integral.
- [21] Cross-section data taken from ANR; Westcott factor calculated from the ENDF/B-VII library, a value of $g = 0.8979$ is reported in ANR; resonance integral adopted from the ENDF/B-VII library, while a value of 1500 ± 450 barns is reported by GRY-87.
- [22] Cross-section data taken from ANR; resonance integral and Westcott factor calculated from the ENDF/B-VII library; resonance integral in the ENDF/B-VII library is in good agreement with the value of 15300 ± 2700 barns reported by SEK-91; a resonance integral of 23200 ± 300 barns is reported in ANR.

C-1.1: Th-232 chain fission yields.

Reference

JEFF-3.1: Joint Evaluated Fission and Fusion File, Incident neutron data, <http://www-nds.iaea.org/exfor/endl00.htm>, 2 October 2006; see also A. Koning, R. Forrest, M. Kellett, R. Mills, H. Henriksson, Y. Rugama, The JEFF-3.1 Nuclear Data Library, JEFF Report 21, OECD/NEA, Paris, France, 2006, ISBN 92-64-02314-3.

Table C-1.1: Th-232 chain fission yields.

FPA	Fast Fission Yield [% per fission]		14-MeV Fission Yield [% per fission]	
1	0.00161	± 0.00027	0.00232	± 0.00039
2	0.000491	± 0.000076	0.00071	± 0.00011
3	0.00701	± 0.00069	0.0101	± 0.0010
4	0.1016	± 0.0059	0.1467	± 0.0085
69	0.0000025	± 0.0000004	0.00083	± 0.00013
70	0.0000111	± 0.0000017	0.00167	± 0.00025
71	0.0000454	± 0.0000068	0.00309	± 0.00046
72	0.000172	± 0.000034	0.00530	± 0.00080
73	0.000507	± 0.000076	0.0108	± 0.0016
74	0.00138	± 0.00020	0.0216	± 0.0032
75	0.00317	± 0.00048	0.0393	± 0.0061
76	0.00656	± 0.00100	0.071	± 0.011
77	0.0109	± 0.0012	0.123	± 0.016
78	0.0330	± 0.0052	0.287	± 0.059
79	0.089	± 0.015	0.81	± 0.22
80	0.233	± 0.045	1.15	± 0.36
81	0.52	± 0.12	1.45	± 0.58
82	1.13	± 0.32	1.86	± 0.83
83	2.08	± 0.44	2.52	± 0.91
84	4.64	± 0.74	3.43	± 0.84
85	4.29	± 0.24	4.01	± 0.69
86	6.9	± 1.5	4.78	± 0.81
87	6.77	± 0.63	5.4	± 1.1
88	7.06	± 0.40	5.07	± 0.25
89	7.21	± 0.70	5.96	± 0.73
90	7.32	± 0.36	6.2	± 1.5
91	7.1	± 1.3	5.85	± 0.28
92	7.07	± 0.28	5.39	± 0.20
93	6.46	± 0.48	5.75	± 0.23
94	5.33	± 0.24	5.6	± 1.1
95	5.52	± 0.17	4.82	± 0.49
96	5.16	± 0.62	4.10	± 0.66
97	4.46	± 0.12	3.11	± 0.24
98	3.74	± 0.62	2.52	± 0.44
99	2.919	± 0.076	1.953	± 0.098
100	1.73	± 0.26	1.79	± 0.37
101	0.86	± 0.13	1.61	± 0.25
102	0.371	± 0.056	1.20	± 0.21
103	0.1538	± 0.0095	0.884	± 0.064
104	0.090	± 0.013	0.95	± 0.14
105	0.0711	± 0.0032	1.017	± 0.060

Table C-1.1: Th-232 chain fission yields.

FPA	Fast Fission Yield [% per fission]		14-MeV Fission Yield [% per fission]	
106	0.0541	± 0.0031	1.101	± 0.083
107	0.0525	± 0.0079	1.07	± 0.17
108	0.0535	± 0.0080	1.06	± 0.16
109	0.0532	± 0.0043	1.03	± 0.11
110	0.0591	± 0.0089	1.14	± 0.19
111	0.0650	± 0.0060	1.187	± 0.065
112	0.0693	± 0.0078	1.219	± 0.067
113	0.068	± 0.010	1.199	± 0.056
114	0.068	± 0.010	1.25	± 0.24
115	0.0662	± 0.0079	1.20	± 0.21
116	0.067	± 0.010	1.17	± 0.21
117	0.068	± 0.010	1.14	± 0.22
118	0.067	± 0.010	1.10	± 0.21
119	0.066	± 0.010	1.06	± 0.20
120	0.0652	± 0.0098	1.01	± 0.19
121	0.0636	± 0.0096	0.929	± 0.078
122	0.0617	± 0.0093	0.98	± 0.18
123	0.0595	± 0.0089	1.00	± 0.18
124	0.0573	± 0.0086	1.02	± 0.18
125	0.0560	± 0.0084	1.04	± 0.18
126	0.0593	± 0.0087	1.08	± 0.17
127	0.0800	± 0.0070	1.138	± 0.065
128	0.170	± 0.026	1.36	± 0.23
129	0.431	± 0.089	1.68	± 0.33
130	0.85	± 0.14	1.82	± 0.44
131	1.513	± 0.083	2.31	± 0.14
132	2.60	± 0.10	2.99	± 0.15
133	4.53	± 0.19	4.12	± 0.21
134	5.84	± 0.31	5.88	± 0.42
135	5.47	± 0.26	5.20	± 0.36
136	5.99	± 0.23	6.69	± 0.35
137	6.30	± 0.30	6.29	± 0.99
138	6.37	± 0.20	6.14	± 0.96
139	7.12	± 0.41	5.64	± 0.42
140	7.71	± 0.25	5.69	± 0.20
141	7.11	± 0.28	5.72	± 0.38
142	6.54	± 0.21	5.14	± 0.40
143	6.49	± 0.30	4.96	± 0.24
144	7.66	± 0.55	3.90	± 0.78
145	5.06	± 0.70	3.1	± 1.2
146	3.6	± 1.1	2.42	± 0.59
147	3.03	± 0.18	1.79	± 0.11
148	1.95	± 0.18	1.39	± 0.36
149	1.11	± 0.16	0.93	± 0.30
150	0.77	± 0.41	0.406	± 0.077
151	0.399	± 0.065	0.165	± 0.035
152	0.300	± 0.083	0.123	± 0.020
153	0.202	± 0.027	0.0858	± 0.0070
154	0.062	± 0.011	0.075	± 0.012
155	0.0158	± 0.0025	0.0552	± 0.0086
156	0.00252	± 0.00032	0.0363	± 0.0073
157	0.00086	± 0.00013	0.0187	± 0.0028

Table C-1.1: Th-232 chain fission yields.

FPA	Fast Fission Yield [% per fission]		14-MeV Fission Yield [% per fission]	
158	0.000275	± 0.000041	0.0093	± 0.0014
159	0.000082	± 0.000012	0.00440	± 0.00044
160	0.0000224	± 0.0000034	0.00222	± 0.00033
161	0.0000058	± 0.0000009	0.001060	± 0.000053
162	0.0000014	± 0.0000002	0.000419	± 0.000063

C-1.2: U-233 chain fission yields.

Reference

JEFF-3.1: Joint Evaluated Fission and Fusion File, Incident neutron data,
<http://www-nds.iaea.org/exfor/endl00.htm>, 2 October 2006;
 see also A. Koning, R. Forrest, M. Kellett, R. Mills, H. Henriksson, Y. Rugama, The JEFF-3.1
 Nuclear Data Library, JEFF Report 21, OECD/NEA, Paris, France, 2006,
 ISBN 92-64-02314-3.

Table C-1.2: U-233 chain fission yields.

FPA	Thermal Fission Yield [% per fission]		Fast Fission Yield [% per fission]		14-MeV Fission Yield [% per fission]	
1	0.00334	± 0.00055	0.00334	± 0.00055	0.00310	± 0.00059
2	0.00085	± 0.00013	0.00102	± 0.00015	0.00095	± 0.00017
3	0.01140	± 0.00050	0.01140	± 0.00050	0.0248	± 0.0056
4	0.2111	± 0.0080	0.2110	± 0.0080	0.196	± 0.021
68	0.0000019	± 0.0000003	0.0000017	± 0.0000002	0.00277	± 0.00041
69	0.0000072	± 0.0000011	0.0000061	± 0.0000009	0.00442	± 0.00067
70	0.0000259	± 0.0000039	0.0000211	± 0.0000032	0.0068	± 0.0010
71	0.000088	± 0.000013	0.000069	± 0.000010	0.0099	± 0.0015
72	0.000281	± 0.000043	0.000212	± 0.000032	0.01365	± 0.00097
73	0.00085	± 0.00013	0.000614	± 0.000092	0.0234	± 0.0036
74	0.00244	± 0.00040	0.00169	± 0.00025	0.0393	± 0.0060
75	0.0066	± 0.0012	0.00431	± 0.00065	0.0637	± 0.0099
76	0.0173	± 0.0037	0.0105	± 0.0016	0.102	± 0.016
77	0.0395	± 0.0045	0.0240	± 0.0036	0.158	± 0.026
78	0.0634	± 0.0054	0.0518	± 0.0078	0.241	± 0.041
79	0.1267	± 0.0076	0.106	± 0.016	0.359	± 0.062
80	0.2496	± 0.0092	0.204	± 0.032	0.526	± 0.095
81	0.371	± 0.014	0.370	± 0.060	0.75	± 0.14
82	0.590	± 0.030	0.64	± 0.10	1.05	± 0.21
83	1.070	± 0.055	1.000	± 0.053	1.36	± 0.12
84	1.697	± 0.040	1.681	± 0.085	1.94	± 0.42
85	2.166	± 0.028	2.10	± 0.10	2.39	± 0.52
86	3.093	± 0.030	2.85	± 0.14	3.02	± 0.61
87	4.008	± 0.055	4.30	± 0.43	3.72	± 0.93
88	5.435	± 0.060	5.18	± 0.26	4.31	± 0.34
89	6.02	± 0.17	6.19	± 0.40	4.88	± 0.62
90	6.648	± 0.073	6.39	± 0.33	5.07	± 0.80
91	6.569	± 0.072	6.26	± 0.32	5.02	± 0.35
92	6.568	± 0.072	6.51	± 0.43	4.99	± 0.59
93	6.950	± 0.076	7.04	± 0.38	5.66	± 0.64
94	6.800	± 0.068	6.70	± 0.36	4.8	± 1.4
95	6.386	± 0.058	6.28	± 0.18	5.05	± 0.28
96	5.742	± 0.057	5.74	± 0.32	4.0	± 1.7
97	5.574	± 0.050	5.51	± 0.16	4.76	± 0.36
98	5.17	± 0.16	5.14	± 0.29	3.6	± 1.4
99	5.03	± 0.14	4.85	± 0.17	3.87	± 0.22
100	4.41	± 0.15	4.42	± 0.26	3.27	± 0.91
101	3.219	± 0.084	3.68	± 0.74	3.18	± 0.64
102	2.429	± 0.027	2.61	± 0.56	2.98	± 0.47
103	1.458	± 0.058	1.58	± 0.16	2.72	± 0.13
104	0.976	± 0.014	1.01	± 0.22	2.26	± 0.35
105	0.501	± 0.013	0.55	± 0.11	1.84	± 0.14

Table C-1.2: U-233 chain fission yields.

FPA	Thermal Fission Yield [% per fission]		Fast Fission Yield [% per fission]		14-MeV Fission Yield [% per fission]	
106	0.2505	± 0.0078	0.291	± 0.029	1.46	± 0.26
107	0.1149	± 0.0034	0.160	± 0.027	1.36	± 0.32
108	0.0797	± 0.0026	0.101	± 0.017	1.31	± 0.35
109	0.0420	± 0.0045	0.076	± 0.013	1.31	± 0.39
110	0.0395	± 0.0043	0.068	± 0.011	1.26	± 0.34
111	0.0247	± 0.0021	0.065	± 0.011	1.31	± 0.16
112	0.0143	± 0.0010	0.063	± 0.010	1.61	± 0.12
113	0.0158	± 0.0027	0.062	± 0.010	1.19	± 0.29
114	0.0173	± 0.0031	0.061	± 0.010	1.12	± 0.32
115	0.0192	± 0.0016	0.0586	± 0.0043	1.27	± 0.17
116	0.0177	± 0.0030	0.0584	± 0.0098	1.36	± 0.34
117	0.0151	± 0.0011	0.0596	± 0.0064	1.33	± 0.32
118	0.0156	± 0.0011	0.0596	± 0.0064	1.30	± 0.32
119	0.0159	± 0.0013	0.0733	± 0.0088	1.26	± 0.30
120	0.0175	± 0.0013	0.0823	± 0.0090	1.22	± 0.28
121	0.0185	± 0.0012	0.080	± 0.013	1.19	± 0.25
122	0.0195	± 0.0012	0.0824	± 0.0089	1.22	± 0.26
123	0.0223	± 0.0034	0.090	± 0.015	1.28	± 0.26
124	0.0322	± 0.0022	0.119	± 0.012	1.39	± 0.23
125	0.116	± 0.014	0.149	± 0.011	1.516	± 0.095
126	0.233	± 0.032	0.325	± 0.075	1.79	± 0.24
127	0.47	± 0.11	0.50	± 0.19	2.14	± 0.11
128	0.93	± 0.15	1.17	± 0.51	2.50	± 0.41
129	1.63	± 0.26	1.73	± 0.24	3.01	± 0.43
130	2.65	± 0.43	2.40	± 0.60	3.69	± 0.64
131	3.565	± 0.100	3.86	± 0.13	4.47	± 0.94
132	4.80	± 0.14	4.71	± 0.12	4.01	± 0.39
133	5.98	± 0.17	5.70	± 0.17	4.56	± 0.49
134	6.29	± 0.25	6.37	± 0.36	4.81	± 0.43
135	5.50	± 0.37	6.28	± 0.27	5.24	± 0.67
136	8.7	± 2.0	6.92	± 0.33	5.8	± 1.3
137	6.21	± 0.22	6.51	± 0.31	5.06	± 0.43
138	6.02	± 0.38	6.62	± 0.42	5.9	± 1.1
139	5.625	± 0.096	6.47	± 0.41	5.81	± 0.31
140	6.45	± 0.26	6.20	± 0.20	4.71	± 0.33
141	6.218	± 0.081	6.49	± 0.23	4.49	± 0.17
142	6.83	± 0.33	6.47	± 0.41	3.75	± 0.60
143	5.91	± 0.12	5.38	± 0.28	3.18	± 0.12
144	4.655	± 0.093	4.49	± 0.18	2.46	± 0.52
145	3.399	± 0.068	3.24	± 0.19	1.93	± 0.46
146	2.529	± 0.048	2.41	± 0.14	1.51	± 0.37
147	1.827	± 0.086	1.737	± 0.050	1.251	± 0.073
148	1.294	± 0.025	1.204	± 0.060	0.98	± 0.22
149	0.769	± 0.031	0.717	± 0.034	0.81	± 0.18
150	0.4884	± 0.0073	0.466	± 0.023	0.64	± 0.12
151	0.333	± 0.017	0.312	± 0.014	0.49	± 0.11
152	0.1962	± 0.0084	0.1936	± 0.0095	0.281	± 0.050
153	0.106	± 0.042	0.118	± 0.022	0.144	± 0.017
154	0.0458	± 0.0022	0.067	± 0.010	0.099	± 0.016
155	0.0214	± 0.0060	0.0351	± 0.0053	0.067	± 0.011
156	0.0109	± 0.0018	0.0169	± 0.0027	0.0444	± 0.0035
157	0.0069	± 0.0011	0.0116	± 0.0019	0.0284	± 0.0044

Table C-1.2: U-233 chain fission yields.

FPA	Thermal Fission Yield [% per fission]		Fast Fission Yield [% per fission]		14-MeV Fission Yield [% per fission]	
158	0.00264	± 0.00045	0.00485	± 0.00073	0.0177	± 0.0027
159	0.00096	± 0.00012	0.00189	± 0.00031	0.0108	± 0.0014
160	0.000350	± 0.000053	0.00110	± 0.00016	0.0073	± 0.0010
161	0.000119	± 0.000016	0.000494	± 0.000086	0.00475	± 0.00041
162	0.0000338	± 0.0000051	0.000140	± 0.000021	0.00277	± 0.00042
163	0.0000090	± 0.0000013	0.0000375	± 0.0000056	0.00157	± 0.00024
164	0.0000022	± 0.0000003	0.0000094	± 0.0000014	0.00087	± 0.00013

C-1.3: U-235 chain fission yields.

Reference

JEFF-3.1: Joint Evaluated Fission and Fusion File, Incident neutron data,
<http://www-nds.iaea.org/exfor/endl00.htm>, 2 October 2006;
 see also A. Koning, R. Forrest, M. Kellett, R. Mills, H. Henriksson, Y. Rugama, The JEFF-3.1 Nuclear Data Library, JEFF Report 21, OECD/NEA, Paris, France, 2006, ISBN 92-64-02314-3.

Table C-1.3: U-235 chain fission yields.

FPA	Thermal Fission Yield [% per fission]		Fast Fission Yield [% per fission]		14-MeV Fission Yield [% per fission]	
1	0.00171	± 0.00018	0.00269	± 0.00044	0.00264	± 0.00045
2	0.00084	± 0.00015	0.00082	± 0.00012	0.00081	± 0.00012
3	0.01080	± 0.00040	0.01080	± 0.00040	0.0174	± 0.0036
4	0.1702	± 0.0049	0.1700	± 0.0049	0.1667	± 0.0088
70	0.0000033	± 0.0000005	0.0000052	± 0.0000008	0.00317	± 0.00046
71	0.0000109	± 0.0000016	0.0000175	± 0.0000026	0.00456	± 0.00068
72	0.0000340	± 0.0000051	0.0000561	± 0.0000084	0.00566	± 0.00043
73	0.000100	± 0.000019	0.000170	± 0.000026	0.0115	± 0.0012
74	0.000343	± 0.000052	0.000492	± 0.000074	0.0189	± 0.0029
75	0.000828	± 0.000084	0.00133	± 0.00020	0.0301	± 0.0046
76	0.00478	± 0.00081	0.00346	± 0.00054	0.0462	± 0.0069
77	0.00849	± 0.00070	0.0085	± 0.0014	0.0682	± 0.0070
78	0.0205	± 0.0011	0.0201	± 0.0035	0.121	± 0.019
79	0.0487	± 0.0053	0.0454	± 0.0091	0.206	± 0.033
80	0.1285	± 0.0068	0.099	± 0.023	0.338	± 0.055
81	0.1975	± 0.0097	0.200	± 0.051	0.530	± 0.085
82	0.328	± 0.012	0.380	± 0.099	0.78	± 0.11
83	0.558	± 0.016	0.587	± 0.034	1.15	± 0.13
84	1.028	± 0.019	1.087	± 0.063	1.42	± 0.29
85	1.310	± 0.012	1.313	± 0.043	1.77	± 0.34
86	2.003	± 0.020	2.04	± 0.13	2.20	± 0.41
87	2.604	± 0.028	2.69	± 0.12	2.68	± 0.28
88	3.569	± 0.063	3.75	± 0.26	3.79	± 0.36
89	4.690	± 0.057	4.38	± 0.12	4.029	± 0.085
90	5.73	± 0.13	5.22	± 0.18	4.41	± 0.18
91	5.849	± 0.053	5.37	± 0.12	4.59	± 0.14
92	6.041	± 0.066	5.86	± 0.16	5.00	± 0.75
93	6.435	± 0.089	6.06	± 0.13	5.40	± 0.58
94	6.403	± 0.090	6.15	± 0.33	5.04	± 0.94
95	6.502	± 0.072	6.349	± 0.083	5.07	± 0.19
96	6.302	± 0.095	6.32	± 0.48	4.8	± 1.1
97	6.000	± 0.083	6.033	± 0.065	5.21	± 0.25
98	5.734	± 0.092	6.20	± 0.63	4.6	± 1.3
99	6.132	± 0.092	5.80	± 0.13	5.02	± 0.13
100	6.25	± 0.11	6.48	± 0.36	4.1	± 1.1
101	5.168	± 0.088	5.24	± 0.20	3.78	± 0.92
102	4.286	± 0.069	4.48	± 0.22	3.42	± 0.71
103	3.103	± 0.084	3.248	± 0.042	3.14	± 0.11
104	1.876	± 0.024	2.29	± 0.27	2.46	± 0.47
105	0.946	± 0.010	1.282	± 0.060	1.73	± 0.22
106	0.410	± 0.011	0.469	± 0.036	2.15	± 0.59
107	0.1393	± 0.0060	0.184	± 0.030	1.82	± 0.47

Table C-1.3: U-235 chain fission yields.

FPA	Thermal Fission Yield [% per fission]		Fast Fission Yield [% per fission]		14-MeV Fission Yield [% per fission]	
108	0.0571	± 0.0030	0.079	± 0.013	1.58	± 0.37
109	0.0288	± 0.0019	0.0457	± 0.0079	1.301	± 0.091
110	0.0254	± 0.0020	0.0363	± 0.0063	1.18	± 0.22
111	0.01970	± 0.00061	0.0329	± 0.0013	1.195	± 0.030
112	0.01183	± 0.00071	0.0265	± 0.0033	0.708	± 0.098
113	0.01596	± 0.00082	0.0346	± 0.0038	1.09	± 0.15
114	0.01288	± 0.00066	0.0315	± 0.0053	0.97	± 0.24
115	0.01136	± 0.00066	0.0270	± 0.0030	0.972	± 0.044
116	0.01604	± 0.00087	0.0363	± 0.0040	1.11	± 0.25
117	0.0123	± 0.0013	0.0381	± 0.0068	1.13	± 0.25
118	0.0136	± 0.0024	0.0407	± 0.0074	1.15	± 0.25
119	0.0150	± 0.0016	0.0427	± 0.0079	1.15	± 0.23
120	0.0146	± 0.0017	0.0442	± 0.0083	1.15	± 0.21
121	0.01260	± 0.00052	0.0451	± 0.0086	1.14	± 0.11
122	0.0180	± 0.0012	0.0456	± 0.0088	1.15	± 0.22
123	0.01506	± 0.00063	0.0465	± 0.0089	1.18	± 0.28
124	0.0316	± 0.0027	0.0505	± 0.0095	1.26	± 0.35
125	0.0260	± 0.0014	0.067	± 0.011	1.42	± 0.42
126	0.0594	± 0.0052	0.098	± 0.020	1.62	± 0.49
127	0.1202	± 0.0048	0.301	± 0.027	1.96	± 0.32
128	0.3306	± 0.0073	0.48	± 0.11	1.80	± 0.36
129	0.706	± 0.032	1.03	± 0.26	1.59	± 0.18
130	1.779	± 0.093	2.19	± 0.49	2.89	± 0.56
131	2.878	± 0.032	3.365	± 0.054	4.11	± 0.14
132	4.296	± 0.043	4.699	± 0.066	4.47	± 0.18
133	6.60	± 0.11	6.61	± 0.13	5.58	± 0.41
134	7.79	± 0.11	7.77	± 0.34	5.73	± 0.42
135	6.62	± 0.23	6.33	± 0.18	6.6	± 1.9
136	6.57	± 0.16	6.42	± 0.34	5.28	± 0.34
137	6.221	± 0.069	5.889	± 0.096	5.6	± 1.3
138	6.72	± 0.11	6.52	± 0.23	5.6	± 1.4
139	6.345	± 0.089	6.365	± 0.089	4.97	± 0.75
140	6.315	± 0.095	5.960	± 0.048	4.508	± 0.081
141	5.86	± 0.15	5.795	± 0.081	4.44	± 0.20
142	5.860	± 0.099	5.72	± 0.11	4.58	± 0.93
143	5.954	± 0.083	5.533	± 0.055	4.02	± 0.54
144	5.475	± 0.055	5.094	± 0.076	3.155	± 0.038
145	3.944	± 0.043	3.796	± 0.068	2.81	± 0.57
146	2.987	± 0.030	2.927	± 0.053	2.30	± 0.50
147	2.232	± 0.040	2.148	± 0.028	1.657	± 0.045
148	1.681	± 0.012	1.697	± 0.020	0.595	± 0.034
149	1.053	± 0.021	1.064	± 0.030	0.557	± 0.090
150	0.6508	± 0.0065	0.702	± 0.017	0.480	± 0.074
151	0.4204	± 0.0071	0.431	± 0.015	0.388	± 0.061
152	0.2526	± 0.0028	0.305	± 0.014	0.304	± 0.049
153	0.1477	± 0.0071	0.1512	± 0.0097	0.230	± 0.015
154	0.0726	± 0.0023	0.1111	± 0.0076	0.144	± 0.023
155	0.0308	± 0.0013	0.044	± 0.010	0.088	± 0.014
156	0.01334	± 0.00023	0.01783	± 0.00068	0.0520	± 0.0018
157	0.00657	± 0.00047	0.0116	± 0.0020	0.0336	± 0.0051
158	0.00194	± 0.00027	0.0065	± 0.0010	0.0210	± 0.0032
159	0.001061	± 0.000066	0.00317	± 0.00054	0.0127	± 0.0013

Table C-1.3: U-235 chain fission yields.

FPA	Thermal Fission Yield [% per fission]		Fast Fission Yield [% per fission]		14-MeV Fission Yield [% per fission]	
160	0.000310	± 0.000047	0.00102	± 0.00015	0.0082	± 0.0012
161	0.0000810	± 0.0000066	0.000302	± 0.000026	0.00505	± 0.00039
162	0.0000272	± 0.0000041	0.000097	± 0.000014	0.00317	± 0.00047
163	0.0000086	± 0.0000013	0.0000293	± 0.0000044	0.00186	± 0.00028
164	0.0000026	± 0.0000004	0.0000084	± 0.0000013	0.00104	± 0.00016

C-1.4: U-238 chain fission yields.

Reference

JEFF-3.1: Joint Evaluated Fission and Fusion File, Incident neutron data, <http://www-nds.iaea.org/exfor/endl00.htm>, 2 October 2006; see also A. Koning, R. Forrest, M. Kellett, R. Mills, H. Henriksson, Y. Rugama, The JEFF-3.1 Nuclear Data Library, JEFF Report 21, OECD/NEA, Paris, France, 2006, ISBN 92-64-02314-3.

Table C-1.4: U-238 chain fission yields.

FPA	Fast Fission Yield [% per fission]		14-MeV Fission Yield [% per fission]	
1	0.00235	± 0.00040	0.00130	± 0.00024
2	0.00072	± 0.00011	0.000398	± 0.000068
3	0.0103	± 0.0010	0.0065	± 0.0014
4	0.1488	± 0.0086	0.0823	± 0.0078
68	0.0000013	± 0.0000002	0.000282	± 0.000042
69	0.0000035	± 0.0000005	0.000528	± 0.000079
70	0.0000094	± 0.0000014	0.00099	± 0.00015
71	0.0000242	± 0.0000036	0.00175	± 0.00026
72	0.0000601	± 0.0000090	0.00300	± 0.00042
73	0.000143	± 0.000021	0.0054	± 0.0010
74	0.000336	± 0.000049	0.0091	± 0.0014
75	0.00071	± 0.00011	0.0141	± 0.0022
76	0.00151	± 0.00023	0.0219	± 0.0034
77	0.00306	± 0.00050	0.0321	± 0.0031
78	0.0077	± 0.0012	0.0416	± 0.0050
79	0.0178	± 0.0027	0.095	± 0.016
80	0.0405	± 0.0061	0.200	± 0.035
81	0.080	± 0.013	0.362	± 0.075
82	0.158	± 0.027	0.55	± 0.13
83	0.304	± 0.054	0.738	± 0.037
84	0.617	± 0.098	1.362	± 0.086
85	0.85	± 0.11	1.052	± 0.066
86	1.157	± 0.065	1.83	± 0.19
87	1.699	± 0.069	1.923	± 0.091
88	2.324	± 0.092	2.23	± 0.16
89	3.035	± 0.079	2.78	± 0.12
90	3.11	± 0.14	3.07	± 0.16
91	4.16	± 0.14	3.635	± 0.084
92	4.37	± 0.16	3.820	± 0.057
93	5.38	± 0.26	4.59	± 0.12
94	4.93	± 0.25	4.67	± 0.61
95	5.188	± 0.089	4.594	± 0.056
96	5.95	± 0.38	4.55	± 0.97
97	5.720	± 0.080	5.206	± 0.046
98	5.71	± 0.37	4.9	± 1.3
99	6.181	± 0.099	5.737	± 0.040
100	6.52	± 0.42	5.4	± 1.1
101	6.43	± 0.29	5.80	± 0.10
102	5.9	± 1.4	4.38	± 0.39
103	6.029	± 0.096	4.495	± 0.085
104	4.94	± 0.81	3.63	± 0.13

Table C-1.4: U-238 chain fission yields.

FPA	Fast Fission Yield [% per fission]		14-MeV Fission Yield [% per fission]	
105	3.74	± 0.12	3.109	± 0.047
106	2.52	± 0.11	2.56	± 0.13
107	1.78	± 0.12	1.83	± 0.22
108	0.602	± 0.096	1.67	± 0.41
109	0.159	± 0.011	1.35	± 0.12
110	0.098	± 0.016	1.18	± 0.23
111	0.0644	± 0.0023	0.971	± 0.049
112	0.0455	± 0.0048	1.022	± 0.032
113	0.0315	± 0.0059	0.912	± 0.042
114	0.0347	± 0.0054	0.92	± 0.14
115	0.0381	± 0.0019	0.900	± 0.025
116	0.0316	± 0.0050	0.91	± 0.14
117	0.0279	± 0.0043	0.90	± 0.14
118	0.0249	± 0.0039	0.92	± 0.18
119	0.0230	± 0.0036	0.99	± 0.18
120	0.0212	± 0.0033	1.05	± 0.19
121	0.0200	± 0.0030	1.10	± 0.18
122	0.0191	± 0.0029	1.13	± 0.21
123	0.0194	± 0.0030	1.22	± 0.31
124	0.0205	± 0.0032	1.23	± 0.23
125	0.0210	± 0.0038	1.277	± 0.063
126	0.093	± 0.020	1.38	± 0.25
127	0.1455	± 0.0080	1.436	± 0.020
128	0.294	± 0.070	1.56	± 0.26
129	0.622	± 0.034	1.66	± 0.19
130	1.65	± 0.53	2.97	± 0.83
131	3.321	± 0.083	3.62	± 0.17
132	4.76	± 0.17	4.690	± 0.066
133	6.71	± 0.23	5.74	± 0.17
134	6.83	± 0.61	6.37	± 0.33
135	6.44	± 0.27	5.46	± 0.12
136	7.31	± 0.66	6.33	± 0.56
137	6.02	± 0.15	5.62	± 0.68
138	6.03	± 0.22	4.65	± 0.20
139	5.85	± 0.34	4.99	± 0.21
140	5.972	± 0.084	4.620	± 0.037
141	5.93	± 0.45	4.418	± 0.080
142	4.90	± 0.26	4.20	± 0.11
143	4.68	± 0.11	3.855	± 0.058
144	4.67	± 0.11	3.58	± 0.14
145	3.88	± 0.21	2.99	± 0.15
146	3.57	± 0.18	2.63	± 0.38
147	2.677	± 0.046	2.134	± 0.041
148	2.296	± 0.037	1.37	± 0.15
149	1.683	± 0.067	1.358	± 0.080
150	1.311	± 0.049	0.98	± 0.24
151	0.810	± 0.012	0.800	± 0.057
152	0.557	± 0.032	0.54	± 0.12
153	0.367	± 0.014	0.395	± 0.021
154	0.239	± 0.018	0.262	± 0.048
155	0.127	± 0.021	0.174	± 0.030
156	0.0655	± 0.0017	0.1138	± 0.0082

Table C-1.4: U-238 chain fission yields.

FPA	Fast Fission Yield [% per fission]		14-MeV Fission Yield [% per fission]	
157	0.0342	± 0.0053	0.071	± 0.011
158	0.0173	± 0.0026	0.0435	± 0.0068
159	0.00836	± 0.00093	0.0259	± 0.0032
160	0.00330	± 0.00050	0.0147	± 0.0022
161	0.001192	± 0.000093	0.00813	± 0.00081
162	0.000548	± 0.000082	0.00543	± 0.00082
163	0.000242	± 0.000036	0.00341	± 0.00052
164	0.000102	± 0.000015	0.00203	± 0.00030
165	0.0000418	± 0.0000063	0.00116	± 0.00017
166	0.0000163	± 0.0000024	0.000630	± 0.000063
167	0.0000062	± 0.0000009	0.000408	± 0.000061
168	0.0000022	± 0.0000003	0.000238	± 0.000036

C-1.5: Pu-239 chain fission yields.

Reference

JEFF-3.1: Joint Evaluated Fission and Fusion File, Incident neutron data, <http://www-nds.iaea.org/exfor/endl00.htm>, 2 October 2006; see also A. Koning, R. Forrest, M. Kellett, R. Mills, H. Henriksson, Y. Rugama, The JEFF-3.1 Nuclear Data Library, JEFF Report 21, OECD/NEA, Paris, France, 2006, ISBN 92-64-02314-3.

Table C-1.5: Pu-239 chain fission yields.

FPA	Thermal Fission Yield [% per fission]		Fast Fission Yield [% per fission]	
1	0.00408	± 0.00041	0.00346	± 0.00057
2	0.00135	± 0.00019	0.00106	± 0.00016
3	0.01420	± 0.00070	0.01420	± 0.00070
4	0.2192	± 0.0090	0.2190	± 0.0090
67	0.0000014	± 0.0000002	0.0000043	± 0.0000006
68	0.0000035	± 0.0000005	0.0000111	± 0.0000017
69	0.0000088	± 0.0000013	0.0000272	± 0.0000041
70	0.0000214	± 0.0000032	0.0000656	± 0.0000098
71	0.0000503	± 0.0000075	0.000153	± 0.000023
72	0.000114	± 0.000017	0.000344	± 0.000052
73	0.000289	± 0.000043	0.00075	± 0.00011
74	0.00070	± 0.00011	0.00160	± 0.00024
75	0.00162	± 0.00024	0.00325	± 0.00050
76	0.00360	± 0.00054	0.0065	± 0.0010
77	0.00768	± 0.00087	0.0125	± 0.0020
78	0.0291	± 0.0028	0.0235	± 0.0039
79	0.0550	± 0.0091	0.0429	± 0.0076
80	0.101	± 0.018	0.077	± 0.015
81	0.177	± 0.031	0.133	± 0.029
82	0.232	± 0.041	0.226	± 0.054
83	0.2820	± 0.0099	0.328	± 0.030
84	0.478	± 0.020	0.525	± 0.036
85	0.588	± 0.026	0.622	± 0.049
86	0.784	± 0.018	0.825	± 0.053
87	0.973	± 0.042	1.051	± 0.042
88	1.306	± 0.036	1.447	± 0.097
89	1.689	± 0.032	1.712	± 0.072
90	2.013	± 0.054	2.031	± 0.057
91	2.443	± 0.029	2.58	± 0.10
92	3.026	± 0.066	3.08	± 0.15
93	3.91	± 0.13	3.92	± 0.19
94	4.32	± 0.12	4.25	± 0.20
95	4.949	± 0.099	4.683	± 0.098
96	4.94	± 0.15	4.89	± 0.22
97	5.294	± 0.073	5.021	± 0.074
98	5.86	± 0.65	5.61	± 0.27
99	6.185	± 0.056	5.82	± 0.13
100	6.84	± 1.00	6.61	± 0.34
101	6.18	± 0.30	6.63	± 0.84
102	6.08	± 0.51	6.76	± 0.82
103	6.948	± 0.083	6.59	± 0.16

Table C-1.5: Pu-239 chain fission yields.

FPA	Thermal Fission Yield [% per fission]		Fast Fission Yield [% per fission]	
104	6.08	± 0.32	6.69	± 0.67
105	5.76	± 0.21	5.28	± 0.10
106	4.190	± 0.092	4.13	± 0.24
107	3.18	± 0.18	3.14	± 0.59
108	2.06	± 0.12	2.06	± 0.64
109	1.67	± 0.27	1.43	± 0.29
110	0.625	± 0.037	0.73	± 0.20
111	0.3079	± 0.0074	0.409	± 0.020
112	0.1282	± 0.0077	0.143	± 0.017
113	0.0810	± 0.0041	0.129	± 0.018
114	0.0539	± 0.0028	0.096	± 0.013
115	0.0364	± 0.0019	0.0767	± 0.0059
116	0.0457	± 0.0023	0.0621	± 0.0078
117	0.0458	± 0.0023	0.055	± 0.011
118	0.0457	± 0.0033	0.051	± 0.011
119	0.0487	± 0.0035	0.054	± 0.010
120	0.0433	± 0.0064	0.0530	± 0.0097
121	0.0551	± 0.0088	0.0540	± 0.0098
122	0.0697	± 0.0036	0.058	± 0.011
123	0.089	± 0.015	0.069	± 0.013
124	0.1283	± 0.0066	0.092	± 0.016
125	0.117	± 0.015	0.138	± 0.022
126	0.314	± 0.049	0.209	± 0.044
127	0.461	± 0.027	0.53	± 0.14
128	0.833	± 0.062	1.00	± 0.34
129	1.407	± 0.086	1.31	± 0.13
130	2.79	± 0.67	2.87	± 0.76
131	3.724	± 0.078	4.09	± 0.12
132	5.274	± 0.095	5.18	± 0.33
133	6.99	± 0.13	7.03	± 0.33
134	6.87	± 0.36	7.52	± 0.26
135	7.38	± 0.24	7.54	± 0.23
136	6.99	± 0.25	7.31	± 0.74
137	6.594	± 0.080	6.36	± 0.12
138	6.11	± 0.16	5.82	± 0.30
139	5.968	± 0.090	5.53	± 0.28
140	5.333	± 0.059	5.324	± 0.075
141	5.205	± 0.073	5.01	± 0.16
142	4.976	± 0.055	4.99	± 0.13
143	4.476	± 0.049	4.296	± 0.056
144	3.756	± 0.030	3.505	± 0.053
145	3.036	± 0.033	3.037	± 0.067
146	2.496	± 0.025	2.527	± 0.053
147	2.044	± 0.039	1.929	± 0.046
148	1.658	± 0.017	1.697	± 0.029
149	1.263	± 0.032	1.275	± 0.056
150	0.977	± 0.013	1.011	± 0.019
151	0.776	± 0.018	0.797	± 0.037
152	0.608	± 0.018	0.615	± 0.047
153	0.380	± 0.030	0.40	± 0.18
154	0.281	± 0.012	0.267	± 0.049
155	0.174	± 0.030	0.171	± 0.054

Table C-1.5: Pu-239 chain fission yields.

FPA	Thermal Fission Yield [% per fission]		Fast Fission Yield [% per fission]	
156	0.1097	± 0.0071	0.1270	± 0.0089
157	0.0767	± 0.0082	0.1048	± 0.0051
158	0.0415	± 0.0066	0.054	± 0.011
159	0.0214	± 0.0020	0.0286	± 0.0052
160	0.0105	± 0.0016	0.0144	± 0.0024
161	0.00490	± 0.00046	0.00696	± 0.00067
162	0.00240	± 0.00036	0.00352	± 0.00054
163	0.00114	± 0.00017	0.00173	± 0.00026
164	0.000523	± 0.000078	0.00082	± 0.00012
165	0.000232	± 0.000035	0.000377	± 0.000057
166	0.000099	± 0.000015	0.000166	± 0.000025
167	0.0000412	± 0.0000062	0.000072	± 0.000011
168	0.0000165	± 0.0000025	0.0000302	± 0.0000045
169	0.0000064	± 0.0000010	0.0000122	± 0.0000018
170	0.0000024	± 0.0000004	0.0000048	± 0.0000007

C-1.6: Pu-241 chain fission yields.

Reference

JEFF-3.1: Joint Evaluated Fission and Fusion File, Incident neutron data, <http://www-nds.iaea.org/exfor/endl00.htm>, 2 October 2006; see also A. Koning, R. Forrest, M. Kellett, R. Mills, H. Henriksson, Y. Rugama, The JEFF-3.1 Nuclear Data Library, JEFF Report 21, OECD/NEA, Paris, France, 2006, ISBN 92-64-02314-3.

Table C-1.6: Pu-241 chain fission yields.

FPA	Thermal Fission Yield [% per fission]		Fast Fission Yield [% per fission]	
1	0.00294	± 0.00048	0.00294	± 0.00048
2	0.00090	± 0.00013	0.00090	± 0.00013
3	0.01410	± 0.00061	0.01410	± 0.00061
4	0.1860	± 0.0071	0.1860	± 0.0071
67	0.0000014	± 0.0000004	0.0000034	± 0.0000010
68	0.0000031	± 0.0000009	0.0000083	± 0.0000025
69	0.0000066	± 0.0000020	0.0000197	± 0.0000059
70	0.0000138	± 0.0000041	0.000046	± 0.000014
71	0.0000277	± 0.0000083	0.000104	± 0.000031
72	0.000053	± 0.000016	0.000228	± 0.000068
73	0.000096	± 0.000029	0.00049	± 0.00015
74	0.000167	± 0.000050	0.00102	± 0.00030
75	0.000265	± 0.000080	0.00203	± 0.00061
76	0.00039	± 0.00012	0.0040	± 0.0012
77	0.000496	± 0.000067	0.0076	± 0.0023
78	0.0033	± 0.0010	0.0142	± 0.0043
79	0.0102	± 0.0031	0.0256	± 0.0078
80	0.0256	± 0.0081	0.046	± 0.014
81	0.057	± 0.019	0.077	± 0.024
82	0.118	± 0.042	0.128	± 0.039
83	0.205	± 0.010	0.2002	± 0.0060
84	0.379	± 0.020	0.366	± 0.011
85	0.431	± 0.069	0.401	± 0.021
86	0.644	± 0.040	0.596	± 0.018
87	0.792	± 0.078	0.795	± 0.022
88	1.018	± 0.063	1.017	± 0.030
89	1.22	± 0.13	1.41	± 0.44
90	1.510	± 0.074	1.502	± 0.041
91	1.86	± 0.10	1.896	± 0.051
92	2.29	± 0.12	2.392	± 0.064
93	2.95	± 0.15	3.101	± 0.078
94	3.18	± 0.39	3.306	± 0.086
95	3.91	± 0.15	3.84	± 0.10
96	4.23	± 0.21	4.36	± 0.12
97	4.70	± 0.22	4.69	± 0.12
98	4.82	± 0.29	4.88	± 0.14
99	5.61	± 0.25	4.1	± 2.3
100	5.75	± 0.49	6.18	± 0.17
101	5.98	± 0.35	6.34	± 0.21
102	6.23	± 0.33	6.70	± 0.21
103	6.54	± 0.32	5.9	± 2.7

Table C-1.6: Pu-241 chain fission yields.

FPA	Thermal Fission Yield [% per fission]		Fast Fission Yield [% per fission]	
104	6.69	± 0.33	7.19	± 0.22
105	6.63	± 0.42	7.3	± 2.0
106	5.95	± 0.70	6.12	± 0.19
107	5.54	± 0.33	5.7	± 2.0
108	4.36	± 0.38	3.9	± 1.3
109	2.97	± 0.43	2.30	± 0.67
110	2.03	± 0.25	1.29	± 0.55
111	0.511	± 0.051	0.83	± 0.26
112	0.190	± 0.025	0.48	± 0.15
113	0.13	± 0.20	0.24	± 0.11
114	0.13	± 0.16	0.133	± 0.063
115	0.12	± 0.11	0.079	± 0.032
116	0.101	± 0.073	0.048	± 0.018
117	0.077	± 0.045	0.029	± 0.010
118	0.057	± 0.029	0.0191	± 0.0063
119	0.047	± 0.022	0.0143	± 0.0046
120	0.058	± 0.018	0.0141	± 0.0044
121	0.091	± 0.019	0.0173	± 0.0054
122	0.104	± 0.023	0.0248	± 0.0079
123	0.134	± 0.031	0.038	± 0.012
124	0.178	± 0.044	0.060	± 0.020
125	0.249	± 0.065	0.092	± 0.020
126	0.362	± 0.089	0.157	± 0.031
127	0.55	± 0.14	0.303	± 0.063
128	0.81	± 0.22	0.57	± 0.11
129	1.28	± 0.36	1.67	± 0.36
130	1.97	± 0.55	2.26	± 0.41
131	3.076	± 0.074	3.164	± 0.085
132	4.529	± 0.095	4.59	± 0.13
133	6.61	± 0.18	6.67	± 0.19
134	7.53	± 0.52	7.73	± 0.21
135	7.02	± 0.24	7.27	± 0.20
136	6.97	± 0.60	7.21	± 0.18
137	6.28	± 0.14	6.37	± 0.18
138	6.42	± 0.23	6.27	± 0.16
139	5.95	± 0.30	6.16	± 0.18
140	5.76	± 0.11	5.36	± 0.14
141	4.90	± 0.12	4.63	± 0.62
142	4.74	± 0.14	4.68	± 0.13
143	4.380	± 0.092	4.59	± 0.12
144	4.123	± 0.095	4.18	± 0.11
145	3.141	± 0.091	3.272	± 0.085
146	2.657	± 0.069	2.740	± 0.071
147	2.252	± 0.095	2.228	± 0.062
148	1.881	± 0.064	1.945	± 0.049
149	1.454	± 0.071	1.452	± 0.041
150	1.155	± 0.032	1.200	± 0.032
151	0.86	± 0.24	0.910	± 0.025
152	0.718	± 0.052	0.711	± 0.019
153	0.40	± 0.23	0.45	± 0.19
154	0.368	± 0.087	0.372	± 0.010
155	0.19	± 0.35	0.231	± 0.084

Table C-1.6: Pu-241 chain fission yields.

FPA	Thermal Fission Yield [% per fission]		Fast Fission Yield [% per fission]	
156	0.18	± 0.24	0.153	± 0.052
157	0.17	± 0.16	0.098	± 0.032
158	0.14	± 0.10	0.060	± 0.020
159	0.112	± 0.058	0.036	± 0.011
160	0.091	± 0.039	0.0209	± 0.0065
161	0.067	± 0.024	0.0118	± 0.0036
162	0.048	± 0.015	0.0064	± 0.0020
163	0.024	± 0.011	0.0034	± 0.0010
164	0.0125	± 0.0046	0.00176	± 0.00053
165	0.0062	± 0.0021	0.00088	± 0.00026
166	0.00293	± 0.00092	0.00043	± 0.00013
167	0.00134	± 0.00041	0.000202	± 0.000061
168	0.00059	± 0.00018	0.000093	± 0.000028
169	0.000252	± 0.000076	0.000041	± 0.000012
170	0.000104	± 0.000031	0.0000179	± 0.0000054
171	0.000042	± 0.000013	0.0000075	± 0.0000023
172	0.0000163	± 0.0000049	0.0000031	± 0.0000009
173	0.0000062	± 0.0000019	0.0000012	± 0.0000004
174	0.0000022	± 0.0000007	0.0	± 0.0

C-2.1: Th-232 fast fission yields for selected fission products.

Reference

JEFF-3.1: Joint Evaluated Fission and Fusion File, Incident neutron data, <http://www-nds.iaea.org/exfor/endl00.htm>, 2 October 2006;
see also A. Koning, R. Forrest, M. Kellett, R. Mills, H. Henriksson, Y. Rugama, The JEFF-3.1 Nuclear Data Library, JEFF Report 21, OECD/NEA, Paris, France, 2006, ISBN 92-64-02314-3.

Table C-2.1: Th-232 fast fission yields for selected fission products.

Fission Product	Independent yield		Cumulative yield	
	[% per fission]		[% per fission]	
1-H-1	0.00161	± 0.00055	0.00161	± 0.00027
1-H-2	0.00049	± 0.00017	0.000491	± 0.000076
1-H-3	0.0070	± 0.0022	0.00701	± 0.00069
2-He-3	0.0	± 0.0	0.00701	± 0.00069
2-He-4	0.102	± 0.031	0.1016	± 0.0059
36-Kr-82	0.00000013	± 0.00000004	0.000088	± 0.000034
36-Kr-85	0.00115	± 0.00040	0.924	± 0.096
40-Zr-95	0.00099	± 0.00036	5.52	± 0.17
41-Nb-95	0.000000136	± 0.000000049	5.52	± 0.17
41-Nb-95m	0.000000027	± 0.000000010	0.0597	± 0.0076
42-Mo-92	0.0	± 0.0	0.0	± 0.0
42-Mo-94	0.0	± 0.0	0.0	± 0.0
42-Mo-96	0.0	± 0.0	0.0000060	± 0.0000024
42-Mo-99	0.0000125	± 0.0000044	2.919	± 0.076
44-Ru-103	0.0	± 0.0	0.1538	± 0.0095
44-Ru-106	0.000000043	± 0.000000016	0.0541	± 0.0031
45-Rh-106	0.0	± 0.0	0.0541	± 0.0031
51-Sb-125	0.000129	± 0.000051	0.0560	± 0.0084
52-Te-132	0.238	± 0.077	2.60	± 0.10
53-I-131	0.000042	± 0.000015	1.513	± 0.083
53-I-135	1.13	± 0.30	5.45	± 0.26
54-Xe-128	0.0	± 0.0	0.0	± 0.0
54-Xe-130	0.0	± 0.0	0.0	± 0.0
54-Xe-131m	0.000000002	± 0.000000001	0.0164	± 0.0020
54-Xe-133	0.0000074	± 0.0000027	4.53	± 0.19
54-Xe-133m	0.0000207	± 0.0000077	0.129	± 0.013
54-Xe-135	0.0039	± 0.0014	5.46	± 0.26
54-Xe-135m	0.0110	± 0.0040	0.911	± 0.095
55-Cs-134	0.000000080	± 0.000000030	0.000000150	± 0.000000041
55-Cs-137	0.0051	± 0.0019	6.30	± 0.30
56-Ba-140	0.0194	± 0.0072	7.71	± 0.25
57-La-140	0.0000095	± 0.0000036	7.71	± 0.25
58-Ce-141	0.000000021	± 0.000000008	7.11	± 0.28
58-Ce-144	0.00106	± 0.00041	7.66	± 0.55
59-Pr-144	0.000000011	± 0.000000004	7.66	± 0.55
60-Nd-142	0.0	± 0.0	0.0	± 0.0
60-Nd-144	0.0	± 0.0	7.66	± 0.55
60-Nd-147	0.000000031	± 0.000000012	3.03	± 0.18
61-Pm-147	0.0	± 0.0	3.03	± 0.18
61-Pm-148	0.0	± 0.0	0.0	± 0.0
61-Pm-148m	0.0	± 0.0	0.0	± 0.0
61-Pm-149	0.000000014	± 0.000000005	1.11	± 0.16
61-Pm-151	0.0000076	± 0.0000030	0.399	± 0.065

Table C-2.1: Th-232 fast fission yields for selected fission products.

Fission Product	Independent yield [% per fission]		Cumulative yield [% per fission]	
62-Sm-148	0.0	± 0.0	0.0	± 0.0
62-Sm-150	0.0	± 0.0	0.00000044	± 0.00000032
62-Sm-151	0.0	± 0.0	0.399	± 0.065
62-Sm-153	0.000000141	± 0.000000055	0.202	± 0.027
63-Eu-151	0.0	± 0.0	0.399	± 0.065
63-Eu-152	0.0	± 0.0	0.0	± 0.0
63-Eu-154	0.0	± 0.0	0.0	± 0.0
63-Eu-155	0.000000005	± 0.000000002	0.0158	± 0.0025

C-2.2: U-233 thermal fission yields for selected fission products.

Reference

JEFF-3.1: Joint Evaluated Fission and Fusion File, Incident neutron data,
<http://www-nds.iaea.org/exfor/endl00.htm>, 2 October 2006;
 see also A. Koning, R. Forrest, M. Kellett, R. Mills, H. Henriksson,
 Y. Rugama, The JEFF-3.1 Nuclear Data Library, JEFF Report 21,
 OECD/NEA, Paris, France, 2006, ISBN 92-64-02314-3.

Table C-2.2: U-233 thermal fission yields for selected fission products.

Fission Product	Independent yield [% per fission]		Cumulative yield [% per fission]	
1-H-1	0.0033	± 0.0011	0.00334	± 0.00055
1-H-2	0.00085	± 0.00023	0.00085	± 0.00013
1-H-3	0.0114	± 0.0023	0.01140	± 0.00050
2-He-3	0.0	± 0.0	0.01140	± 0.00050
2-He-4	0.211	± 0.012	0.2111	± 0.0080
36-Kr-82	0.000037	± 0.000013	0.0070	± 0.0018
36-Kr-85	0.073	± 0.025	0.523	± 0.048
40-Zr-95	0.261	± 0.087	6.385	± 0.058
41-Nb-95	0.00075	± 0.00026	6.382	± 0.057
41-Nb-95m	0.000173	± 0.000061	0.0692	± 0.0082
42-Mo-92	0.0	± 0.0	0.0	± 0.0
42-Mo-94	0.000000005	± 0.000000002	0.000000101	± 0.000000035
42-Mo-96	0.0000097	± 0.0000034	0.0083	± 0.0029
42-Mo-99	0.0197	± 0.0071	5.03	± 0.14
44-Ru-103	0.000120	± 0.000044	1.458	± 0.058
44-Ru-106	0.000188	± 0.000072	0.2505	± 0.0078
45-Rh-106	0.000000004	± 0.000000002	0.2505	± 0.0078
51-Sb-125	0.0146	± 0.0053	0.116	± 0.014
52-Te-132	3.29	± 0.38	4.59	± 0.14
53-I-131	0.036	± 0.013	3.565	± 0.100
53-I-135	2.96	± 0.48	4.31	± 0.32
54-Xe-128	0.0000000010	± 0.0000000004	0.0000064	± 0.0000025
54-Xe-130	0.0000044	± 0.0000016	0.00325	± 0.00100
54-Xe-131m	0.000092	± 0.000033	0.0388	± 0.0040
54-Xe-133	0.0113	± 0.0041	5.98	± 0.17
54-Xe-133m	0.0273	± 0.0100	0.197	± 0.016
54-Xe-135	0.343	± 0.091	5.47	± 0.37
54-Xe-135m	0.83	± 0.22	1.54	± 0.20
55-Cs-134	0.00066	± 0.00023	0.00114	± 0.00029
55-Cs-137	0.49	± 0.17	6.20	± 0.22
56-Ba-140	1.50	± 0.40	6.43	± 0.26
57-La-140	0.0178	± 0.0062	6.45	± 0.26
58-Ce-141	0.00063	± 0.00022	6.218	± 0.081
58-Ce-144	0.283	± 0.094	4.654	± 0.093
59-Pr-144	0.000107	± 0.000038	4.655	± 0.093
60-Nd-142	0.0	± 0.0	0.0000331	± 0.0000092
60-Nd-144	0.00000069	± 0.00000025	4.655	± 0.093
60-Nd-147	0.00212	± 0.00078	1.827	± 0.086
61-Pm-147	0.00000098	± 0.00000036	1.827	± 0.086
61-Pm-148	0.0000048	± 0.0000018	0.0000053	± 0.0000018
61-Pm-148m	0.0000112	± 0.0000043	0.0000112	± 0.0000043
61-Pm-149	0.000188	± 0.000070	0.769	± 0.031

Table C-2.2: U-233 thermal fission yields for selected fission products.

Fission Product	Independent yield [% per fission]		Cumulative yield [% per fission]	
61-Pm-151	0.0048	± 0.0021	0.333	± 0.017
62-Sm-148	0.000000003	± 0.000000001	0.0000159	± 0.0000045
62-Sm-150	0.00000242	± 0.00000088	0.00113	± 0.00042
62-Sm-151	0.000030	± 0.000011	0.333	± 0.017
62-Sm-153	0.00021	± 0.00013	0.106	± 0.042
63-Eu-151	0.000000004	± 0.000000002	0.333	± 0.017
63-Eu-152	0.000000032	± 0.000000013	0.000000068	± 0.000000020
63-Eu-154	0.0000041	± 0.0000016	0.0000078	± 0.0000022
63-Eu-155	0.000048	± 0.000020	0.0214	± 0.0060

C-2.3: U-235 thermal fission yields for selected fission products.

Reference

JEFF-3.1: Joint Evaluated Fission and Fusion File, Incident neutron data, <http://www-nds.iaea.org/exfor/endl00.htm>, 2 October 2006; see also A. Koning, R. Forrest, M. Kellett, R. Mills, H. Henriksson, Y. Rugama, The JEFF-3.1 Nuclear Data Library, JEFF Report 21, OECD/NEA, Paris, France, 2006, ISBN 92-64-02314-3.

Table C-2.3: U-235 thermal fission yields for selected fission products.

Fission Product	Independent yield [% per fission]		Cumulative yield [% per fission]	
1-H-1	0.00171	± 0.00029	0.00171	± 0.00018
1-H-2	0.00084	± 0.00024	0.00084	± 0.00015
1-H-3	0.01080	± 0.00059	0.01080	± 0.00040
2-He-3	0.0	± 0.0	0.01080	± 0.00040
2-He-4	0.1700	± 0.0081	0.1702	± 0.0049
36-Kr-82	0.00000217	± 0.00000075	0.000285	± 0.000076
36-Kr-85	0.0049	± 0.0018	0.286	± 0.021
40-Zr-95	0.035	± 0.013	6.502	± 0.072
41-Nb-95	0.0000175	± 0.0000065	6.498	± 0.072
41-Nb-95m	0.0000041	± 0.0000015	0.0702	± 0.0067
42-Mo-92	0.0	± 0.0	0.0	± 0.0
42-Mo-94	0.0	± 0.0	0.0	± 0.0
42-Mo-96	0.000000069	± 0.000000025	0.00042	± 0.00015
42-Mo-99	0.00180	± 0.00066	6.132	± 0.092
44-Ru-103	0.0000099	± 0.0000036	3.103	± 0.084
44-Ru-106	0.0000028	± 0.0000011	0.410	± 0.011
45-Rh-106	0.0	± 0.0	0.410	± 0.011
51-Sb-125	0.00072	± 0.00026	0.0260	± 0.0014
52-Te-132	1.61	± 0.37	4.276	± 0.043
53-I-131	0.00136	± 0.00047	2.878	± 0.032
53-I-135	2.55	± 0.54	6.39	± 0.22
54-Xe-128	0.0	± 0.0	0.0	± 0.0
54-Xe-130	0.000000005	± 0.000000002	0.0000380	± 0.0000098
54-Xe-131m	0.00000036	± 0.00000012	0.0313	± 0.0030
54-Xe-133	0.00044	± 0.00016	6.60	± 0.11
54-Xe-133m	0.00106	± 0.00038	0.189	± 0.015
54-Xe-135	0.069	± 0.024	6.61	± 0.22
54-Xe-135m	0.167	± 0.057	1.22	± 0.12
55-Cs-134	0.0000070	± 0.0000026	0.0000121	± 0.0000032
55-Cs-137	0.072	± 0.026	6.221	± 0.069
56-Ba-140	0.29	± 0.10	6.314	± 0.095
57-La-140	0.00052	± 0.00019	6.315	± 0.095
58-Ce-141	0.0000056	± 0.0000020	5.86	± 0.15
58-Ce-144	0.035	± 0.013	5.474	± 0.055
59-Pr-144	0.00000168	± 0.00000063	5.474	± 0.055
60-Nd-142	0.0	± 0.0	0.000000006	± 0.000000002
60-Nd-144	0.000000011	± 0.000000004	5.475	± 0.055
60-Nd-147	0.000074	± 0.000026	2.232	± 0.040
61-Pm-147	0.000000003	± 0.000000001	2.232	± 0.040
61-Pm-148	0.000000044	± 0.000000017	0.000000050	± 0.000000017
61-Pm-148m	0.000000104	± 0.000000039	0.000000104	± 0.000000039
61-Pm-149	0.0000047	± 0.0000017	1.053	± 0.021

Table C-2.3: U-235 thermal fission yields for selected fission products.

Fission Product	Independent yield [% per fission]		Cumulative yield [% per fission]	
61-Pm-151	0.00067	± 0.00025	0.4204	± 0.0071
62-Sm-148	0.0	± 0.0	0.000000149	± 0.000000041
62-Sm-150	0.000000016	± 0.000000006	0.000061	± 0.000022
62-Sm-151	0.000000052	± 0.000000019	0.4204	± 0.0071
62-Sm-153	0.0000221	± 0.0000095	0.1477	± 0.0071
63-Eu-151	0.0	± 0.0	0.4204	± 0.0071
63-Eu-152	0.0	± 0.0	0.0	± 0.0
63-Eu-154	0.000000103	± 0.000000047	0.000000195	± 0.000000064
63-Eu-155	0.0000029	± 0.0000011	0.0308	± 0.0013

C-2.4: U-238 fast fission yields for selected fission products.

Reference

JEFF-3.1: Joint Evaluated Fission and Fusion File, Incident neutron data,
<http://www-nds.iaea.org/exfor/endl00.htm>, 2 October 2006;
 see also A. Koning, R. Forrest, M. Kellett, R. Mills, H. Henriksson,
 Y. Rugama, The JEFF-3.1 Nuclear Data Library, JEFF Report 21,
 OECD/NEA, Paris, France, 2006, ISBN 92-64-02314-3.

Table C-2.4: U-238 fast fission yields for selected fission products.

Fission Product	Independent yield [% per fission]		Cumulative yield [% per fission]	
1-H-1	0.00235	± 0.00081	0.00235	± 0.00040
1-H-2	0.00072	± 0.00024	0.00072	± 0.00011
1-H-3	0.0103	± 0.0032	0.0103	± 0.0010
2-He-3	0.0	± 0.0	0.0103	± 0.0010
2-He-4	0.149	± 0.045	0.1488	± 0.0086
36-Kr-82	0.0000000011	± 0.0000000004	0.0000089	± 0.0000030
36-Kr-85	0.000185	± 0.000066	0.182	± 0.030
40-Zr-95	0.00094	± 0.00034	5.188	± 0.089
41-Nb-95	0.000000132	± 0.000000048	5.185	± 0.089
41-Nb-95m	0.000000027	± 0.000000010	0.0561	± 0.0069
42-Mo-92	0.0	± 0.0	0.0	± 0.0
42-Mo-94	0.0	± 0.0	0.0	± 0.0
42-Mo-96	0.0	± 0.0	0.0000063	± 0.0000024
42-Mo-99	0.0000260	± 0.0000094	6.181	± 0.099
44-Ru-103	0.000000070	± 0.000000025	6.029	± 0.096
44-Ru-106	0.00197	± 0.00076	2.52	± 0.11
45-Rh-106	0.000000182	± 0.000000070	2.52	± 0.11
51-Sb-125	0.0000161	± 0.0000065	0.0210	± 0.0038
52-Te-132	0.34	± 0.11	4.76	± 0.17
53-I-131	0.000051	± 0.000017	3.321	± 0.083
53-I-135	1.12	± 0.32	6.42	± 0.27
54-Xe-128	0.0	± 0.0	0.0	± 0.0
54-Xe-130	0.0	± 0.0	0.0	± 0.0
54-Xe-131m	0.000000002	± 0.000000001	0.0361	± 0.0036
54-Xe-133	0.0000067	± 0.0000024	6.71	± 0.23
54-Xe-133m	0.0000188	± 0.0000067	0.191	± 0.017
54-Xe-135	0.0038	± 0.0014	6.43	± 0.27
54-Xe-135m	0.0106	± 0.0038	1.07	± 0.11
55-Cs-134	0.000000060	± 0.000000021	0.000000113	± 0.000000030
55-Cs-137	0.0044	± 0.0016	6.02	± 0.15
56-Ba-140	0.0142	± 0.0052	5.972	± 0.084
57-La-140	0.0000068	± 0.0000025	5.972	± 0.084
58-Ce-141	0.000000016	± 0.000000005	5.93	± 0.45
58-Ce-144	0.00066	± 0.00024	4.67	± 0.11
59-Pr-144	0.000000007	± 0.000000002	4.67	± 0.11
60-Nd-142	0.0	± 0.0	0.0	± 0.0
60-Nd-144	0.0	± 0.0	4.67	± 0.11
60-Nd-147	0.00000032	± 0.00000012	2.677	± 0.046
61-Pm-147	0.0	± 0.0	2.677	± 0.046
61-Pm-148	0.0	± 0.0	0.0	± 0.0
61-Pm-148m	0.0	± 0.0	0.0	± 0.0
61-Pm-149	0.000000025	± 0.000000009	1.683	± 0.067

Table C-2.4: U-238 fast fission yields for selected fission products.

Fission Product	Independent yield [% per fission]		Cumulative yield [% per fission]	
61-Pm-151	0.0000182	± 0.0000067	0.810	± 0.012
62-Sm-148	0.0	± 0.0	0.0	± 0.0
62-Sm-150	0.0	± 0.0	0.00000084	± 0.00000032
62-Sm-151	0.0000000012	± 0.0000000004	0.810	± 0.012
62-Sm-153	0.000000033	± 0.000000012	0.367	± 0.014
63-Eu-151	0.0	± 0.0	0.810	± 0.012
63-Eu-152	0.0	± 0.0	0.0	± 0.0
63-Eu-154	0.0	± 0.0	0.000000002	± 0.000000001
63-Eu-155	0.000000056	± 0.000000022	0.127	± 0.021

C-2.5: Pu-239 thermal fission yields for selected fission products.

Reference

JEFF-3.1: Joint Evaluated Fission and Fusion File, Incident neutron data,
<http://www-nds.iaea.org/exfor/endlf00.htm>, 2 October 2006;
 see also A. Koning, R. Forrest, M. Kellett, R. Mills, H. Henriksson,
 Y. Rugama, The JEFF-3.1 Nuclear Data Library, JEFF Report 21,
 OECD/NEA, Paris, France, 2006, ISBN 92-64-02314-3.

Table C-2.5: Pu-239 thermal fission yields for selected fission products.

Fission Product	Independent yield [% per fission]		Cumulative yield [% per fission]	
1-H-1	0.00408	± 0.00071	0.00408	± 0.00041
1-H-2	0.00135	± 0.00029	0.00135	± 0.00019
1-H-3	0.0142	± 0.0011	0.01420	± 0.00070
2-He-3	0.0	± 0.0	0.01420	± 0.00070
2-He-4	0.219	± 0.012	0.2192	± 0.0090
36-Kr-82	0.0000050	± 0.0000019	0.00175	± 0.00060
36-Kr-85	0.0117	± 0.0042	0.136	± 0.014
40-Zr-95	0.133	± 0.048	4.949	± 0.099
41-Nb-95	0.00036	± 0.00013	4.946	± 0.099
41-Nb-95m	0.000084	± 0.000031	0.0535	± 0.0066
42-Mo-92	0.0	± 0.0	0.0	± 0.0
42-Mo-94	0.000000002	± 0.000000001	0.000000036	± 0.000000013
42-Mo-96	0.0000048	± 0.0000017	0.0051	± 0.0018
42-Mo-99	0.0191	± 0.0069	6.185	± 0.056
44-Ru-103	0.00035	± 0.00013	6.948	± 0.083
44-Ru-106	0.30	± 0.10	4.188	± 0.092
45-Rh-106	0.00082	± 0.00030	4.188	± 0.092
51-Sb-125	0.0125	± 0.0044	0.117	± 0.015
52-Te-132	2.94	± 0.45	5.095	± 0.094
53-I-131	0.0234	± 0.0081	3.724	± 0.078
53-I-135	4.19	± 0.62	6.33	± 0.23
54-Xe-128	0.0	± 0.0	0.00000234	± 0.00000085
54-Xe-130	0.00000116	± 0.00000036	0.00166	± 0.00056
54-Xe-131m	0.000032	± 0.000011	0.0405	± 0.0040
54-Xe-133	0.0071	± 0.0026	6.99	± 0.13
54-Xe-133m	0.0172	± 0.0063	0.216	± 0.016
54-Xe-135	0.306	± 0.097	7.36	± 0.24
54-Xe-135m	0.74	± 0.24	1.78	± 0.21
55-Cs-134	0.00039	± 0.00014	0.00067	± 0.00018
55-Cs-137	0.46	± 0.16	6.588	± 0.080
56-Ba-140	0.88	± 0.28	5.322	± 0.059
57-La-140	0.0113	± 0.0040	5.333	± 0.059
58-Ce-141	0.00029	± 0.00011	5.205	± 0.073
58-Ce-144	0.163	± 0.060	3.755	± 0.030
59-Pr-144	0.000064	± 0.000024	3.756	± 0.030
60-Nd-142	0.0	± 0.0	0.00000145	± 0.00000040
60-Nd-144	0.000000261	± 0.000000096	3.756	± 0.030
60-Nd-147	0.00174	± 0.00063	2.044	± 0.039
61-Pm-147	0.00000077	± 0.00000028	2.044	± 0.039
61-Pm-148	0.0000050	± 0.0000019	0.0000056	± 0.0000019
61-Pm-148m	0.0000118	± 0.0000044	0.0000118	± 0.0000044
61-Pm-149	0.000272	± 0.000098	1.263	± 0.032

Table C-2.5: Pu-239 thermal fission yields for selected fission products.

Fission Product	Independent yield [% per fission]		Cumulative yield [% per fission]	
61-Pm-151	0.0140	± 0.0048	0.776	± 0.018
62-Sm-148	0.000000002	± 0.000000001	0.0000168	± 0.0000046
62-Sm-150	0.0000032	± 0.0000011	0.00227	± 0.00078
62-Sm-151	0.000053	± 0.000019	0.776	± 0.018
62-Sm-153	0.00087	± 0.00031	0.380	± 0.030
63-Eu-151	0.000000007	± 0.000000003	0.776	± 0.018
63-Eu-152	0.000000092	± 0.000000033	0.00000195	± 0.00000050
63-Eu-154	0.0000258	± 0.0000092	0.000049	± 0.000012
63-Eu-155	0.00037	± 0.00014	0.174	± 0.030

C-2.6: Pu-241 thermal fission yields for selected fission products.

Reference

JEFF-3.1: Joint Evaluated Fission and Fusion File, Incident neutron data, <http://www-nds.iaea.org/exfor/endl00.htm>, 2 October 2006; see also A. Koning, R. Forrest, M. Kellett, R. Mills, H. Henriksson, Y. Rugama, The JEFF-3.1 Nuclear Data Library, JEFF Report 21, OECD/NEA, Paris, France, 2006, ISBN 92-64-02314-3.

Table C-2.6: Pu-241 thermal fission yields for selected fission products.

Fission Product	Independent yield [% per fission]		Cumulative yield [% per fission]	
1-H-1	0.0029	± 0.0010	0.00294	± 0.00048
1-H-2	0.00090	± 0.00030	0.00090	± 0.00013
1-H-3	0.0141	± 0.0021	0.01410	± 0.00061
2-He-3	0.0	± 0.0	0.01410	± 0.00061
2-He-4	0.186	± 0.020	0.1860	± 0.0071
36-Kr-82	0.000000080	± 0.000000034	0.000124	± 0.000059
36-Kr-85	0.00152	± 0.00062	0.094	± 0.018
40-Zr-95	0.0200	± 0.0075	3.91	± 0.15
41-Nb-95	0.0000130	± 0.0000049	3.91	± 0.15
41-Nb-95m	0.0000030	± 0.0000011	0.0423	± 0.0048
42-Mo-92	0.0	± 0.0	0.0	± 0.0
42-Mo-94	0.0	± 0.0	0.0	± 0.0
42-Mo-96	0.000000061	± 0.000000024	0.00033	± 0.00013
42-Mo-99	0.00177	± 0.00064	5.61	± 0.25
44-Ru-103	0.0000165	± 0.0000061	6.54	± 0.32
44-Ru-106	0.105	± 0.043	5.95	± 0.70
45-Rh-106	0.000073	± 0.000030	5.95	± 0.70
51-Sb-125	0.0032	± 0.0014	0.249	± 0.065
52-Te-132	1.16	± 0.34	4.512	± 0.095
53-I-131	0.00092	± 0.00033	3.076	± 0.074
53-I-135	2.41	± 0.60	6.84	± 0.23
54-Xe-128	0.0	± 0.0	0.0	± 0.0
54-Xe-130	0.000000002	± 0.000000001	0.000023	± 0.000010
54-Xe-131m	0.000000166	± 0.000000060	0.0334	± 0.0036
54-Xe-133	0.000262	± 0.000094	6.61	± 0.18
54-Xe-133m	0.00063	± 0.00023	0.189	± 0.017
54-Xe-135	0.051	± 0.019	7.01	± 0.24
54-Xe-135m	0.124	± 0.046	1.25	± 0.13
55-Cs-134	0.0000053	± 0.0000020	0.0000092	± 0.0000026
55-Cs-137	0.065	± 0.024	6.28	± 0.14
56-Ba-140	0.178	± 0.068	5.76	± 0.11
57-La-140	0.00038	± 0.00014	5.76	± 0.11
58-Ce-141	0.00000275	± 0.00000099	4.90	± 0.12
58-Ce-144	0.0174	± 0.0067	4.123	± 0.095
59-Pr-144	0.00000098	± 0.00000038	4.123	± 0.095
60-Nd-142	0.0	± 0.0	0.000000004	± 0.000000001
60-Nd-144	0.0	± 0.0	4.123	± 0.095
60-Nd-147	0.000043	± 0.000016	2.252	± 0.095
61-Pm-147	0.000000002	± 0.000000001	2.252	± 0.095
61-Pm-148	0.000000038	± 0.000000014	0.000000042	± 0.000000014
61-Pm-148m	0.000000089	± 0.000000032	0.000000089	± 0.000000032
61-Pm-149	0.0000045	± 0.0000018	1.454	± 0.071

Table C-2.6: Pu-241 thermal fission yields for selected fission products.

Fission Product	Independent yield [% per fission]		Cumulative yield [% per fission]	
61-Pm-151	0.00102	± 0.00048	0.86	± 0.24
62-Sm-148	0.0	± 0.0	0.000000127	± 0.000000034
62-Sm-150	0.000000014	± 0.000000006	0.000079	± 0.000031
62-Sm-151	0.000000055	± 0.000000026	0.86	± 0.24
62-Sm-153	0.000045	± 0.000023	0.40	± 0.23
63-Eu-151	0.0	± 0.0	0.86	± 0.24
63-Eu-152	0.0	± 0.0	0.0	± 0.0
63-Eu-154	0.00000047	± 0.00000020	0.00000089	± 0.00000034
63-Eu-155	0.000013	± 0.000012	0.19	± 0.35

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