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HANDBOOK OF NUCLEAR DATA FOR SAFEGUARDS: DATABASE EXTENSIONS, AUGUST 2008

Prepared by

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HANDBOOK OF NUCLEAR DATA FOR SAFEGUARDS: ADDENDUM, AUGUST 2008

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Abstract

A set of recommended nuclear data were assembled in January 2007 that were judged to be suitable for universal adoption with respect to nuclear materials accounting techniques. These data were fully documented in IAEA report INDC(NDS)-0502, January 2007, and superseded the tabulations to be found within IAEA report INDC(NDS)-376, December 1997. 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; and Section C presents fission product yield data for selected actinides. Following the issue of this material, the authors were asked by users to extend the decay database to encompass a specific number of activation products, and also include additional fission product yield data. These requests have been addressed by creating Section D dedicated to decay data for relevant activation products, and extending Section C of the fission product yield database. All of the recommended data sets can be inspected as tables in this INDC(NDS) report, or through the adoption and use of appropriate software for which a Web site containing all of the data sets is located at http://www-nds.iaea.org/sgnucdat/

August 2008

CONTENTS

1. Introduction

The aim of the present handbook is to provide carefully selected and evaluated nuclear data suitable for application with respect to nuclear materials accounting techniques. These revised data supersede the tabulations to be found within IAEA reports INDC(NDS)-376, December 1997 and INDC(NDS)-0502, January 2007. 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 the 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 four 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;

Section D provides decay data for some important activation products.

Additional remarks are given as footnotes to the corresponding tables.

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, or per 100 disintegrations (%).

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 [≈ 365.2422 d])

J: joule; eV: electronvolt (1 eV = 1.602177 x 10^{-19} J)

barn: 10^{-24} cm^2

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^{-1}

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^{-1} cross section σ_0 ($g = \sigma/\sigma_o$); 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 four 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.

Section D: Decay data for activation products.

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 ± ΔBF)
6. Source of data

Data sources are listed below in order of preference:

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, "Update of X-ray and Gamma-ray Decay Data Standards for Detector Calibration and Other Applications", IAEA Scientific and Technical Information report STI/PUB/1287, May 2007, International Atomic Energy Agency, Vienna, Austria, ISBN 92-0-113606-4.

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. 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.

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, "Update of X-ray and Gamma-ray Decay Data Standards for Detector Calibration and Other Applications", IAEA Scientific and Technical Information report STI/PUB/1287, May 2007, International Atomic Energy Agency, Vienna, Austria, ISBN 92-0-113606-4.

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-destructve 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, "Update of X-ray and Gamma-ray Decay Data Standards for Detector Calibration and Other Applications", IAEA Scientific and Technical Information report STI/PUB/1287,

May 2007, International Atomic Energy Agency, Vienna, Austria, ISBN 92-0-113606-4.

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 relatives 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 β3, Incident neutron data, http://www.nndc.bnl.gov/exfor4/endf00.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/endf00.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, Chen Zhenpeng, A.D. Carlson, E.V. Gai, G.M. Hale, F.-J. Hambsch, H.M. Hofmann, T. Kawano, N.M. Larson, V.G. Pronyaev, D.L. Smith, Soo-Youl Oh, S. Tagesen, H.K. Vonach, A.L. Nichols, "International Evaluation of Neutron Cross-section Standards", IAEA Scientific and Technical Information report STI/PUB/1291, November 2007, International Atomic Energy Agency, Vienna, Austria, ISBN 92-0-100807-4.

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 β3, Incident neutron data, http://www.nndc.bnl.gov/exfor4/endf00.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:

$$\sigma_\nu = [(\nu - \nu_{exp})^2 + \sigma_{\nu,exp}{}^2]^{½} \quad ,$$

where σ_ν is the standard deviation of ν (total or delayed-neutron yield),

ν is the recommended value of ν given in Table A-6,

ν_{exp} is the weighted average value of ν calculated from the selected experimental data - weights were the inverse of the squares of the individual measured uncertainties, and

$\sigma_{\nu,exp}$ is the standard deviation of ν_{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 $\alpha_i = \nu_{di}/\nu_d$ and associated 1σ uncertainty
7. Delayed neutron ratio $\beta_i = \nu_{di}/\nu_t$ [%] 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: X-ray energies and intensities for fission products.

Table B-4: 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 ± ΔBF)
6. Source of data

Data sources are listed below in order of preference:

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, "Update of X-ray and Gamma-ray Decay Data Standards for Detector Calibration and Other Applications", IAEA Scientific and Technical Information report STI/PUB/1287, May 2007, International Atomic Energy Agency, Vienna, Austria, ISBN 92-0-113606-4.

LNHB: Laboratoire National Henri Becquerel, Decay Data Evaluation Project, 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.

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:

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, "Update of X-ray and Gamma-ray Decay Data Standards for Detector Calibration and Other Applications", IAEA Scientific and Technical Information report STI/PUB/1287, May 2007, International Atomic Energy Agency, Vienna, Austria, ISBN 92-0-113606-4.

LNHB: Laboratoire National Henri Becquerel, Decay Data Evaluation Project, 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.

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: X-ray energies and intensities for fission products.

Content of Table B-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. Decay mode (β^+, β^-, EC, IT)
5. Origin of X-rays - element of origin is specified, and the X-rays associated with $K\alpha_2$, $K\alpha_1$, $K'\beta_1$, $K'\beta_2$ and eventually L shell transitions are listed in the table.
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:

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, "Update of X-ray and Gamma-ray Decay Data Standards for Detector Calibration and Other Applications", IAEA Scientific and Technical Information report STI/PUB/1287, May 2007, International Atomic Energy Agency, Vienna, Austria, ISBN 92-0-113606-4.

LNHB: Laboratoire National Henri Becquerel, Decay Data Evaluation Project,

http://www.nucleide.org/DDEP_WG/DDEPdata.htm, 5 June 2008.

4.2.4. Table B-4: Fission product data: Thermal neutron cross sections, resonance integrals and Westcott factors

Content of Table B-4:

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 β3, Incident neutron data, http://www.nndc.bnl.gov/exfor4/endf00.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/endf00.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 independent fission yields for selected fission products

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

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

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

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

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

Table C-3.1: Th-232 cumulative fission yields for selected fission products

Table C-3.2: U-233 cumulative fission yields for selected fission products

Table C-3.3: U-235 cumulative fission yields for selected fission products

Table C-3.4: U-238 cumulative fission yields for selected fission products

Table C-3.5: Pu-239 cumulative fission yields for selected fission products

Table C-3.6: Pu-241 cumulative 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 fission yields for 61 selected fission products at different neutron energies; units are % per fission.

Tables C-3.1 to C-3.6 present the cumulative fission yields in units of % per fission for the same 61 selected fission products at different neutron energies.

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/endf00.htm, 2 October 2006 and 6 May 2008;

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 independent fission yields for selected fission products

1. Fission product.
2. Independent fast fission product yields and uncertainties as % per fission.
3. Independent 14-MeV fission product yields and uncertainties as % per fission.

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

1. Fission product.
2. Independent thermal fission product yields and uncertainties as % per fission.
3. Independent fast fission product yields and uncertainties as % per fission.
4. Independent 14-MeV fission product yields and uncertainties as % per fission.

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

1. Fission product.
2. Independent thermal fission product yields and uncertainties as % per fission.
3. Independent fast fission product yields and uncertainties as % per fission.
4. Independent 14-MeV fission product yields and uncertainties as % per fission.

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

1. Fission product.
2. Independent fast fission product yields and uncertainties as % per fission.
3. Independent 14-MeV fission product yields and uncertainties as % per fission.

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

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

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

1. Fission product.

2. Independent thermal fission product yields and uncertainties as % per fission.
3. Independent fast fission product yields and uncertainties as % per fission.

4.3.13. Table C-3.1: Th-232 cumulative fission yields for selected fission product

1. Fission product.
2. Cumulative fast fission product yields and uncertainties as % per fission.
3. Cumulative 14-MeV fission product yields and uncertainties as % per fission.

4.3.14. Table C-3.2: U-233 cumulative fission yields for selected fission products

1. Fission product.
2. Cumulative thermal fission product yields and uncertainties as % per fission.
3. Cumulative fast fission product yields and uncertainties as % per fission.
4. Cumulative 14-MeV fission product yields and uncertainties as % per fission.

4.3.15. Table C-3.3: U-235 cumulative fission yields for selected fission products

1. Fission product.
2. Cumulative thermal fission product yields and uncertainties as % per fission.
3. Cumulative fast fission product yields and uncertainties as % per fission.
4. Cumulative 14-MeV fission product yields and uncertainties as % per fission.

4.3.16. Table C-3.4: U-238 cumulative fission yields for selected fission products

1. Fission product.
2. Cumulative fast fission product yields and uncertainties as % per fission.
3. Cumulative 14-MeV fission product yields and uncertainties as % per fission.

4.3.17. Table C-3.5: Pu-239 cumulative fission yields for selected fission products

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

4.3.18. Table C-3.6: Pu-241 cumulative fission yields for selected fission products

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

4.4. Section D – Activation products

Table D-1: Half-lives and branching fractions for activation products

Table D-2: Gamma-ray energies and emission probabilities for activation products

Table D-3: X-ray energies and intensities for activation products.

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

4.4.1. Table D-1: Half-lives and branching fractions for activation products

Content of Table D-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 ± ΔBF)
6. Source of data

Data sources are listed below in order of preference:

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, "Update of X-ray and Gamma-ray Decay Data Standards for Detector Calibration and Other Applications", IAEA Scientific and Technical Information report STI/PUB/1287, May 2007, International Atomic Energy Agency, Vienna, Austria, ISBN 92-0-113606-4.

LNHB: Laboratoire National Henri Becquerel, Decay Data Evaluation Project, http://www.nucleide.org/DDEP_WG/DDEPdata.htm, 5 June 2008.

ENSDF: Evaluated Nuclear Structure Data File,

http://www-nds.iaea.org/ensdf/, 5 June 2008.

Data from IAEA-CRP-XG and LNHB were adopted in preference to ENSDF data.

4.4.2. Table D-2: Gamma-ray energies and emission probabilities for activation products

Content of Table D-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

Data sources are listed below in order of preference:

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, "Update of X-ray and Gamma-ray Decay Data Standards for Detector Calibration and Other Applications", IAEA Scientific and Technical Information report STI/PUB/1287, May 2007, International Atomic Energy Agency, Vienna, Austria, ISBN 92-0-113606-4.

LNHB: Laboratoire National Henri Becquerel, Decay Data Evaluation Project, http://www.nucleide.org/DDEP_WG/DDEPdata.htm, 5 June 2008.

ENSDF: Evaluated Nuclear Structure Data File,

http://www-nds.iaea.org/ensdf/, 5 June 2008.

Same comments about preference are applicable as noted for Table D-1.

4.4.3. Table D-3: X-ray energies and intensities for activation products.

Content of Table D-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. Decay mode (β^+, β^-, EC, IT)
5. Origin of X-rays - element of origin is specified, and the X-rays associated with $K\alpha_2$, $K\alpha_1$, $K'\beta_1$, $K'\beta_2$ and eventually L shell transitions are listed in the table.
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:

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, "Update of X-ray and Gamma-ray Decay Data Standards for Detector Calibration and Other Applications", IAEA Scientific and Technical Information report STI/PUB/1287, May 2007, International Atomic Energy Agency, Vienna, Austria, ISBN 92-0-113606-4.

LNHB: Laboratoire National Henri Becquerel, Decay Data Evaluation Project, http://www.nucleide.org/DDEP_WG/DDEPdata.htm, 5 June 2008.

5. Concluding Remarks

The most respected nuclear databases have been assessed in detail over the course of 2006 to mid-2008 in order to 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 users and analytical specialists associated with the non-destructive assay of nuclear materials.

The recommended data sets can be inspected in tabulated form (see the section dedicated to Data Tables), or through the adoption and use of appropriate software. Users are referred to a previous IAEA report (INDC(NDS)-0502, January 2007) 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).

RECOMMENDED NUCLEAR DATA TABLES, AUGUST 2008

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: X-ray energies and intensities for fission products.

B-4: Fission product data: Thermal neutron cross sections, resonance integrals and Westcott factors.

C-1: Chain fission yields for selected actinides.

C-2: Selected independent fission product yields.

C-3: Selected cumulative fission product yields.

D-1 Half-lives and branching fractions for activation products.

D-2: Gamma-ray energies and emission probabilities for activation products.

D-3: X-ray energies and intensities for activation products.

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 Scientific and Technical Information report STI/PUB/1287, May 2007, International Atomic Energy Agency, Vienna, Austria, ISBN 92-0-113606-4.

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	1.0	ENSDF
			^{14}C	(8.9 ± 0.4) × 10^{-10}	
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 $< 1. \times 10^{-14}$	ENSDF
92-U-233	$(1.592 \pm 0.002) \times 10^{5}$	y	α SF	1.0 $< 6. \times 10^{-11}$	ENSDF
92-U-234	$(2.455 \pm 0.006) \times 10^{5}$	y	α SF	1.0 $(1.6 \pm 0.2) \times 10^{-11}$	LNHB
92-U-235	$(7.038 \pm 0.005) \times 10^{8}$	y	α SF	1.0 $(7. \pm 2.) \times 10^{-11}$	ENSDF
92-U-235m	26. ± 1.	m	IT	1.0	ENSDF
92-U-236	$(2.342 \pm 0.004) \times 10^{7}$	y	α SF	1.0 $(9.4 \pm 0.4) \times 10^{-10}$	ENSDF
92-U-237	6.749 ± 0.016	d	β-	1.0	LNHB
92-U-238	$(4.468 \pm 0.005) \times 10^{9}$	y	α SF	1.0 $(5.45 \pm 0.04) \times 10^{-7}$	LNHB
92-U-239	23.45 ± 0.02	m	β-	1.0	ENSDF
93-Np-236	$(1.55 \pm 0.08) \times 10^{5}$	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	$(2.144 \pm 0.007) \times 10^{6}$	y	α SF	1.0 $< 2. \times 10^{-12}$	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 $(1.9 \pm 0.4) \times 10^{-9}$	ENSDF
94-Pu-238	87.74 ± 0.03	y	α SF	1.0 $(1.85 \pm 0.05) \times 10^{-9}$	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	1.0	ENSDF
			SF	$(3.1 \pm 0.6) \times 10^{-12}$	
94-Pu-240	$(6.561 \pm 0.007) \times 10^{3}$	y	α	1.0	BIPM-5
			SF	$(5.7 \pm 0.2) \times 10^{-8}$	
94-Pu-241	14.290 ± 0.006	y	α	0.0000245 ± 0.0000002	ENSDF
			β-	0.9999755 ± 0.0000002	
94-Pu-242	$(3.73 \pm 0.03) \times 10^{5}$	y	α	1.0	BIPM-5
			SF	$(5.49 \pm 0.09) \times 10^{-6}$	
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	0.99879 ± 0.00004	ENSDF
			SF	0.00121 ± 0.00004	
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	0.9999981 ± 0.0000007	ENSDF
			α	0.0000019 ± 0.0000007	
95-Am-241	432.6 ± 0.6	y	α	1.0	BIPM-5
			SF	$(4.3 \pm 1.8) \times 10^{-12}$	
95-Am-242	16.02 ± 0.02	h	β-	0.827 ± 0.003	ENSDF
			EC	0.173 ± 0.003	
95-Am-242m	141. ± 2.	y	IT	0.9955 ± 0.0002	ENSDF
			α	0.0045 ± 0.0002	
			SF	$< 4.7 \times 10^{-11}$	
95-Am-243	$(7.370 \pm 0.017) \times 10^{3}$	y	α	1.0	LNHB
			SF	$(3.8 \pm 0.7) \times 10^{-11}$	
96-Cm-242	162.86 ± 0.08	d	α	1.0	LNHB
			SF	$(6.36 \pm 0.14) \times 10^{-8}$	
96-Cm-243	29.1 ± 0.1	y	α	0.9971 ± 0.0003	ENSDF
			EC	0.0029 ± 0.0003	
			SF	$(5.3 \pm 0.9) \times 10^{-11}$	
96-Cm-244	18.11 ± 0.03	y	α	1.0	LNHB
			SF	$(1.36 \pm 0.01) \times 10^{-6}$	
98-Cf-252	2.645 ± 0.008	y	α	0.96908 ± 0.00008	ENSDF
			SF	0.03092 ± 0.00008	

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, R. Helmer, A. Nichols, E. Schönfeld, R. Dersch, Monographie BIPM-5, Table of Radionuclides, Vol. 2 - A = 151 to 242, 2004.

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

Nuclide	Half-life $T_{1/2}$	Units	α particles Energy [keV]		Emission probability P_α [% decay]		Source	Notes
83-Bi-211	2.14 ± 0.02	m	6278.2	± 0.7	16.19	± 0.14	ENSDF	
			6622.9	± 0.6	83.54	± 0.14		
83-Bi-212	60.54 ± 0.06	m	5606.63	± 0.14	0.43	± 0.04	LNHB	
			5768.27	± 0.10	0.63	± 0.03		
			6050.92	± 0.04	25.1	± 0.1		
			6090.02	± 0.04	9.7	± 0.1		
84-Po-210	138.376 ± 0.002	d	5304.33	± 0.07	100.		ENSDF	
86-Rn-219	3.96 ± 0.01	s	6425.	± 1.	7.5	± 0.6	ENSDF	
			6552.6	± 1.0	12.9	± 0.6		
			6819.1	± 0.3	79.4	± 1.0		
86-Rn-220	55.8 ± 0.3	s	5748.46	± 0.14	0.118	± 0.015	LNHB	
			6288.22	± 0.10	99.882	± 0.015		
88-Ra-223	11.43 ± 0.05	d	5433.6	± 0.5	2.22	± 0.20	ENSDF	
			5539.8	± 0.9	9.0	± 0.2		
			5606.73	± 0.30	25.2	± 0.5		
			5716.23	± 0.29	51.6	± 1.3		
			5747.0	± 0.4	9.0	± 0.2		
			5871.3	± 1.0	1.0	± 0.2		
88-Ra-224	3.627 ± 0.007	d	5448.81	± 0.16	5.26	± 0.07	LNHB	
			5685.50	± 0.15	94.72	± 0.07		
88-Ra-226	(1.600 ± 0.007) × 10^3	y	4601.	± 1.	5.96	± 0.08	LNHB	
			4784.34	± 0.25	94.03	± 0.08		
90-Th-227	18.718 ± 0.005	d	5668.0	± 1.5	2.06	± 0.12	LNHB	
			5693.0	± 1.6	1.5	± 0.1		
			5700.8	± 1.6	3.63	± 0.20		
			5708.8	± 1.6	8.3	± 0.3		
			5713.2	± 1.6	4.89	± 0.20		
			5756.87	± 0.15	20.4	± 0.9		
			5807.5	± 1.5	1.27	± 0.02		
			5866.6	± 1.5	2.42	± 0.10		
			5959.7	± 1.5	3.00	± 0.15		
			5977.72	± 0.10	23.5	± 0.9		
			6008.8	± 1.5	2.90	± 0.15		
			6038.01	± 0.15	24.2	± 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 Energy [keV]	Emission probability P_α [% decay]	Source	Notes
90-Th-228	698.60 ± 0.23	d	5340.38 ± 0.22	26.2 ± 0.2	BIPM-5	
			5423.28 ± 0.22	73.2 ± 0.2		
90-Th-229	(7.34 ± 0.16) × 10^3	y	4797.8 ± 1.2	1.5 ± 0.2	ENSDF	
			4814.6 ± 1.2	9.30 ± 0.08		
			4838. ± 2.	5.0 ± 0.2		
			4845.3 ± 1.2	56.2 ± 0.2		
			4901.0 ± 1.2	10.20 ± 0.08		
			4967.5 ± 1.2	5.97 ± 0.06		
			4978.5 ± 1.2	3.17 ± 0.04		
			5053. ± 2.	6.6 ± 0.1		
90-Th-230	(7.538 ± 0.030) × 10^4	y	4620.5 ± 1.5	23.4 ± 0.1	ENSDF	
			4687.0 ± 1.5	76.3 ± 0.3		
90-Th-232	(1.405 ± 0.006) × 10^{10}	y	3947.2 ± 2.0	21.7 ± 1.3	ENSDF	
			4012.3 ± 1.4	78.2 ± 1.3		
91-Pa-231	(3.276 ± 0.011) × 10^4	y	4681. ± 2.	1.5 ± 0.6	ENSDF	[1]
			4736.0 ± 0.8	8.4 ± 1.2		
			4853. ± 2.	1.4 ± 0.4		
			4934. ± 2.	3.0 ± 0.3		
			4951.3 ± 1.4	22.8 ± 5.8		
			4986. ± 2.	1.4 ± 0.4		
			5013.8 ± 1.4	25.4 ± 14.1		
			5028.4 ± 1.0	20.0 ± 4.2		
			5058.6 ± 1.5	11.0 ± 2.0		
92-U -232	68.9 ± 0.4	y	5263.36 ± 0.09	31.55 ± 0.23	ENSDF	
			5320.12 ± 0.14	68.15 ± 0.23		
92-U -233	(1.592 ± 0.002) × 10^5	y	4729. ± 1.	1.61 ± 0.17	ENSDF	[2]
			4783.5 ± 1.2	13.2 ± 0.2		
			4824.2 ± 1.2	84.4 ± 0.5		
92-U -234	(2.455 ± 0.006) × 10^5	y	4722.4 ± 0.7	28.42 ± 0.02	LNHB	
			4774.6 ± 0.7	71.37 ± 0.02		
92-U -235	(7.038 ± 0.005) × 10^8	y	4150. ± 5.	0.9 ± 0.2	ENSDF	
			4214.7 ± 1.9	5.7 ± 0.6		
			4366.1 ± 2.0	17. ± 2.		
			4397.8 ± 1.3	55. ± 3.		
			4414. ± 4.	2.1 ± 0.2		
			4502. ± 2.	1.7 ± 0.2		
			4556. ± 2.	4.2 ± 0.3		
			4596.4 ± 1.3	5.0 ± 0.5		
92-U -236	(2.342 ± 0.004) × 10^7	y	4445. ± 5.	25.9 ± 4.0	ENSDF	
			4494. ± 3.	73.8 ± 4.0		
92-U -238	(4.468 ± 0.005) × 10^9	y	4151. ± 5.	22.33 ± 0.50	LNHB	
			4198. ± 3.	77.54 ± 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 Energy [keV]	Emission probability P_α [% decay]	Source	Notes
93-Np-237	(2.144 ± 0.007) × 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 ± 0.003) × 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 ± 0.007) × 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 ± 0.03) × 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. ± 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 ± 0.017) × 10^3	y	5181. ± 1.	1.383 ± 0.007	LNHB	
			5233.3 ± 1.0	11.46 ± 0.05		
			5275.3 ± 1.0	86.74 ± 0.05		
			5321. ± 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. ± 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. ± 3.	1.1 ± 0.1		
			6058. ± 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.	±	2.	2.06	±	0.18
4736.0	±	0.8	9.3	±	0.7
4853.	±	2.	1.5	±	0.3
4934.	±	2.	3.0	±	0.3
4951.3	±	1.4	27.	±	4.
4986.	±	2.	1.2	±	0.3
5013.8	±	1.4	27.	±	14.
5028.4	±	1.0	19.	±	4.
5058.6	±	1.5	~ 9.		

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

[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.

References

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

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

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.

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

Nuclide	Half-life $T_{1/2}$	Units	γ rays Energy [keV]	Emission probability [% decay]	Source	Notes
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	γ rays Energy [keV]	Emission probability [% decay]	Source	Notes
83-Bi-214	19.9 ± 0.4	m	609.316 ± 0.003	45.16 ± 0.33	IAEA-CRP-XG	
			665.453 ± 0.022	1.521 ± 0.011		
			768.367 ± 0.011	4.850 ± 0.038		
			806.185 ± 0.011	1.255 ± 0.011		
			934.061 ± 0.012	3.074 ± 0.025		
			1120.287 ± 0.010	14.78 ± 0.11		
			1155.19 ± 0.02	1.624 ± 0.014		
			1238.110 ± 0.012	5.785 ± 0.045		
			1280.96 ± 0.02	1.425 ± 0.012		
			1377.669 ± 0.012	3.954 ± 0.033		
			1401.516 ± 0.014	1.324 ± 0.011		
			1407.993 ± 0.007	2.369 ± 0.019		
			1509.217 ± 0.008	2.108 ± 0.021		
			1661.316 ± 0.013	1.037 ± 0.010		
			1729.640 ± 0.012	2.817 ± 0.023		
			1764.539 ± 0.015	15.17 ± 0.12		
			1847.420 ± 0.025	2.000 ± 0.018		
			2118.536 ± 0.008	1.148 ± 0.011		
			2204.071 ± 0.021	4.89 ± 0.10		
			2447.673 ± 0.010	1.536 ± 0.015		
86-Rn-219	3.96 ± 0.01	s	271.23 ± 0.01	10.8 ± 0.6	ENSDF	
			401.81 ± 0.01	6.6 ± 0.4		
86-Rn-220	55.8 ± 0.3	s	549.76 ± 0.04	0.115 ± 0.015	BIPM-5	
88-Ra-223	11.43 ± 0.05	d	122.319 ± 0.010	1.21 ± 0.02	ENSDF	
			144.235 ± 0.010	3.27 ± 0.08		
			154.208 ± 0.010	5.70 ± 0.16		
			269.463 ± 0.010	13.9 ± 0.3		
			323.871 ± 0.010	3.99 ± 0.09		
			338.282 ± 0.010	2.84 ± 0.07		
			445.033 ± 0.012	1.29 ± 0.05		
88-Ra-224	3.627 ± 0.007	d	240.986 ± 0.006	4.12 ± 0.04	BIPM-5	
88-Ra-226	(1.600 ± 0.007) × 10^3	y	186.211 ± 0.013	3.533 ± 0.028	IAEA-CRP-XG	
90-Th-227	18.718 ± 0.005	d	50.13 ± 0.01	8.2 ± 0.5*	LNHB	[2]
			79.69 ± 0.02	1.90 ± 0.11		
			93.88 ± 0.05	1.48 ± 0.08		
			210.62 ± 0.05	1.22 ± 0.11		
			235.96 ± 0.02	12.6 ± 0.6		
			256.23 ± 0.02	6.8 ± 0.4		
			286.09 ± 0.02	1.70 ± 0.17*		
			289.59 ± 0.10	1.9 ± 0.4*		
			299.98 ± 0.03	2.16 ± 0.12*		
			304.50 ± 0.02	1.12 ± 0.14		
			329.85 ± 0.02	2.9 ± 0.2		
			334.37 ± 0.02	1.11 ± 0.09		
90-Th-228	698.60 ± 0.23	d	84.373 ± 0.003	1.17 ± 0.05	BIPM-5	
			131.612 ± 0.004	0.124 ± 0.006		
			166.410 ± 0.004	0.094 ± 0.007		
			215.985 ± 0.004	0.226 ± 0.020		
90-Th-229	(7.34 ± 0.16) × 10^3	y	107.108 ± 0.008	0.81 ± 0.05	ENSDF	
			136.99 ± 0.04	1.18 ± 0.04		
			148.15 ± 0.04	0.88 ± 0.07		
			156.409 ± 0.009	1.19 ± 0.04		
			193.509 ± 0.004	4.41 ± 0.07		
			210.853 ± 0.003	2.8 ± 0.4		

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

Nuclide	Half-life $T_{1/2}$	Units	γ rays Energy [keV]	Emission probability [% decay]	Source	Notes
90-Th-230	(7.538 ± 0.030) × 10^4	y	67.672 ± 0.002	0.38 ± 0.04	ENSDF	
			143.872 ± 0.004	0.049 ± 0.004		
			253.729 ± 0.010	0.0111 ± 0.0009		
90-Th-231	25.52 ± 0.01	h	58.5700 ± 0.0024	0.46 ± 0.03	ENSDF	
			81.2280 ± 0.0014	0.90 ± 0.06		
			82.0870 ± 0.0014	0.42 ± 0.03		
			84.2140 ± 0.0013	6.6 ± 0.4		
			89.95 ± 0.02	1.00 ± 0.06		
			102.2700 ± 0.0013	0.44 ± 0.03		
90-Th-232	(1.405 ± 0.006) × 10^{10}	y	63.81 ± 0.01	0.263 ± 0.013	ENSDF	
			140.88 ± 0.01	0.021 ± 0.004		
90-Th-233	22.15 ± 0.15	m	29.373 ± 0.010	2.5 ± 0.4	LNHB	[3]
			86.477 ± 0.010	2.7 ± 0.4		
			94.65 ± 0.05	0.8 ± 0.1		
			169.159 ± 0.010	0.34 ± 0.05		
			459.222 ± 0.007	1.4 ± 0.3		
			669.902 ± 0.016	0.68 ± 0.14		
90-Th-234	24.10 ± 0.03	d	63.29 ± 0.02	3.70 ± 0.06	ADS-98	[4]
			92.38 ± 0.01	2.62 ± 0.06		
			92.80 ± 0.02	2.59 ± 0.06		
			112.81 ± 0.05	0.244 ± 0.015		
91-Pa-231	(3.276 ± 0.011) × 10^4	y	260.19 ± 0.06	0.188 ± 0.012	ENSDF	
			283.69 ± 0.01	1.7 ± 0.1		
			300.07 ± 0.01	2.5 ± 0.2		
			302.65 ± 0.05	2.2 ± 0.4		
			330.06 ± 0.01	1.40 ± 0.09		
			340.74 ± 0.05	0.181 ± 0.011		
			357.12 ± 0.09	0.175 ± 0.013		
91-Pa-233	26.98 ± 0.02	d	75.269 ± 0.010	1.30 ± 0.03	LNHB	
			86.595 ± 0.010	1.99 ± 0.11		
			103.86 ± 0.01	0.853 ± 0.006		
			271.555 ± 0.010	0.323 ± 0.003		
			300.129 ± 0.005	6.60 ± 0.21		
			311.904 ± 0.005	38.25 ± 0.23		
			340.476 ± 0.005	4.47 ± 0.03		
			375.404 ± 0.005	0.684 ± 0.007		
			398.492 ± 0.005	1.408 ± 0.014		
			415.764 ± 0.005	1.747 ± 0.007		
91-Pa-234m	1.159 ± 0.016	m	258.24 ± 0.07	0.0726 ± 0.0009	IAEA-CRP-XG	
			742.814 ± 0.022	0.096 ± 0.003		
			766.358 ± 0.020	0.318 ± 0.005		
			786.272 ± 0.022	0.054 ± 0.001		
			1001.025 ± 0.022	0.832 ± 0.010		
92-U-232	68.9 ± 0.4	y	57.78 ± 0.05	0.200 ± 0.002	ENSDF	[5]
			129.08 ± 0.05	0.0682 ± 0.0004		
			270.2 ± 0.2	0.00316 ± 0.00005		
			327.9 ± 0.2	0.00283 ± 0.00006		

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

Nuclide	Half-life $T_{1/2}$	Units	γ rays Energy [keV]	Emission probability [% decay]	Source	Notes
92-U-233	(1.592 ± 0.002) × 10^5	y	54.699 ± 0.001	0.0182 ± 0.0003	ENSDF	[5]
			118.968 ± 0.002	0.00406 ± 0.00004		
			120.816 ± 0.001	0.00332 ± 0.00003		
			135.36 ± 0.03	0.00232 ± 0.00002		
			146.345 ± 0.002	0.00657 ± 0.00006		
			164.522 ± 0.002	0.00623 ± 0.00005		
			208.171 ± 0.002	0.00229 ± 0.00003		
			245.345 ± 0.002	0.00362 ± 0.00003		
			291.354 ± 0.004	0.00537 ± 0.00005		
			317.16 ± 0.01	0.00776 ± 0.00007		
			320.541 ± 0.005	0.00290 ± 0.00003		
92-U-234	(2.455 ± 0.006) × 10^5	y	53.20 ± 0.02	0.1253 ± 0.0040	LNHB	[5]
			120.90 ± 0.04	0.0386 ± 0.0032		
92-U-235	(7.038 ± 0.005) × 10^8	y	109.16 ± 0.02	1.54 ± 0.06	ENSDF	
			140.76 ± 0.04	0.22 ± 0.03		
			143.76 ± 0.02	10.96 ± 0.14		
			163.33 ± 0.02	5.08 ± 0.07		
			182.61 ± 0.05	0.34 ± 0.03		
			185.715 ± 0.005	57.2 ± 0.8		
			194.94 ± 0.01	0.63 ± 0.02		
			202.11 ± 0.02	1.08 ± 0.03		
			205.311 ± 0.010	5.01 ± 0.06		
			221.38 ± 0.02	0.12 ± 0.02		
92-U-236	(2.342 ± 0.004) × 10^7	y	49.369 ± 0.009	0.078 ± 0.012	ENSDF	
			112.750 ± 0.015	0.019 ± 0.003		
92-U-237	6.749 ± 0.016	d	59.5409 ± 0.0001	34.1 ± 0.8	LNHB	
			64.83 ± 0.02	1.286 ± 0.017		
			164.61 ± 0.02	1.86 ± 0.03		
			208.00 ± 0.01	21.3 ± 0.3		
			332.36 ± 0.04	1.199 ± 0.016		
92-U-238	(4.468 ± 0.005) × 10^9	y	49.55 ± 0.06	0.0697 ± 0.0026	LNHB	
			113.5 ± 0.1	0.0174 ± 0.0047		
92-U-239	23.45 ± 0.02	m	43.533 ± 0.001	4.07 ± 0.13	ENSDF	
			74.664 ± 0.001	49.2 ± 1.2		
			662.24 ± 0.03	0.182 ± 0.005		
			819.22 ± 0.04	0.148 ± 0.004		
			844.10 ± 0.04	0.162 ± 0.004		
93-Np-236m	22.5 ± 0.4	h	538.11 ± 0.10	0.0125 ± 0.0015	LNHB	
			642.35 ± 0.09	1.08 ± 0.06		
			687.60 ± 0.05	0.292 ± 0.021		
93-Np-237	(2.144 ± 0.007) × 10^6	y	57.104 ± 0.020	0.354 ± 0.008	ENSDF	
			86.477 ± 0.010	12.4 ± 0.3		
			87.99 ± 0.03	0.167 ± 0.004		
			117.702 ± 0.020	0.169 ± 0.004		
			143.249 ± 0.020	0.443 ± 0.008		
			151.414 ± 0.020	0.23 ± 0.02		
			194.95 ± 0.03	0.177 ± 0.005		
			212.29 ± 0.05	0.151 ± 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 Energy [keV]	Emission probability [% decay]	Source	Notes
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. ± 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 ± 0.003) × 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 ± 0.007) × 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	γ rays Energy [keV]	Emission probability [% decay]	Source	Notes
94-Pu-242	(3.73 ± 0.03) × 10^5	y	44.915 ± 0.013	0.0376 ± 0.0008	BIPM-5	[7]
			103.50 ± 0.04	0.00251 ± 0.00011		
			158.80 ± 0.08	0.000298 ± 0.000020		
95-Am-241	432.6 ± 0.6	y	26.3446 ± 0.0002	2.40 ± 0.03	BIPM-5	[8]
			33.1963 ± 0.0003	0.121 ± 0.003		
			59.5409 ± 0.0001	35.78 ± 0.09		
			98.95 ± 0.01	0.0203 ± 0.0004		
			102.97 ± 0.01	0.0195 ± 0.0004		
			123.02 ± 0.02	0.00100 ± 0.00004		
			125.29 ± 0.01	0.0041 ± 0.0002		
			146.57 ± 0.01	0.00046 ± 0.00001		
			169.55 ± 0.02	0.00017 ± 0.00001		
			208.00 ± 0.02	0.000786 ± 0.000005		
			322.53 ± 0.03	0.000151 ± 0.000003		
			335.40 ± 0.03	0.000496 ± 0.000005		
			368.63 ± 0.03	0.000214 ± 0.000004		
			662.41 ± 0.02	0.000367 ± 0.000005		
95-Am-242m	141. ± 2.	y	49.35 ± 0.02	0.13 ± 0.01	ENSDF	[9]
			60.13 ± 0.06	0.005 ± 0.001		
			66.89 ± 0.02	0.015 ± 0.001		
			73.66 ± 0.02	0.008 ± 0.001		
			86.65 ± 0.02	0.023 ± 0.001		
			135.19 ± 0.02	0.007 ± 0.001		
			136.03 ± 0.02	0.009 ± 0.001		
95-Am-243	(7.370 ± 0.017) × 10^3	y	43.53 ± 0.02	5.89 ± 0.10	LNHB	
			74.66 ± 0.02	67.2 ± 1.2		
			86.71 ± 0.02	0.346 ± 0.009		
			141.90 ± 0.06	0.115 ± 0.008		
96-Cm-242	162.86 ± 0.08	d	44.08 ± 0.03	0.0330 ± 0.0007	LNHB	[7]
			101.92 ± 0.04	0.00251 ± 0.00014		
			157.42 ± 0.09	0.00145 ± 0.00016		
96-Cm-243	29.1 ± 0.1	y	209.753 ± 0.002	3.29 ± 0.1	ENSDF	
			228.183 ± 0.002	10.6 ± 0.3		
			277.599 ± 0.002	14.0 ± 0.4		
			285.460 ± 0.002	0.73 ± 0.02		
96-Cm-244	18.11 ± 0.03	y	42.824 ± 0.008	0.0258 ± 0.0007	LNHB	[7]
			98.860 ± 0.013	0.00136 ± 0.00009		
			152.63 ± 0.02	0.00102 ± 0.00005		
98-Cf-252	2.645 ± 0.008	y	43.399 ± 0.025	0.0148 ± 0.0009	ENSDF	[7]
			100.2 ± 0.4	0.013 ± 0.006		

[1] 510.7-keV emission probability of 22.6 ± 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 ± 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. 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/, 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 $K\alpha_2$	72.8049	0.026 ± 0.003	[1]
				Pb $K\alpha_1$	74.9700	0.044 ± 0.005	
				Pb $K'\beta_1$	84.451 – 85.470	0.0150 ± 0.0017	
				Pb $K'\beta_2$	87.238 – 88.003	0.0045 ± 0.0006	
81-Tl-208	3.060 ± 0.008	m	β-	Pb $K\alpha_2$	72.8049	2.15 ± 0.06	[1]
				Pb $K\alpha_1$	74.9700	3.61 ± 0.09	
				Pb $K'\beta_1$	84.451 - 85.470	1.23 ± 0.04	
				Pb $K'\beta_2$	87.238 - 88.003	0.373 ± 0.013	
82-Pb-212	10.64 ± 0.01	h	β-	Bi $K\alpha_2$	74.8157	10.7 ± 0.3	[2]
				Bi $K\alpha_1$	77.1088	17.9 ± 0.5	
				Bi $K'\beta_1$	86.835 - 87.862	6.12 ± 0.20	
				Bi $K'\beta_2$	89.732 - 90.522	1.87 ± 0.07	
83-Bi -212	60.54 ± 0.06	m	α	Tl $K\alpha_2$	70.8325	0.0563 ± 0.0027	[2]
				Tl $K\alpha_1$	72.8725	0.095 ± 0.005	
				Tl $K'\beta_1$	82.118 - 83.115	0.0323 ± 0.0016	
				Tl $K'\beta_2$	84.838 - 85.530	0.0096 ± 0.0005	
83-Bi -212	60.54 ± 0.06	m	β-	Po $K\alpha_2$	76.864	0.0404 ± 0.0010	[2]
				Po $K\alpha_1$	79.293	0.0672 ± 0.0017	
				Po $K'\beta_1$	89.256 - 90.363	0.0231 ± 0.0007	
				Po $K'\beta_2$	92.263 - 93.095	0.00720 ± 0.00024	
88-Ra-224	3.627 ± 0.007	d	α	Rn $K\alpha_2$	81.07	0.130 ± 0.004	[2]
				Rn $K\alpha_1$	83.78	0.215 ± 0.007	
				Rn $K'\beta_1$	94.247 - 95.449	0.0744 ± 0.0024	
				Rn $K'\beta_2$	97.48 - 98.389	0.0238 ± 0.0009	
88-Ra-226	(1.600 ± 0.007) × 10^3	y	α	Rn $K\alpha_2$	81.07	0.191 ± 0.007	[2]
				Rn $K\alpha_1$	83.78	0.315 ± 0.011	
				Rn $K'\beta_1$	94.247 – 95.449	0.109 ± 0.004	
				Rn $K'\beta_2$	97.48 – 98.389	0.0349 ± 0.0014	
89-Ac-224	2.78 ± 0.17	h	EC	Ra $K\alpha_2$	85.43	22.2 ± 0.8	[3]
				Ra $K\alpha_1$	88.47	36.2 ± 1.2	
				Ra $K'\beta_1$	99.432 - 100.738	12.8 ± 0.5	
				Ra $K'\beta_2$	102.89 - 103.899	4.22 ± 0.16	
89-Ac-224	2.78 ± 0.17	h	α	Fr $K\alpha_2$	83.231	0.150 ± 0.015	[3]
				Fr $K\alpha_1$	86.105	0.247 ± 0.023	
				Fr $K'\beta_1$	96.815 -98.069	0.087 ± 0.009	
				Fr $K'\beta_2$	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 $T_{1/2}$	Units	Decay 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	3.1 ± 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	2.96 ± 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	0.60 ± 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	0.78 ± 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 ± 0.011) × 10^4	y	α	Ac $K\alpha_2$	87.768	0.75 ± 0.04	[3]
				Ac $K\alpha_1$	90.885	1.22 ± 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	1.70 ± 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 ± 0.002) × 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 ± 0.005) × 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 ± 0.08) × 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 ± 0.007) × 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 ± 0.003) × 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 ± 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 ± 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 ± 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 ± 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 ($g = \sigma/\sigma_o$). 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 σ_x [barn]	Westcott Factor g	Resonance Integral RI [barn]	Source
90-Th-232	$\sigma_{0\gamma}$	7.35 ± 0.03	0.9982	83.3 ± 1.5	[1]
92-U -233	$\sigma_{0\gamma}$	45.5 ± 0.7	1.0495 ± 0.0223	138. ± 6.	[2]
	σ_{0f}	529.1 ± 1.2	0.9955 ± 0.0015	775. ± 17.	
92-U -234	$\sigma_{0\gamma}$	99.8 ± 1.3	0.9903	640. ± 20.	[1]
92-U -235	$\sigma_{0\gamma}$	98.8 ± 0.8	0.9956 ± 0.0016	146. ± 6.	[3]
	σ_{0f}	582.6 ± 1.1	0.9771 ± 0.0008	275. ± 5.	
92-U -236	$\sigma_{0\gamma}$	5.09 ± 0.10	1.0027	345. ± 15.	[4]
92-U -237	σ_{γ}	443. ± 167.	0.9767	1200. ± 200.	[5]
92-U -238	$\sigma_{0\gamma}$	2.683 ± 0.012	1.0009	277. ± 3.	[6]
93-Np-237	$\sigma_{0\gamma}$	175.9 ± 2.9	0.982	652. ± 24.	[1]
93-Np-239	$\sigma_{r\gamma}$	68. ± 10.	1.0005	455.	[7]
94-Pu-238	$\sigma_{0\gamma}$	540. ± 7.	0.9563	162. ± 15.	[1]
	σ_{0f}	17.9 ± 0.4	0.9562	33. ± 5.	
94-Pu-239	$\sigma_{0\gamma}$	269.3 ± 2.9	1.1369 ± 0.0119	180. ± 20.	[2]
	σ_{0f}	748.1 ± 2.0	1.0553 ± 0.0013	303. ± 10.	
94-Pu-240	$\sigma_{0\gamma}$	289.5 ± 1.4	1.0264	8452. ± 200.	[1]
94-Pu-241	$\sigma_{0\gamma}$	362.1 ± 5.1	1.038	162. ± 8.	[8]
	σ_{0f}	1011.1 ± 6.2	1.046 ± 0.006	570. ± 15.	
94-Pu-242	$\sigma_{0\gamma}$	18.5 ± 0.5	1.0096	1115. ± 40.	[1]
95-Am-241	$\sigma_{0\gamma}$	587. ± 12.	1.051	1425. ± 100.	[1]
	σ_{0f}	3.20 ± 0.09	0.996	14.4 ± 1.0	
	$\sigma_{0\gamma(g)}$	533. ± 13.		1230. ± 100.	
	$\sigma_{0\gamma(m)}$	54. ± 5.		195. ± 20.	
95-Am-242	σ_{γ}	330. ± 50.	1.0471	186.	[7]
	σ_{f}	2100. ± 200.	1.0502	986.	
95-Am-242m	σ_{γ}	1290. ± 300.	1.100	211.	[9]
	σ_{0f}	6200. ± 200.	1.104	1570. ± 80.	

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

Nuclide	Type	Thermal Cross Section σ_x [barn]	Westcott Factor g	Resonance Integral RI [barn]	Source
95-Am-243	$\sigma_{0\gamma}$	75.1 ± 1.8	1.014	1820. ± 70.	[10]
	σ_f	0.1983 ± 0.0043	1.012	8.5 ± 0.5	
96-Cm-242	σ_γ	16. ± 5.	0.9939	110. ± 20.	[11]
	σ_f	< 5.	0.9964	12.9 ± 0.7	
96-Cm-243	$\sigma_{0\gamma}$	130. ± 10.	1.005	215. ± 20.	[1]
	σ_{0f}	617. ± 20.	1.0054	1570. ± 100.	
96-Cm-244	$\sigma_{0\gamma}$	15.2 ± 1.2	0.999	655. ± 30.	[1]
	σ_{0f}	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; σ_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.

References

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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 β3; uncertainty in prompt-neutron yield estimated from the U-238 covariance files included in the ENDF/B-VII β1 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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Table 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	

Table 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	

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

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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 $T_{1/2}$		Units	Decay mode	Branching Fraction		Source	Notes
35-Br- 85	2.90	± 0.06	m	β^-	1.0		ENSDF	[1]
36-Kr- 85	10.752	± 0.023	y	β^-	1.0		BIPM-5	
36-Kr- 85m	4.480	± 0.008	h	IT	0.214	± 0.005	ENSDF	
				β^-	0.786	± 0.005		
38-Sr- 90	28.80	± 0.07	y	β^-	1.0		LNHB	
40-Zr- 95	64.032	± 0.006	d	β^-	1.0		LNHB	
41-Nb- 94	(7.3	± 0.9) × 10^6	d	β^-	1.0		IAEA-CRP-XG	
41-Nb- 95	34.985	± 0.012	d	β^-	1.0		IAEA-CRP-XG	
41-Nb- 95m	3.61	± 0.03	d	IT	0.975	± 0.001	LNHB	[2]
				β^-	0.025	± 0.001		
43-Tc- 99	(2.111	± 0.012) × 10^5	y	β^-	1.0		ENSDF	
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	
50-Sn-121m	55.	± 5.	y	β^-	0.224	± 0.020	ENSDF	
				IT	0.776	± 0.020		

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

Nuclide	Half-life $T_{1/2}$		Units	Decay mode	Branching Fraction		Source	Notes
51-Sb-122	2.7238	± 0.0002	d	EC	0.0241	± 0.0012	ENSDF	
				β^-	0.9759	± 0.0012		
51-Sb-124	60.20	± 0.03	d	β^-	1.0		ENSDF	
51-Sb-125	2.7584	± 0.0006	y	β^-	1.0		IAEA-CRP-XG	
53- I -129	(5.89	± 0.23) × 10^9	d	β^-	1.0		IAEA-CRP-XG	
53- I -131	8.0233	± 0.0019	d	β^-	1.0		BIPM-5	
53- I -133	20.87	± 0.08	h	β^-	1.0		LNHB	[3]
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	0.997	± 0.003	ENSDF	[4]
				β^-	0.003	± 0.003		
55-Cs-134	2.063	± 0.003	y	β^-	0.999997	± 0.000001	IAEA-CRP-XG	[5]
				EC	0.000003	± 0.000001		
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	± 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^-	0.958	± 0.007	ENSDF	
				IT	0.042	± 0.007		

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

Nuclide	Half-life $T_{1/2}$	Units	Decay mode	Branching Fraction		Source	Notes
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. ± 8.	y	β^-	1.0		ENSDF	
62-Sm-153	1.938 ± 0.010	d	β^-	1.0		IAEA-CRP-XG	
63-Eu-152	(4.941 ± 0.007) × 10^3	d	EC	0.721	± 0.003	IAEA-CRP-XG	[6]
			β^-	0.279	± 0.003		
63-Eu-154	(3.1381 ± 0.0014) × 10^3	d	β^-	0.99982	± 0.00013	IAEA-CRP-XG	[6]
			EC	0.00018	± 0.00013		
63-Eu-155	4.753 ± 0.016	y	β^-	1.0		IAEA-CRP-XG	

1 y = 1 year = 365.24219878 days

[1] β- decay branches of 0.9982 ± 0.0002 to Kr-85m and 0.0018 ± 0.0002 to Kr-85.

[2] ENSDF branching fractions: 0.944 ± 0.007 for IT and 0.056 ± 0.007 for β-.

[3] β- decay branch of 0.0288 ± 0.0002 to Xe-133m.

[4] Branching fractions were averaged from ENSDF database.

[5] Branching fractions were adopted from ENSDF database.

[6] Branching fractions were adopted from LNHB 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, 2004.

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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 $T_{1/2}$	Units	γ rays Energy [keV]	Emission probability [% decay]	Source	Notes
35-Br-85	2.90 ± 0.06	m	802.41 ± 0.10	2.56 ± 0.16	ENSDF	
			861.76 ± 0.08	0.228 ± 0.019		
	0.06		919.06 ± 0.08	0.65 ± 0.05		
			924.63 ± 0.08	1.63 ± 0.13		
			1727.02 ± 0.11	0.38 ± 0.03		
36-Kr- 85	10.752 ± 0.023	y	513.997 ± 0.005	0.435 ± 0.010	BIPM-5	
36-Kr-85m	4.480 ± 0.008	h	129.81 ± 0.02	0.300 ± 0.008	ENSDF	[1]
			151.195 ± 0.006	75.0 ± 0.6		[1]
			304.87 ± 0.02	14.0 ± 0.3		[2]
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-94	(7.3 ± 0.9) × 10^6	d	702.639 ± 0.004	99.815 ± 0.006	IAEA-CRP-XG	
			871.114 ± 0.003	99.892 ± 0.003		
41-Nb- 95	34.985 ± 0.012	d	765.803 ± 0.006	99.808 ± 0.007	IAEA-CRP-XG	
41-Nb- 95m	3.61 ± 0.03	d	235.69 ± 0.02	25.1 ± 0.3	LNHB	
43-Tc-99	(2.111 ± 0.012) × 10^5	y	89.5 ± 0.2	0.00065 ± 0.00015	ENSDF	
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		
			610.33 ± 0.02	5.78 ± 0.03		
45-Rh-106	30.1 ± 0.3	s	511.8534 ± 0.0023	20.50 ± 0.21	IAEA-CRP-XG	[3]
			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		
			1128.07 ± 0.05	0.399 ± 0.006		
50-Sn-121m	55. ± 5.	y	37.15 ± 0.04	1.85 ± 0.17	ENSDF	[1]

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

Nuclide	Half-life $T_{1/2}$	Units	γ rays Energy [keV]	Emission probability [% decay]	Source	Notes
51-Sb-122	2.7238 ± 0.0002	d	564.24 ± 0.04	70.68 ± 0.18	ENSDF	[1]
			692.65 ± 0.04	3.85 ± 0.13		[1]
			1140.67 ± 0.04	0.76 ± 0.04		[4]
			1256.93 ± 0.04	0.81 ± 0.04		[1]
51-Sb-124	60.20 ± 0.03	d	602.7275 ± 0.0017	98.3 ± 0.3	ENSDF	
			645.8537 ± 0.0013	7.46 ± 0.03		
			709.320 ± 0.013	1.360 ± 0.012		
			713.781 ± 0.005	2.287 ± 0.017		
			722.7842 ± 0.0022	10.81 ± 0.05		
			790.711 ± 0.005	0.743 ± 0.005		
			968.199 ± 0.003	1.892 ± 0.010		
			1045.128 ± 0.003	1.841 ± 0.012		
			1325.508 ± 0.003	1.588 ± 0.015		
			1355.175 ± 0.022	1.043 ± 0.013		
			1368.160 ± 0.004	2.623 ± 0.018		
			1436.561 ± 0.006	1.222 ± 0.008		
			1488.888 ± 0.024	0.675 ± 0.006		
			1690.975 ± 0.004	47.79 ± 0.18		
			2090.936 ± 0.005	5.51 ± 0.03		
51-Sb-125	2.7584 ± 0.0006	y	176.314 ± 0.002	6.82 ± 0.07	IAEA-CRP-XG	
			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		
53-I-129	(5.89 ± 0.23) × 10^9	d	39.578 ± 0.004	7.42 ± 0.08	IAEA-CRP-XG	
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		
53-I-133	20.87 ± 0.08	h	262.70 ± 0.06	0.356 ± 0.012	LNHB	
			422.903 ± 0.007	0.309 ± 0.010		
			510.530 ± 0.022	1.81 ± 0.06		
			529.8709 ± 0.0030	86.3 ± 0.2		
			617.978 ± 0.010	0.539 ± 0.015		
			680.252 ± 0.009	0.645 ± 0.019		
			706.575 ± 0.006	1.49 ± 0.04		
			768.360 ± 0.006	0.457 ± 0.015		
			856.278 ± 0.009	1.23 ± 0.04		
			875.328 ± 0.005	4.47 ± 0.12		
			1052.393 ± 0.017	0.551 ± 0.016		
			1236.443 ± 0.005	1.49 ± 0.04		
			1298.227 ± 0.005	2.33 ± 0.07		
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		

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

Nuclide	Half-life $T_{1/2}$	Units	γ rays Energy [keV]	Emission probability [% decay]	Source	Notes
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	[5]
			1489.148 ± 0.003	0.296 ± 0.005		
			2185.645 ± 0.005	0.680 ± 0.018		
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	[6]
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		

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

Nuclide	Half-life $T_{1/2}$	Units	γ rays Energy [keV]	Emission probability [% decay]	Source	Notes
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-152	(4.941 ± 0.007) × 10^3	d	121.7817 ± 0.0003	28.41 ± 0.13	IAEA-CRP-XG	[4]
			244.6974 ± 0.0008	7.55 ± 0.04		[4]
			344.2785 ± 0.0012	26.58 ± 0.12		[1]
			411.1165 ± 0.0012	2.237 ± 0.010		[1]
			443.965 ± 0.003	3.125 ± 0.014		[4]
			778.9045 ± 0.0024	12.96 ± 0.06		[1]
			867.380 ± 0.003	4.241 ± 0.023		[4]
			964.072 ± 0.018	14.62 ± 0.06		[4]
			1085.837 ± 0.010	10.13 ± 0.06		[4]
			1089.737 ± 0.005	1.731 ± 0.010		[1]
			1112.076 ± 0.003	13.40 ± 0.06		[4]
			1212.948 ± 0.011	1.415 ± 0.009		[4]
			1299.142 ± 0.008	1.632 ± 0.009		[1]
			1408.013 ± 0.003	20.85 ± 0.09		[4]
63-Eu-154	(3.1381 ± 0.0014) × 10^3	d	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] Gamma emission arises from β^- decay mode.
[2] Gamma emission arises from isomeric transition decay mode.
[3] 511.8534-keV emission is extremely close in energy to any annihilation radiation.
[4] Gamma emission arises from electron-capture decay mode.
[5] Half-life adopted from ENSDF; gamma-ray data taken from IAEA-CRP-XG.
[6] Only low intensity emission (no alternative).

B-3. X-ray energies and emission probabilities for fission products.

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LNHB: Laboratoire National Henri Becquerel, Recommended Data, http://www.nucleide.org/DDEP_WG/DDEPdata.htm, 5 June 2008.

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Table B-3. X-ray energies and emission probabilities for fission products.

Nuclide	Half-life $T_{1/2}$	Units	Decay mode	Origin	Energy [keV]	Emission probability [% decay]	Source
41-Nb-95m	3.61 ± 0.03	d	IT	Nb	$K\alpha_2$ 16.521	12.5 ± 0.6	LNHB
					$K\alpha_1$ 16.615	23.9 ± 1.0	
					$K'\beta_1$ 18.607 - 18.780	6.19 ± 0.27	
					$K'\beta_2$ 18.952 - 18.982	0.93 ± 0.05	
44-Ru-103	39.247 ± 0.013	d	β^-	Rh	L 2.38 - 3.36	4.12 ± 0.19	IAEA-CRP-XG
					$K\alpha_2$ 20.074	2.48 ± 0.15	
					$K\alpha_1$ 20.216	4.7 ± 0.3	
					$K'\beta_1$ 22.699 - 22.911	1.28 ± 0.08	
					$K'\beta_2$ 23.172 - 23.217	0.212 ± 0.015	
51-Sb-125	2.7584 ± 0.0006	y	β^-	Te	$K\alpha_2$ 27.2020 ± 0.0002	19.1 ± 0.7	IAEA-CRP-XG
					$K\alpha_1$ 27.4726 ± 0.0002	35.7 ± 1.2	
					$K'\beta_1$ 30.945 - 31.236	10.2 ± 0.4	
					$K'\beta_2$ 31.701 - 31.774	2.21 ± 0.10	
53-I-129	$(5.89 \pm 0.23) \times 10^9$	d	β^-	Xe	L 3.64 - 5.30	7.9 ± 0.4	IAEA-CRP-XG
					$K\alpha_2$ 29.459 ± 0.002	20.1 ± 0.3	
					$K\alpha_1$ 29.779 ± 0.001	37.2 ± 0.6	
					$K'\beta_1$ 33.56 - 33.88	10.3 ± 0.4	
					$K'\beta_2$ 34.41 - 34.55	2.30 ± 0.13	
53-I-131	8.0233 ± 0.0019	d	β^-	Xe	L 3.64 - 5.30	0.635 ± 0.013	LNHB
					$K\alpha_2$ 29.459 ± 0.002	1.54 ± 0.04	
					$K\alpha_1$ 29.779 ± 0.001	2.85 ± 0.07	
					$K'\beta_1$ 33.56 - 33.88	0.826 ± 0.021	
					$K'\beta_2$ 34.41 - 34.55	0.195 ± 0.007	
54-Xe-131m	11.930 ± 0.016	d	IT	Xe	L 3.64 - 5.3	8.13 ± 0.21	LNHB
					$K\alpha_2$ 29.459 ± 0.002	15.4 ± 0.7	
					$K\alpha_1$ 29.779 ± 0.001	28.5 ± 1.3	
					$K'\beta_1$ 33.56 - 33.88	8.3 ± 0.4	
					$K'\beta_2$ 34.41 - 34.55	1.95 ± 0.10	
55-Cs-137	30.05 ± 0.08	y	β^-	Ba	L 3.954 - 5.973	0.90 ± 0.05	IAEA-CRP-XG
					$K\alpha_2$ 31.8174	1.95 ± 0.04	
					$K\alpha_1$ 32.1939	3.59 ± 0.07	
					$K'\beta_1$ 36.31 - 36.67	1.055 ± 0.022	
					$K'\beta_2$ 37.26 - 37.43	0.266 ± 0.008	
58-Ce-141	32.508 ± 0.010	d	β^-	Pr	L 4.45 - 6.81	2.43 ± 0.10	IAEA-CRP-XG
					$K\alpha_2$ 35.5506 ± 0.0002	4.74 ± 0.11	
					$K\alpha_1$ 36.0267 ± 0.0002	8.65 ± 0.12	
					$K'\beta_1$ 40.65 - 41.05	2.63 ± 0.05	
					$K'\beta_2$ 41.77 - 41.97	0.674 ± 0.018	

Table B-3. X-ray energies and emission probabilities for fission products.

Nuclide	Half-life $T_{1/2}$	Units	Decay mode	Origin		Energy [keV]			Emission probability [% decay]		Source
58-Ce-144/ 59-Pr-144	285.1 ± 0.6	d	β^-	Pr	L	4.45	-	6.81	1.42	± 0.14	IAEA-CRP-XG
					$K\alpha_2$	35.5506	±	0.0002	2.56	± 0.11	
					$K\alpha_1$	36.0267	±	0.0002	4.69	± 0.19	
					$K'\beta_1$	40.65	-	41.05	1.41	± 0.06	
					$K'\beta_2$	41.77	-	41.97	0.360	± 0.015	
62-Sm-153	1.938 ± 0.010	d	β^-	Eu	L	5.18	-	8.03	10.04	± 0.15	IAEA-CRP-XG
					$K\alpha_2$	40.9024			16.3	± 0.3	
					$K\alpha_1$	41.5427			29.3	± 0.4	
					$K'\beta_1$	46.90	-	48.27	9.20	± 0.14	
					$K'\beta_2$	48.39	-	48.50	2.36	± 0.11	
63-Eu-152	$(4.941 \pm 0.007) \times 10^3$	d	EC	Sm	L	5.61	-	7.18	13.0	± 0.4	IAEA-CRP-XG
					$K\alpha_2$	39.5229			20.8	± 0.3	
					$K\alpha_1$	40.1186			37.7	± 0.5	
					$K'\beta_1$	45.289	-	45.731	11.78	± 0.19	
					$K'\beta_2$	46.575	-	46.813	3.04	± 0.08	
63-Eu-154	$(3.1381 \pm 0.0014) \times 10^3$	d	β^-	Gd	L	5.36	-	8.10	7.1	± 0.3	IAEA-CRP-XG
					$K\alpha_2$	42.3093			7.2	± 0.2	
					$K\alpha_1$	42.9967			13.0	± 0.3	
					$K'\beta_1$	48.556	-	49.053	4.1	± 0.1	
					$K'\beta_2$	49.961	-	50.219	1.08	± 0.03	
63-Eu-155	4.753 ± 0.016	y	β^-	Gd	L	5.36	-	8.10	7.5	± 0.5	IAEA-CRP-XG
					$K\alpha_2$	42.3093			6.70	± 0.13	
					$K\alpha_1$	42.9967			12.05	± 0.23	
					$K'\beta_1$	48.556	-	49.053	3.84	± 0.11	
					$K'\beta_2$	49.961	-	50.219	0.98	± 0.03	

B-4. Fission product data: Thermal neutron cross sections, resonance integrals and Westcott factors.

References

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 β3, Incident neutron data, http://www.nndc.bnl.gov/exfor4/endf00.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/endf00.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.

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 ($g = \sigma/\sigma_o$). 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-4. Fission product data: Thermal neutron cross sections, resonance integrals and Westcott factors.

Nuclide	Type	Thermal Cross Section σ_x [barn]			Westcott Factor g	Resonance Integral RI [barn]			Source
36-Kr- 82	σ_γ	19.	±	4.	1.0004	156.	±	20.	[1]
36-Kr- 83	σ_γ	197.	±	10.	0.9979	157.	±	25.	[1]
36-Kr 84	σ_γ	0.110	±	0.015	1.0004	2.43		0.20	[1]
	$\sigma_{\gamma(g)}$	0.042	±	0.004					
	$\sigma_{\gamma(m)}$	0.090	±	0.013					
36-Kr- 85	σ_γ	1.66	±	0.20	0.9996	1.8	±	1.0	[1]
38-Sr- 90	$\sigma_{0\gamma}$	0.0104	±	0.0014	1.000	0.104	±	0.016	[1]
40-Zr- 90	σ_γ	0.077	±	0.016	1.0003	0.17	±	0.02	[1]
40-Zr- 91	σ_γ	0.83	±	0.08	1.0003	5.76	±	0.40	[1]
40-Zr- 92	σ_γ	0.26	±	0.08	1.0004	0.64	±	0.11	[2]

Table B-4. Fission product data: Thermal neutron cross sections, resonance integrals and Westcott factors.

Nuclide	Type	Thermal Cross Section σ_x [barn]	Westcott Factor g	Resonance Integral RI [barn]	Source
40-Zr- 93	σ_γ	0.696	1.0007	17.8	[3]
40-Zr- 94	σ_γ	0.0494 ± 0.0017	1.0004	0.280 ± 0.010	[1]
40-Zr- 95	$\sigma_{0\gamma}$	1.2	1.0004	7.79	[4]
40-Zr- 96	σ_γ	0.0229 ± 0.0010	1.0006	5.28 ± 0.11	[1]
41-Nb- 94	$\sigma_{0\gamma}$	14.9 ± 1.0	0.999	125. ± 8.	[1]
42-Mo- 95	σ_γ	13.4 ± 0.3	1.0000	118. ± 7.	[1]
42-Mo- 96	σ_γ	0.5 ± 0.2	1.0006	17. ± 3.	[1]
42-Mo- 97	σ_γ	2.2 ± 0.2	1.0001	14.4 ± 3.0	[1]
42-Mo- 98	$\sigma_{0\gamma}$	0.130 ± 0.006	1.0008	6.7 ± 0.3	[1]
42-Mo-100	σ_γ	0.199 ± 0.003	1.0003	3.76 ± 0.15	[1]
43 -Tc- 99	$\sigma_{0\gamma}$	22.8 ± 1.3	1.004	358. ± 20.	[1]
44-Ru-100	$\sigma_{0\gamma}$	5.8 ± 0.4	1.0003	11.2 ± 1.1	[1]
44-Ru-101	$\sigma_{0\gamma}$	5.2 ± 0.3	1.0011	102. ± 10.	[1]
44-Ru-102	$\sigma_{0\gamma}$	1.27 ± 0.04	1.0003	4.9 ± 0.3	[1]
44-Ru-103	σ_γ	1.2	1.0017	47.	[5]
44-Ru-104	$\sigma_{0\gamma}$	0.491 ± 0.010	1.0004	6.3 ± 0.2	[1]
44-Ru-106	$\sigma_{0\gamma}$	0.146 ± 0.045	1.0004	2.0 ± 0.6	[1]
51-Sb-124	$\sigma_{0\gamma}$	17.4 ± 2.8	1.000	156.	[6]
53-I-129	$\sigma_{0\gamma}$	30.3 ± 1.2	0.998	33.8 ± 1.4	[1]
54-Xe-130	$\sigma_{0\gamma}$ $\sigma_{0\gamma(m)}$	4.8 ± 1.2 0.45 ± 0.10	0.9984	4.8	[7]
54-Xe-131	$\sigma_{0\gamma}$	87. ± 10.	1.0015	890. ± 50.	[1]
54-Xe-132	$\sigma_{0\gamma}$ $\sigma_{0\gamma(m)}$	0.45 ± 0.06 0.05 ± 0.01	1.0004	5.0 ± 0.6 0.9 ± 0.2	[1]
54-Xe-133	$\sigma_{r\gamma}$	190. ± 90.	1.0004	90.	[6]
54-Xe-135	$\sigma_{0\gamma}$	2650000. ± 110000.	1.1594	7600. ± 500.	[1]
54-Xe-136	$\sigma_{0\gamma}$	0.26 ± 0.02	1.0007	0.74 ± 0.21	[8]
55-Cs-133	$\sigma_{0\gamma}$ $\sigma_{0\gamma(m)}$	30.3 ± 1.1 2.6 ± 0.1	1.0029	437. ± 26. 29.0 ± 1.1	[1]

Table B-4. Fission product data: Thermal neutron cross sections, resonance integrals and Westcott factors.

Nuclide	Type	Thermal Cross Section σ_x [barn]			Westcott Factor g	Resonance Integral RI [barn]			Source
55-Cs-134	$\sigma_{r\gamma}$	140.	±	12.	0.9985	105.			[9]
55-Cs-135	σ_{γ}	8.3	±	0.3	0.9977	37.9	±	2.7	[10]
55-Cs-137	$\sigma_{r\gamma}$	0.27	±	0.03	1.0005	0.35			[11]
58-Ce-144	σ_{γ}	1.0	±	0.1	1.0005	2.6	±	0.3	[1]
59-Pr-141	$\sigma_{0\gamma}$	11.5	±	0.3	0.9996	17.4	±	2.0	[1]
	$\sigma_{0\gamma(m)}$	3.9	±	0.3					
59-Pr-143	$\sigma_{0\gamma}$	90.	±	10.	0.9998	190.	±	25.	[1]
60-Nd-142	σ_{γ}	18.7	±	0.7	0.9990	6.2			[12]
60-Nd-143	$\sigma_{0\gamma}$	325.	±	10.	0.9967	129.	±	30.	[1]
60-Nd-144	σ_{γ}	3.6	±	0.3	1.0004	4.2	±	0.5	[1]
60-Nd-145	$\sigma_{0\gamma}$	50.0	±	1.0	1.0001	230.	±	35.	[1]
60-Nd-146	$\sigma_{0\gamma}$	1.49	±	0.06	1.0004	2.57	±	0.14	[1]
60-Nd-147	σ_{γ}	440.	±	150.	0.9957	539.8			[13]
60-Nd-148	$\sigma_{0\gamma}$	2.58	±	0.07	1.0005	15.5	±	1.5	[1]
60-Nd-150	$\sigma_{0\gamma}$	1.04	±	0.04	1.0003	15.2	±	0.8	[1]
61-Pm-147	$\sigma_{0\gamma}$	168.4	±	3.5	0.9971	2064.	±	100.	[1]
	$\sigma_{0\gamma(g)}$	96.0	±	1.8		1274.	±	66.	
	$\sigma_{0\gamma(m)}$	72.4	±	3.0		790.	±	100.	
61-Pm-148	$\sigma_{r\gamma}$	2000.	±	1000.	1.0005	2515.			[14]
61-Pm-148m	$\sigma_{0\gamma}$	10600.	±	1000.	1.4863	3600.	±	2400.	[1]
61-Pm-149	σ_{γ}	1400.	±	300.	1.0005	1577.			[14]
61-Pm-151	$\sigma_{0\gamma}$	150.			1.0068	2977.			[15]
62-Sm-147	$\sigma_{0\gamma}$	57.	±	3.	0.9965	777.	±	30.	[1]
62-Sm-148	σ_{γ}	2.4	±	0.6	0.9995	27.	±	14.	[1]
62-Sm-149	$\sigma_{0\gamma}$	40140.	±	600.	1.7102	3390.			[16]
62-Sm-150	$\sigma_{0\gamma}$	100.	±	4.	0.9985	358.	±	50.	[17]
62-Sm-151	$\sigma_{0\gamma}$	15170.	±	300.	0.9274	3765.	±	160.	[17]
62-Sm-152	$\sigma_{0\gamma}$	206.	±	6.	1.0036	2970.	±	100.	[1]
62-Sm-153	$\sigma_{0\gamma}$	420.	±	180.	0.9999	4872.			[18]

Table B-4. Fission product data: Thermal neutron cross sections, resonance integrals and Westcott factors.

Nuclide	Type	Thermal Cross Section σ_x [barn]	Westcott Factor g	Resonance Integral RI [barn]	Source
62-Sm-154	σ_γ	8.3 ± 0.5	0.9994	36. ± 4.	[1]
63-Eu-151	$\sigma_{0\gamma}$	9200. ± 100.	0.8940	3300. ± 300.	[19]
	$\sigma_{0\gamma(g)}$	5900. ± 200.		1510. ± 330.	
	$\sigma_{0\gamma(m1)}$	3300. ± 200.		1790. ± 140.	
	$\sigma_{r\,\gamma(m2)}$	4.0 ± 2.0			
63-Eu-152	$\sigma_{0\gamma}$	12800. ± 600.	0.967 ± 0.058	2310.	[20]
63-Eu-153	$\sigma_{0\gamma}$	312. ± 7.	0.9860	1420. ± 100.	[17]
63-Eu-154	$\sigma_{0\gamma}$	1340. ± 130.	1.229	1300.	[21]
63-Eu-155	σ_γ	3950. ± 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; σ_γ < 4 barns and RI = 17.5 barns are reported in ANR; σ_γ = 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 adopted from ANR; resonance integral and Westcott factor calculated from the ENDF/B-VII library; resonance integral not reported in ANR.

[7] Cross-section data and resonance integral adopted from ANR; RI uncertainty not available; Westcott factor calculated from the ENDF/B-VII library.

[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 resonace 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-152m_2 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/endf00.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

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

FPA	Fast Fission Yield [% per fission]		14-MeV Fission Yield [% per fission]	
105	0.0711	± 0.0032	1.017	± 0.060
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

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

FPA	Fast Fission Yield [% per fission]			14-MeV Fission Yield [% per fission]		
156	0.00252	±	0.00032	0.0363	±	0.0073
157	0.00086	±	0.00013	0.0187	±	0.0028
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/endf00.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

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]	
105	0.501	± 0.013	0.55	± 0.11	1.84	± 0.14
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

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]
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
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/endf00.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

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]	
107	0.1393	± 0.0060	0.184	± 0.030	1.82	± 0.47
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

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]		
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
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/endf00.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

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

FPA	Fast Fission Yield [% per fission]		14-MeV Fission Yield [% per fission]	
104	4.94	± 0.81	3.63	± 0.13
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

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

FPA	Fast Fission Yield [% per fission]			14-MeV Fission Yield [% per fission]		
155	0.127	±	0.021	0.174	±	0.030
156	0.0655	±	0.0017	0.1138	±	0.0082
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/endf00.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

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

FPA	Thermal Fission Yield [% per fission]		Fast Fission Yield [% per fission]	
103	6.948	± 0.083	6.59	± 0.16
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

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

FPA	Thermal Fission Yield [% per fission]			Fast Fission Yield [% per fission]		
154	0.281	±	0.012	0.267	±	0.049
155	0.174	±	0.030	0.171	±	0.054
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/endf00.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

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

FPA	Thermal Fission Yield [% per fission]		Fast Fission Yield [% per fission]	
103	6.54	± 0.32	5.9	± 2.7
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

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

FPA	Thermal Fission Yield [% per fission]			Fast Fission Yield [% per fission]		
154	0.368	±	0.087	0.372	±	0.010
155	0.19	±	0.35	0.231	±	0.084
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 independent 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/endf00.htm, 6 May 2008;
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 independent fission yields for selected fission products.

Fission product	Fast fission yields [% per fission]			14 MeV fission yields [% per fission]		
1- H- 1	0.00161	±	0.00055	0.00232	±	0.00080
1- H- 2	0.00049	±	0.00017	0.00071	±	0.00024
1- H- 3	0.0070	±	0.0022	0.0101	±	0.0032
2-He- 3	0.	±	0.	0.	±	0.
2-He- 4	0.102	±	0.031	0.147	±	0.045
35-Br- 85	0.270	±	0.087	0.29	±	0.10
36-Kr- 82	0.000000013	±	0.000000004	0.000000021	±	0.000000009
36-Kr- 85	0.00115	±	0.00040	0.00131	±	0.00055
36-Kr- 85m	0.000231	±	0.000081	0.000165	±	0.000070
38-Sr- 90	0.00192	±	0.00072	0.0031	±	0.0011
40-Zr- 95	0.00099	±	0.00036	0.00263	±	0.00096
41-Nb- 94	1.44E-09	±	0.51E-09	9.9E-09	±	3.5E-09
41-Nb- 95	0.000000136	±	0.000000049	0.00000066	±	0.00000024
41-Nb- 95m	0.000000027	±	0.000000010	0.000000082	±	0.000000030
42-Mo- 92	0.	±	0.	0.	±	0.
42-Mo- 94	0.	±	0.	0.	±	0.
42-Mo- 96	1.27E-10	±	0.50E-10	8.2E-10	±	3.0E-10
42-Mo- 99	0.0000125	±	0.0000044	0.000036	±	0.000013
43-Tc- 99	3.5E-10	±	1.2E-10	1.90E-09	±	0.67E-09
44-Ru-103	0.	±	0.	0.	±	0.
44-Ru-106	0.000000043	±	0.000000016	0.000056	±	0.000021
45-Rh-106	0.	±	0.	9.6E-10	±	3.5E-10
50-Sn-121m	0.0000029	±	0.0000011	0.00058	±	0.00021
51-Sb-122	7.0E-09	±	2.7E-09	0.00000122	±	0.00000045
51-Sb-124	0.0000028	±	0.0000011	0.000127	±	0.000048
51-Sb-125	0.000129	±	0.000051	0.0057	±	0.0022
52-Te-132	0.238	±	0.077	0.78	±	0.20
53- I-129	0.	±	0.	3.6E-10	±	1.5E-10
53- I-131	0.000042	±	0.000015	0.00051	±	0.00019
53- I-133	0.0155	±	0.0057	0.055	±	0.019
53- I-135	1.13	±	0.30	2.70	±	0.48
54-Xe-128	0.	±	0.	0.	±	0.
54-Xe-130	0.	±	0.	9.2E-10	±	3.7E-10
54-Xe-131m	2.19E-09	±	0.79E-09	0.000000075	±	0.000000028
54-Xe-133	0.0000074	±	0.0000027	0.000070	±	0.000026
54-Xe-133m	0.0000207	±	0.0000077	0.00032	±	0.00012

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

Fission product	Fast fission yields [% per fission]			14 MeV fission yields [% per fission]		
54-Xe-135	0.0039	±	0.0014	0.0223	±	0.0077
54-Xe-135m	0.0110	±	0.0040	0.102	±	0.035
55-Cs-134	0.000000080	±	0.000000030	0.00000254	±	0.00000098
55-Cs-137	0.0051	±	0.0019	0.077	±	0.027
56-Ba-140	0.0194	±	0.0072	0.209	±	0.066
57-La-140	0.0000095	±	0.0000036	0.00049	±	0.00017
58-Ce-141	0.000000021	±	0.000000008	0.0000032	±	0.0000012
58-Ce-144	0.00106	±	0.00041	0.0191	±	0.0065
59-Pr-144	0.000000011	±	0.000000004	0.00000077	±	0.00000027
60-Nd-142	0.	±	0.	0.	±	0.
60-Nd-144	0.	±	0.	5.3E-10	±	1.9E-10
60-Nd-147	0.00000031	±	0.00000012	0.000040	±	0.000014
61-Pm-147	0.	±	0.	2.67E-09	±	0.94E-09
61-Pm-148	0.	±	0.	0.000000024	±	0.000000009
61-Pm-148m	1.83E-10	±	0.74E-10	0.000000108	±	0.000000039
61-Pm-149	0.000000014	±	0.000000005	0.0000044	±	0.0000016
61-Pm-151	0.0000076	±	0.0000030	0.00028	±	0.00011
62-Sm-148	0.	±	0.	0.	±	0.
62-Sm-150	0.	±	0.	7.2E-09	±	2.7E-09
62-Sm-151	4.6E-10	±	1.8E-10	0.000000141	±	0.000000056
62-Sm-153	0.000000141	±	0.000000055	0.0000067	±	0.0000025
63-Eu-151	0.	±	0.	0.	±	0.
63-Eu-152	0.	±	0.	5.6E-11	±	2.1E-11
63-Eu-154	1.75E-10	±	0.69E-10	0.000000096	±	0.000000038
63-Eu-155	5.2E-09	±	2.1E-09	0.0000055	±	0.0000021

C-2.2. U-233 independent 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/endf00.htm, 6 May 2008; 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 independent fission yields for selected fission products.

Fission product	Thermal fission yields [% per fission]			Fast fission yields [% per fission]			14 MeV fission yields [% per fission]		
1- H- 1	0.0033	±	0.0011	0.0033	±	0.0011	0.0031	±	0.0011
1- H- 2	0.00085	±	0.00023	0.00102	±	0.00034	0.00095	±	0.00033
1- H- 3	0.0114	±	0.0023	0.0114	±	0.0035	0.0248	±	0.0097
2-He- 3	0.	±	0.	0.	±	0.	0.	±	0.
2-He- 4	0.211	±	0.012	0.211	±	0.033	0.196	±	0.036
35-Br- 85	0.79	±	0.19	0.72	±	0.18	0.84	±	0.23
36-Kr- 82	0.000037	±	0.000013	0.00000213	±	0.00000081	0.0000036	±	0.0000013
36-Kr- 85	0.073	±	0.025	0.0204	±	0.0072	0.030	±	0.011
36-Kr- 85m	0.0168	±	0.0058	0.0041	±	0.0015	0.0038	±	0.0013
38-Sr- 90	0.29	±	0.10	0.090	±	0.032	0.126	±	0.045
40-Zr- 95	0.261	±	0.087	0.085	±	0.030	0.160	±	0.056
41-Nb- 94	0.0000270	±	0.0000099	0.0000028	±	0.0000010	0.0000117	±	0.0000052
41-Nb- 95	0.00075	±	0.00026	0.000128	±	0.000046	0.00046	±	0.00017
41-Nb- 95m	0.000173	±	0.000061	0.0000257	±	0.0000092	0.000058	±	0.000021
42-Mo- 92	0.	±	0.	0.	±	0.	0.	±	0.
42-Mo- 94	5.4E-09	±	2.0E-09	0.	±	0.	5.7E-10	±	2.6E-10
42-Mo- 96	0.0000097	±	0.0000034	0.00000059	±	0.00000021	0.0000028	±	0.0000013
42-Mo- 99	0.0197	±	0.0071	0.0057	±	0.0021	0.0152	±	0.0054
43-Tc- 99	0.0000216	±	0.0000079	0.00000199	±	0.00000072	0.0000108	±	0.0000039
44-Ru-103	0.000120	±	0.000044	0.0000227	±	0.0000080	0.000120	±	0.000045
44-Ru-106	0.000188	±	0.000072	0.000026	±	0.000010	0.0092	±	0.0038
45-Rh-106	4.5E-09	±	1.7E-09	0.	±	0.	0.00000185	±	0.00000077
50-Sn-121m	0.00046	±	0.00016	0.00159	±	0.00062	0.112	±	0.038
51-Sb-122	0.0000130	±	0.0000047	0.000033	±	0.000012	0.00228	±	0.00083
51-Sb-124	0.00052	±	0.00019	0.00169	±	0.00062	0.030	±	0.010
51-Sb-125	0.0146	±	0.0053	0.0161	±	0.0059	0.174	±	0.059
52-Te-132	3.29	±	0.38	3.19	±	0.38	2.77	±	0.35
53- I-129	0.000195	±	0.000069	0.000204	±	0.000080	0.00217	±	0.00086
53- I-131	0.036	±	0.013	0.055	±	0.020	0.229	±	0.076
53- I-133	0.66	±	0.19	0.95	±	0.24	1.10	±	0.18
53- I-135	2.96	±	0.48	4.00	±	0.52	2.32	±	0.47
54-Xe-128	1.03E-09	±	0.37E-09	3.5E-10	±	1.7E-10	1.81E-08	±	0.69E-08
54-Xe-130	0.0000044	±	0.0000016	0.00000208	±	0.00000092	0.000035	±	0.000013
54-Xe-131m	0.000092	±	0.000033	0.000074	±	0.000027	0.00082	±	0.00029
54-Xe-133	0.0113	±	0.0041	0.0107	±	0.0038	0.029	±	0.010
54-Xe-133m	0.0273	±	0.0100	0.030	±	0.011	0.135	±	0.046

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

Fission product	Thermal fission yields [% per fission]			Fast fission yields [% per fission]			14 MeV fission yields [% per fission]		
54-Xe-135	0.343	±	0.091	0.37	±	0.10	0.463	±	0.086
54-Xe-135m	0.83	±	0.22	1.04	±	0.28	2.12	±	0.40
55-Cs-134	0.00066	±	0.00023	0.00084	±	0.00030	0.0057	±	0.0020
55-Cs-137	0.49	±	0.17	0.92	±	0.28	2.14	±	0.46
56-Ba-140	1.50	±	0.40	1.75	±	0.44	3.03	±	0.45
57-La-140	0.0178	±	0.0062	0.029	±	0.010	0.238	±	0.083
58-Ce-141	0.00063	±	0.00022	0.00072	±	0.00026	0.0158	±	0.0057
58-Ce-144	0.283	±	0.094	0.37	±	0.12	0.90	±	0.26
59-Pr-144	0.000107	±	0.000038	0.000171	±	0.000061	0.00162	±	0.00066
60-Nd-142	2.02E-10	±	0.73E-10	0.	±	0.	3.4E-08	±	1.3E-08
60-Nd-144	0.00000069	±	0.00000025	0.00000062	±	0.00000022	0.000059	±	0.000024
60-Nd-147	0.00212	±	0.00078	0.0029	±	0.0011	0.047	±	0.017
61-Pm-147	0.00000098	±	0.00000036	0.00000155	±	0.00000057	0.000180	±	0.000066
61-Pm-148	0.0000048	±	0.0000018	0.0000082	±	0.0000030	0.00037	±	0.00015
61-Pm-148m	0.0000112	±	0.0000043	0.0000222	±	0.0000083	0.00167	±	0.00069
61-Pm-149	0.000188	±	0.000070	0.00039	±	0.00014	0.0156	±	0.0064
61-Pm-151	0.0048	±	0.0021	0.0118	±	0.0041	0.147	±	0.050
62-Sm-148	3.2E-09	±	1.2E-09	2.8E-09	±	1.0E-09	0.00000152	±	0.00000063
62-Sm-150	0.00000242	±	0.00000088	0.0000032	±	0.0000011	0.00056	±	0.00024
62-Sm-151	0.000030	±	0.000011	0.000043	±	0.000016	0.0043	±	0.0018
62-Sm-153	0.00021	±	0.00013	0.00046	±	0.00019	0.0047	±	0.0016
63-Eu-151	4.3E-09	±	1.6E-09	6.5E-09	±	2.4E-09	0.0000058	±	0.0000025
63-Eu-152	3.2E-08	±	1.3E-08	6.6E-08	±	2.4E-08	0.0000179	±	0.0000071
63-Eu-154	0.0000041	±	0.0000016	0.0000147	±	0.0000057	0.00071	±	0.00028
63-Eu-155	0.000048	±	0.000020	0.000185	±	0.000073	0.0072	±	0.0027

C-2.3. U-235 independent 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/endf00.htm, 6 May 2008; 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 independent fission yields for selected fission products.

Fission product	Thermal fission yields [% per fission]			Fast fission yields [% per fission]			14 MeV fission yields [% per fission]		
1- H- 1	0.00171	±	0.00029	0.00269	±	0.00092	0.00264	±	0.00091
1- H- 2	0.00084	±	0.00024	0.00082	±	0.00027	0.00081	±	0.00027
1- H- 3	0.01080	±	0.00059	0.0108	±	0.0015	0.0174	±	0.0062
2-He- 3	0.	±	0.	0.	±	0.	0.	±	0.
2-He- 4	0.1700	±	0.0081	0.170	±	0.018	0.167	±	0.014
35-Br- 85	0.219	±	0.071	0.304	±	0.091	1.04	±	0.22
36-Kr- 82	0.000000217	±	0.000000075	0.000000108	±	0.000000033	0.00070	±	0.00026
36-Kr- 85	0.0049	±	0.0018	0.0037	±	0.0013	0.109	±	0.041
36-Kr- 85m	0.00112	±	0.00042	0.00074	±	0.00026	0.0137	±	0.0052
38-Sr- 90	0.031	±	0.012	0.0125	±	0.0046	0.211	±	0.074
40-Zr- 95	0.035	±	0.013	0.0093	±	0.0034	0.088	±	0.031
41-Nb- 94	0.000000248	±	0.000000092	1.82E-08	±	0.65E-08	0.000030	±	0.000012
41-Nb- 95	0.0000175	±	0.0000065	0.00000183	±	0.00000067	0.00056	±	0.00020
41-Nb- 95m	0.0000041	±	0.0000015	0.00000037	±	0.00000013	0.000071	±	0.000025
42-Mo- 92	0.	±	0.	0.	±	0.	0.	±	0.
42-Mo- 94	0.	±	0.	0.	±	0.	1.01E-08	±	0.41E-08
42-Mo- 96	6.9E-08	±	2.5E-08	1.66E-09	±	0.59E-09	0.0000047	±	0.0000019
42-Mo- 99	0.00180	±	0.00066	0.000188	±	0.000068	0.0044	±	0.0015
43-Tc- 99	0.00000029	±	0.00000011	5.3E-09	±	1.9E-09	0.0000046	±	0.0000016
44-Ru-103	0.0000099	±	0.0000036	0.000000236	±	0.000000084	0.0000080	±	0.0000027
44-Ru-106	0.0000028	±	0.0000011	0.0000035	±	0.0000013	0.0151	±	0.0052
45-Rh-106	0.	±	0.	0.	±	0.	0.0000093	±	0.0000032
50-Sn-121m	0.0000189	±	0.0000069	0.000041	±	0.000017	0.036	±	0.013
51-Sb-122	0.000000172	±	0.000000063	0.000000173	±	0.000000070	0.00058	±	0.00023
51-Sb-124	0.000038	±	0.000014	0.000044	±	0.000018	0.0076	±	0.0030
51-Sb-125	0.00072	±	0.00026	0.00172	±	0.00067	0.174	±	0.062
52-Te-132	1.61	±	0.37	2.15	±	0.42	3.05	±	0.35
53- I-129	0.	±	0.	0.0000027	±	0.0000013	0.0057	±	0.0022
53- I-131	0.00136	±	0.00047	0.0044	±	0.0017	0.268	±	0.092
53- I-133	0.153	±	0.053	0.33	±	0.11	0.95	±	0.20
53- I-135	2.55	±	0.54	3.79	±	0.55	3.99	±	0.60
54-Xe-128	0.	±	0.	0.	±	0.	0.00000191	±	0.00000075
54-Xe-130	4.8E-09	±	1.6E-09	9.3E-09	±	3.5E-09	0.00030	±	0.00011
54-Xe-131m	0.00000036	±	0.00000012	0.00000074	±	0.00000028	0.00237	±	0.00087

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

Fission product	Thermal fission yields [% per fission]			Fast fission yields [% per fission]			14 MeV fission yields [% per fission]		
54-Xe-133	0.00044	±	0.00016	0.00071	±	0.00026	0.0277	±	0.0096
54-Xe-133m	0.00106	±	0.00038	0.00198	±	0.00072	0.127	±	0.044
54-Xe-135	0.069	±	0.024	0.084	±	0.030	0.301	±	0.078
54-Xe-135m	0.167	±	0.057	0.236	±	0.083	1.38	±	0.36
55-Cs-134	0.0000070	±	0.0000026	0.0000148	±	0.0000054	0.0051	±	0.0018
55-Cs-137	0.072	±	0.026	0.122	±	0.044	1.14	±	0.32
56-Ba-140	0.29	±	0.10	0.278	±	0.097	1.22	±	0.32
57-La-140	0.00052	±	0.00019	0.00057	±	0.00021	0.034	±	0.012
58-Ce-141	0.0000056	±	0.0000020	0.00000219	±	0.00000080	0.00123	±	0.00044
58-Ce-144	0.035	±	0.013	0.0219	±	0.0081	0.180	±	0.057
59-Pr-144	0.00000168	±	0.00000063	0.00000072	±	0.00000027	0.000070	±	0.000025
60-Nd-142	0.	±	0.	0.	±	0.	3.0E-09	±	1.1E-09
60-Nd-144	1.08E-09	±	0.41E-09	0.	±	0.	0.00000165	±	0.00000058
60-Nd-147	0.000074	±	0.000026	0.0000168	±	0.0000062	0.00108	±	0.00039
61-Pm-147	3.5E-09	±	1.2E-09	3.1E-10	±	1.1E-10	0.00000145	±	0.00000052
61-Pm-148	4.4E-08	±	1.7E-08	6.5E-09	±	2.4E-09	0.00000106	±	0.00000040
61-Pm-148m	0.000000104	±	0.000000039	1.78E-08	±	0.66E-08	0.0000048	±	0.0000018
61-Pm-149	0.0000047	±	0.0000017	0.00000100	±	0.00000038	0.000088	±	0.000034
61-Pm-151	0.00067	±	0.00025	0.00025	±	0.00010	0.0029	±	0.0011
62-Sm-148	0.	±	0.	0.	±	0.	1.98E-09	±	0.75E-09
62-Sm-150	1.64E-08	±	0.60E-08	8.3E-10	±	3.1E-10	0.00000091	±	0.00000035
62-Sm-151	0.00000052	±	0.00000019	3.7E-08	±	1.5E-08	0.0000078	±	0.0000031
62-Sm-153	0.0000221	±	0.0000095	0.0000043	±	0.0000016	0.000058	±	0.000021
63-Eu-151	0.	±	0.	0.	±	0.	2.6E-09	±	1.0E-09
63-Eu-152	1.53E-10	±	0.57E-10	0.	±	0.	1.0E-08	±	0.4E-08
63-Eu-154	0.000000103	±	0.000000047	1.91E-08	±	0.71E-08	0.00000113	±	0.00000045
63-Eu-155	0.0000029	±	0.0000011	0.00000062	±	0.00000026	0.000026	±	0.000010

C-2.4. U-238 independent 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/endf00.htm, 6 May 2008; 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 independent fission yields for selected fission products.

Fission product	Fast fission yields [% per fission]			14 MeV fission yields [% per fission]		
1- H- 1	0.00235	±	0.00081	0.00130	±	0.00046
1- H- 2	0.00072	±	0.00024	0.00040	±	0.00014
1- H- 3	0.0103	±	0.0032	0.0065	±	0.0025
2-He- 3	0.	±	0.	0.	±	0.
2-He- 4	0.149	±	0.045	0.082	±	0.011
35-Br- 85	0.046	±	0.016	0.077	±	0.028
36-Kr- 82	1.14E-09	±	0.44E-09	6.5E-09	±	2.3E-09
36-Kr- 85	0.000185	±	0.000066	0.00047	±	0.00017
36-Kr- 85m	0.000037	±	0.000013	0.000060	±	0.000021
38-Sr- 90	0.00078	±	0.00029	0.00288	±	0.00099
40-Zr- 95	0.00094	±	0.00034	0.0053	±	0.0019
41-Nb- 94	1.18E-09	±	0.43E-09	2.51E-08	±	0.93E-08
41-Nb- 95	0.000000132	±	0.000000048	0.00000196	±	0.00000069
41-Nb- 95m	2.66E-08	±	0.96E-08	0.000000247	±	0.000000087
42-Mo- 92	0.	±	0.	0.	±	0.
42-Mo- 94	0.	±	0.	0.	±	0.
42-Mo- 96	1.50E-10	±	0.57E-10	3.2E-09	±	1.4E-09
42-Mo- 99	0.0000260	±	0.0000094	0.000256	±	0.000092
43-Tc- 99	7.3E-10	±	2.6E-10	2.01E-08	±	0.73E-08
44-Ru-103	7.0E-08	±	2.5E-08	0.00000072	±	0.00000026
44-Ru-106	0.00197	±	0.00076	0.000221	±	0.000087
45-Rh-106	0.000000182	±	0.000000070	9.3E-11	±	3.7E-11
50-Sn-121m	0.00000027	±	0.00000010	0.00059	±	0.00022
51-Sb-122	4.1E-10	±	1.6E-10	0.00000085	±	0.00000032
51-Sb-124	0.00000027	±	0.00000010	0.000075	±	0.000027
51-Sb-125	0.0000161	±	0.0000065	0.0036	±	0.0013
52-Te-132	0.34	±	0.11	0.90	±	0.28
53- I-129	1.33E-10	±	0.50E-10	3.5E-10	±	1.3E-10
53- I-131	0.000051	±	0.000017	0.00057	±	0.00020
53- I-133	0.0170	±	0.0060	0.068	±	0.025
53- I-135	1.12	±	0.32	1.99	±	0.48
54-Xe-128	0.	±	0.	0.	±	0.
54-Xe-130	0.	±	0.	6.9E-10	±	2.2E-10
54-Xe-131m	2.03E-09	±	0.68E-09	7.2E-08	±	2.5E-08
54-Xe-133	0.0000067	±	0.0000024	0.000089	±	0.000032

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

Fission product	Fast fission yields [% per fission]			14 MeV fission yields [% per fission]		
54-Xe-133m	0.0000188	±	0.0000067	0.00041	±	0.00015
54-Xe-135	0.0038	±	0.0014	0.0256	±	0.0095
54-Xe-135m	0.0106	±	0.0038	0.117	±	0.044
55-Cs-134	6.0E-08	±	2.1E-08	0.0000033	±	0.0000012
55-Cs-137	0.0044	±	0.0016	0.083	±	0.030
56-Ba-140	0.0142	±	0.0052	0.192	±	0.076
57-La-140	0.0000068	±	0.0000025	0.00072	±	0.00027
58-Ce-141	1.58E-08	±	0.55E-08	0.0000058	±	0.0000021
58-Ce-144	0.00066	±	0.00024	0.028	±	0.011
59-Pr-144	6.9E-09	±	2.5E-09	0.00000168	±	0.00000065
60-Nd-142	0.	±	0.	0.	±	0.
60-Nd-144	0.	±	0.	1.70E-09	±	0.66E-09
60-Nd-147	0.00000032	±	0.00000012	0.000132	±	0.000048
61-Pm-147	0.	±	0.	1.39E-08	±	0.51E-08
61-Pm-148	1.0E-10	±	0.4E-10	0.000000105	±	0.000000039
61-Pm-148m	2.72E-10	±	0.99E-10	0.00000048	±	0.00000018
61-Pm-149	2.53E-08	±	0.92E-08	0.0000237	±	0.0000087
61-Pm-151	0.0000182	±	0.0000067	0.0035	±	0.0013
62-Sm-148	0.	±	0.	0.	±	0.
62-Sm-150	0.	±	0.	9.2E-08	±	3.9E-08
62-Sm-151	1.19E-09	±	0.44E-09	0.0000031	±	0.0000012
62-Sm-153	0.00000033	±	0.00000012	0.000094	±	0.000035
63-Eu-151	0.	±	0.	1.04E-10	±	0.39E-10
63-Eu-152	0.	±	0.	1.60E-09	±	0.66E-09
63-Eu-154	9.1E-10	±	3.3E-10	0.00000150	±	0.00000061
63-Eu-155	5.6E-08	±	2.2E-08	0.000063	±	0.000025

C-2.5. Pu-239 independent 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/endf00.htm, 6 May 2008; 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 independent fission yields for selected fission products.

Fission product	Thermal fission yields [% per fission]			Fast fission yields [% per fission]		
1- H- 1	0.00408	±	0.00071	0.0035	±	0.0012
1- H- 2	0.00135	±	0.00029	0.00106	±	0.00035
1- H- 3	0.0142	±	0.0011	0.0142	±	0.0033
2-He- 3	0.	±	0.	0.	±	0.
2-He- 4	0.219	±	0.012	0.219	±	0.025
35-Br- 85	0.209	±	0.051	0.171	±	0.051
36-Kr- 82	0.0000050	±	0.0000019	0.00000046	±	0.00000016
36-Kr- 85	0.0117	±	0.0042	0.0048	±	0.0017
36-Kr- 85m	0.00270	±	0.00098	0.00096	±	0.00034
38-Sr- 90	0.057	±	0.021	0.0240	±	0.0088
40-Zr- 95	0.133	±	0.048	0.058	±	0.021
41-Nb- 94	0.0000099	±	0.0000036	0.00000160	±	0.00000058
41-Nb- 95	0.00036	±	0.00013	0.000085	±	0.000031
41-Nb- 95m	0.000084	±	0.000031	0.0000170	±	0.0000062
42-Mo- 92	0.	±	0.	0.	±	0.
42-Mo- 94	1.52E-09	±	0.56E-09	0.	±	0.
42-Mo- 96	0.0000048	±	0.0000017	0.00000050	±	0.00000018
42-Mo- 99	0.0191	±	0.0069	0.0064	±	0.0023
43-Tc- 99	0.0000133	±	0.0000048	0.00000216	±	0.00000077
44-Ru-103	0.00035	±	0.00013	0.000083	±	0.000030
44-Ru-106	0.30	±	0.10	0.187	±	0.072
45-Rh-106	0.00082	±	0.00030	0.000255	±	0.000096
50-Sn-121m	0.00047	±	0.00018	0.00044	±	0.00017
51-Sb-122	0.0000112	±	0.0000041	0.0000066	±	0.0000025
51-Sb-124	0.00097	±	0.00035	0.00060	±	0.00022
51-Sb-125	0.0125	±	0.0044	0.0155	±	0.0055
52-Te-132	2.94	±	0.45	3.00	±	0.46
53- I-129	0.000065	±	0.000023	0.000074	±	0.000025
53- I-131	0.0234	±	0.0081	0.037	±	0.013
53- I-133	0.64	±	0.20	0.87	±	0.26
53- I-135	4.19	±	0.62	4.96	±	0.61
54-Xe-128	1.64E-10	±	0.58E-10	0.	±	0.
54-Xe-130	0.00000116	±	0.00000036	0.00000099	±	0.00000033
54-Xe-131m	0.000032	±	0.000011	0.000036	±	0.000013
54-Xe-133	0.0071	±	0.0026	0.0085	±	0.0031
54-Xe-133m	0.0172	±	0.0063	0.0238	±	0.0086

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

Fission product	Thermal fission yields [% per fission]			Fast fission yields [% per fission]		
54-Xe-135	0.306	±	0.097	0.34	±	0.11
54-Xe-135m	0.74	±	0.24	0.94	±	0.30
55-Cs-134	0.00039	±	0.00014	0.00061	±	0.00022
55-Cs-137	0.46	±	0.16	0.69	±	0.25
56-Ba-140	0.88	±	0.28	1.11	±	0.35
57-La-140	0.0113	±	0.0040	0.0209	±	0.0075
58-Ce-141	0.00029	±	0.00011	0.00044	±	0.00016
58-Ce-144	0.163	±	0.060	0.243	±	0.088
59-Pr-144	0.000064	±	0.000024	0.000114	±	0.000041
60-Nd-142	0.	±	0.	0.	±	0.
60-Nd-144	0.000000261	±	0.000000096	0.00000038	±	0.00000014
60-Nd-147	0.00174	±	0.00063	0.0030	±	0.0011
61-Pm-147	0.00000077	±	0.00000028	0.00000155	±	0.00000057
61-Pm-148	0.0000050	±	0.0000019	0.0000105	±	0.0000040
61-Pm-148m	0.0000118	±	0.0000044	0.000029	±	0.000011
61-Pm-149	0.000272	±	0.000098	0.00066	±	0.00024
61-Pm-151	0.0140	±	0.0048	0.028	±	0.011
62-Sm-148	2.18E-09	±	0.81E-09	3.5E-09	±	1.3E-09
62-Sm-150	0.0000032	±	0.0000011	0.0000066	±	0.0000024
62-Sm-151	0.000053	±	0.000019	0.000110	±	0.000041
62-Sm-153	0.00087	±	0.00031	0.00150	±	0.00077
63-Eu-151	7.3E-09	±	2.6E-09	1.67E-08	±	0.62E-08
63-Eu-152	9.2E-08	±	3.3E-08	0.000000208	±	0.000000081
63-Eu-154	0.0000258	±	0.0000092	0.000061	±	0.000024
63-Eu-155	0.00037	±	0.00014	0.00094	±	0.00042

C-2.6. Pu-241 independent 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/endf00.htm, 6 May 2008; 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 independent fission yields for selected fission products.

Fission product	Thermal fission yields [% per fission]			Fast fission yields [% per fission]		
1- H- 1	0.0029	±	0.0010	0.0029	±	0.0010
1- H- 2	0.00090	±	0.00030	0.00090	±	0.00030
1- H- 3	0.0141	±	0.0021	0.0141	±	0.0043
2-He- 3	0.	±	0.	0.	±	0.
2-He- 4	0.186	±	0.020	0.186	±	0.056
35-Br- 85	0.069	±	0.028	0.066	±	0.021
36-Kr- 82	8.0E-08	±	3.4E-08	2.6E-08	±	1.2E-08
36-Kr- 85	0.00152	±	0.00062	0.00078	±	0.00028
36-Kr- 85m	0.00035	±	0.00014	0.000157	±	0.000057
38-Sr- 90	0.0082	±	0.0031	0.0043	±	0.0016
40-Zr- 95	0.0200	±	0.0075	0.0108	±	0.0039
41-Nb- 94	0.000000177	±	0.000000068	8.0E-08	±	2.8E-08
41-Nb- 95	0.0000130	±	0.0000049	0.0000062	±	0.0000023
41-Nb- 95m	0.0000030	±	0.0000011	0.00000125	±	0.00000045
42-Mo- 92	0.	±	0.	0.	±	0.
42-Mo- 94	0.	±	0.	0.	±	0.
42-Mo- 96	6.1E-08	±	2.4E-08	2.00E-08	±	0.75E-08
42-Mo- 99	0.00177	±	0.00064	0.00059	±	0.00031
43-Tc- 99	0.000000252	±	0.000000092	7.5E-08	±	4.0E-08
44-Ru-103	0.0000165	±	0.0000061	0.0000058	±	0.0000029
44-Ru-106	0.105	±	0.043	0.071	±	0.027
45-Rh-106	0.000073	±	0.000030	0.000033	±	0.000012
50-Sn-121m	0.0000103	±	0.0000043	0.0000026	±	0.0000012
51-Sb-122	0.000000188	±	0.000000079	5.7E-08	±	2.6E-08
51-Sb-124	0.000073	±	0.000031	0.000027	±	0.000012
51-Sb-125	0.0032	±	0.0014	0.00136	±	0.00055
52-Te-132	1.16	±	0.34	1.39	±	0.39
53- I-129	2.3E-10	±	1.1E-10	3.8E-10	±	1.4E-10
53- I-131	0.00092	±	0.00033	0.00255	±	0.00090
53- I-133	0.130	±	0.046	0.227	±	0.081
53- I-135	2.41	±	0.60	3.36	±	0.65
54-Xe-128	0.	±	0.	0.	±	0.
54-Xe-130	1.90E-09	±	0.87E-09	1.0E-08	±	0.4E-08
54-Xe-131m	0.000000166	±	0.000000060	0.00000063	±	0.00000022
54-Xe-133	0.000262	±	0.000094	0.00059	±	0.00021

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

Fission product	Thermal fission yields [% per fission]			Fast fission yields [% per fission]		
54-Xe-133m	0.00063	±	0.00023	0.00166	±	0.00059
54-Xe-135	0.051	±	0.019	0.081	±	0.030
54-Xe-135m	0.124	±	0.046	0.227	±	0.083
55-Cs-134	0.0000053	±	0.0000020	0.0000203	±	0.0000076
55-Cs-137	0.065	±	0.024	0.141	±	0.052
56-Ba-140	0.178	±	0.068	0.29	±	0.11
57-La-140	0.00038	±	0.00014	0.00126	±	0.00046
58-Ce-141	0.00000275	±	0.00000099	0.0000098	±	0.0000038
58-Ce-144	0.0174	±	0.0067	0.039	±	0.015
59-Pr-144	0.00000098	±	0.00000038	0.0000040	±	0.0000015
60-Nd-142	0.	±	0.	0.	±	0.
60-Nd-144	4.4E-10	±	1.7E-10	2.9E-09	±	1.1E-09
60-Nd-147	0.000043	±	0.000016	0.000141	±	0.000051
61-Pm-147	2.23E-09	±	0.83E-09	1.50E-08	±	0.55E-08
61-Pm-148	3.8E-08	±	1.4E-08	0.000000195	±	0.000000071
61-Pm-148m	8.9E-08	±	3.2E-08	0.00000053	±	0.00000019
61-Pm-149	0.0000045	±	0.0000018	0.0000215	±	0.0000079
61-Pm-151	0.00102	±	0.00048	0.0033	±	0.0012
62-Sm-148	0.	±	0.	0.	±	0.
62-Sm-150	1.42E-08	±	0.56E-08	8.6E-08	±	3.1E-08
62-Sm-151	0.00000055	±	0.00000026	0.00000257	±	0.00000094
62-Sm-153	0.000045	±	0.000023	0.000122	±	0.000062
63-Eu-151	0.	±	0.	0.	±	0.
63-Eu-152	2.9E-10	±	1.1E-10	1.89E-09	±	0.68E-09
63-Eu-154	0.00000047	±	0.00000020	0.00000203	±	0.00000075
63-Eu-155	0.000013	±	0.000012	0.000059	±	0.000029

C-3.1. Th-232 cumulative 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/endf00.htm, 6 May 2008; 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-3.1. Th-232 cumulative fission yields for selected fission products.

Fission product	Fast fission yields [% per fission]			14 MeV fission yields [% per fission]		
1- H- 1	0.00161	±	0.00027	0.00232	±	0.00039
1- H- 2	0.000491	±	0.000076	0.00071	±	0.00011
1- H- 3	0.00701	±	0.00069	0.0101	±	0.0010
2-He- 3	0.00701	±	0.00069	0.0101	±	0.0010
2-He- 4	0.1016	±	0.0059	0.1467	±	0.0085
35-Br- 85	4.29	±	0.24	4.01	±	0.69
36-Kr- 82	0.000088	±	0.000034	0.000144	±	0.000085
36-Kr- 85	0.924	±	0.096	0.86	±	0.18
36-Kr- 85m	4.28	±	0.24	4.00	±	0.69
38-Sr- 90	7.32	±	0.36	6.2	±	1.5
40-Zr- 95	5.52	±	0.17	4.82	±	0.49
41-Nb- 94	2.30E-09	±	0.61E-09	1.33E-08	±	0.46E-08
41-Nb- 95	5.52	±	0.17	4.82	±	0.49
41-Nb- 95m	0.0597	±	0.0076	0.0521	±	0.0085
42-Mo- 92	0.	±	0.	0.	±	0.
42-Mo- 94	0.	±	0.	0.	±	0.
42-Mo- 96	0.0000060	±	0.0000024	0.0000220	±	0.0000087
42-Mo- 99	2.919	±	0.076	1.953	±	0.098
43-Tc- 99	2.919	±	0.076	1.953	±	0.098
44-Ru-103	0.1538	±	0.0095	0.884	±	0.064
44-Ru-106	0.0541	±	0.0031	1.101	±	0.083
45-Rh-106	0.0541	±	0.0031	1.101	±	0.083
50-Sn-121m	0.00432	±	0.00091	0.080	±	0.011
51-Sb-122	1.64E-08	±	0.52E-08	0.0000040	±	0.0000014
51-Sb-124	0.0000073	±	0.0000020	0.00046	±	0.00014
51-Sb-125	0.0560	±	0.0084	1.04	±	0.18
52-Te-132	2.60	±	0.10	2.98	±	0.15
53- I-129	0.431	±	0.089	1.68	±	0.33
53- I-131	1.513	±	0.083	2.31	±	0.14
53- I-133	4.53	±	0.19	4.12	±	0.21
53- I-135	5.45	±	0.26	5.08	±	0.35
54-Xe-128	0.	±	0.	2.5E-10	±	1.1E-10
54-Xe-130	1.56E-10	±	0.56E-10	0.0000161	±	0.0000067
54-Xe-131m	0.0164	±	0.0020	0.0250	±	0.0032
54-Xe-133	4.53	±	0.19	4.12	±	0.21

Table C-3.1. Th-232 cumulative fission yields for selected fission products.

Fission product	Fast fission yields [% per fission]			14 MeV fission yields [% per fission]		
54-Xe-133m	0.129	±	0.013	0.117	±	0.013
54-Xe-135	5.46	±	0.26	5.19	±	0.36
54-Xe-135m	0.911	±	0.095	0.94	±	0.12
55-Cs-134	0.000000150	±	0.000000041	0.0000066	±	0.0000019
55-Cs-137	6.30	±	0.30	6.29	±	0.99
56-Ba-140	7.71	±	0.25	5.69	±	0.20
57-La-140	7.71	±	0.25	5.69	±	0.20
58-Ce-141	7.11	±	0.28	5.72	±	0.38
58-Ce-144	7.66	±	0.55	3.90	±	0.78
59-Pr-144	7.66	±	0.55	3.90	±	0.78
60-Nd-142	0.	±	0.	5.1E-09	±	1.6E-09
60-Nd-144	7.66	±	0.55	3.90	±	0.78
60-Nd-147	3.03	±	0.18	1.79	±	0.11
61-Pm-147	3.03	±	0.18	1.79	±	0.11
61-Pm-148	0.	±	0.	2.9E-08	±	1.2E-08
61-Pm-148m	1.83E-10	±	0.76E-10	0.000000108	±	0.000000048
61-Pm-149	1.11	±	0.16	0.93	±	0.30
61-Pm-151	0.399	±	0.065	0.165	±	0.035
62-Sm-148	2.50E-10	±	0.79E-10	0.000000132	±	0.000000051
62-Sm-150	0.00000044	±	0.00000032	0.000042	±	0.000018
62-Sm-151	0.399	±	0.065	0.165	±	0.035
62-Sm-153	0.202	±	0.027	0.0858	±	0.0070
63-Eu-151	0.399	±	0.065	0.165	±	0.035
63-Eu-152	0.	±	0.	1.84E-10	±	0.61E-10
63-Eu-154	3.6E-10	±	1.2E-10	0.000000279	±	0.000000093
63-Eu-155	0.0158	±	0.0025	0.0552	±	0.0086

C-3.2. U-233 cumulative 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/endf00.htm, 6 May 2008;
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-3.2. U-233 cumulative fission yields for selected fission products.

Fission product	Thermal fission yields [% per fission]			Fast fission yields [% per fission]			14 MeV fission yields [% per fission]		
1- H- 1	0.00334	±	0.00055	0.00334	±	0.00055	0.00310	±	0.00059
1- H- 2	0.00085	±	0.00013	0.00102	±	0.00015	0.00095	±	0.00017
1- H- 3	0.01140	±	0.00050	0.01140	±	0.00050	0.0248	±	0.0056
2-He- 3	0.01140	±	0.00050	0.01140	±	0.00050	0.0248	±	0.0056
2-He- 4	0.2111	±	0.0080	0.2110	±	0.0080	0.196	±	0.021
35-Br- 85	2.076	±	0.030	2.08	±	0.10	2.36	±	0.52
36-Kr- 82	0.0070	±	0.0018	0.00216	±	0.00073	0.0036	±	0.0013
36-Kr- 85	0.523	±	0.048	0.468	±	0.051	0.54	±	0.13
36-Kr- 85m	2.089	±	0.029	2.08	±	0.10	2.35	±	0.52
38-Sr- 90	6.647	±	0.073	6.39	±	0.33	5.07	±	0.80
40-Zr- 95	6.385	±	0.058	6.28	±	0.18	5.05	±	0.28
41-Nb- 94	0.000046	±	0.000012	0.0000045	±	0.0000012	0.0000157	±	0.0000073
41-Nb- 95	6.382	±	0.057	6.28	±	0.18	5.05	±	0.28
41-Nb- 95m	0.0692	±	0.0082	0.0679	±	0.0084	0.0546	±	0.0077
42-Mo- 92	0.	±	0.	0.	±	0.	0.	±	0.
42-Mo- 94	0.000000101	±	0.000000035	8.4E-09	±	3.2E-09	2.1E-08	±	1.1E-08
42-Mo- 96	0.0083	±	0.0029	0.00216	±	0.00079	0.0055	±	0.0034
42-Mo- 99	5.03	±	0.14	4.85	±	0.17	3.87	±	0.22
43-Tc- 99	5.03	±	0.14	4.85	±	0.17	3.87	±	0.22
44-Ru-103	1.458	±	0.058	1.58	±	0.16	2.72	±	0.13
44-Ru-106	0.2505	±	0.0078	0.291	±	0.029	1.46	±	0.26
45-Rh-106	0.2505	±	0.0078	0.291	±	0.029	1.46	±	0.26
50-Sn-121m	0.00207	±	0.00028	0.0087	±	0.0019	0.217	±	0.056
51-Sb-122	0.0000276	±	0.0000073	0.000077	±	0.000022	0.0075	±	0.0026
51-Sb-124	0.00123	±	0.00026	0.0044	±	0.0010	0.109	±	0.030
51-Sb-125	0.116	±	0.014	0.149	±	0.011	1.515	±	0.095
52-Te-132	4.59	±	0.14	4.38	±	0.12	3.23	±	0.32
53- I-129	1.63	±	0.26	1.73	±	0.24	3.01	±	0.43
53- I-131	3.565	±	0.100	3.86	±	0.13	4.47	±	0.94
53- I-133	5.94	±	0.17	5.66	±	0.17	4.40	±	0.48
53- I-135	4.31	±	0.32	4.84	±	0.25	2.47	±	0.40
54-Xe-128	0.0000064	±	0.0000025	0.0000065	±	0.0000043	0.000135	±	0.000056
54-Xe-130	0.00325	±	0.00100	0.0034	±	0.0014	0.0246	±	0.0085
54-Xe-131m	0.0388	±	0.0040	0.0420	±	0.0044	0.049	±	0.012
54-Xe-133	5.98	±	0.17	5.70	±	0.17	4.56	±	0.49
54-Xe-133m	0.197	±	0.016	0.191	±	0.017	0.260	±	0.053

Table C-3.2. U-233 cumulative fission yields for selected fission products.

Fission product	Thermal fission yields [% per fission]			Fast fission yields [% per fission]			14 MeV fission yields [% per fission]		
54-Xe-135	5.47	±	0.37	6.25	±	0.27	5.04	±	0.64
54-Xe-135m	1.54	±	0.20	1.84	±	0.23	2.53	±	0.38
55-Cs-134	0.00114	±	0.00029	0.00158	±	0.00041	0.0147	±	0.0040
55-Cs-137	6.20	±	0.22	6.50	±	0.31	4.95	±	0.43
56-Ba-140	6.43	±	0.26	6.17	±	0.20	4.47	±	0.32
57-La-140	6.45	±	0.26	6.20	±	0.20	4.71	±	0.33
58-Ce-141	6.218	±	0.081	6.49	±	0.23	4.49	±	0.17
58-Ce-144	4.654	±	0.093	4.49	±	0.18	2.43	±	0.52
59-Pr-144	4.655	±	0.093	4.49	±	0.18	2.46	±	0.52
60-Nd-142	0.00000331	±	0.00000092	0.0000042	±	0.0000012	0.000247	±	0.000090
60-Nd-144	4.655	±	0.093	4.49	±	0.18	2.46	±	0.52
60-Nd-147	1.827	±	0.086	1.737	±	0.050	1.251	±	0.073
61-Pm-147	1.827	±	0.086	1.737	±	0.050	1.251	±	0.073
61-Pm-148	0.0000053	±	0.0000018	0.0000093	±	0.0000031	0.00045	±	0.00019
61-Pm-148m	0.0000112	±	0.0000043	0.0000222	±	0.0000083	0.00167	±	0.00079
61-Pm-149	0.769	±	0.031	0.717	±	0.034	0.81	±	0.18
61-Pm-151	0.333	±	0.017	0.312	±	0.014	0.49	±	0.11
62-Sm-148	0.0000159	±	0.0000045	0.0000304	±	0.0000086	0.00204	±	0.00082
62-Sm-150	0.00113	±	0.00042	0.00248	±	0.00089	0.055	±	0.023
62-Sm-151	0.333	±	0.017	0.312	±	0.014	0.49	±	0.11
62-Sm-153	0.106	±	0.042	0.118	±	0.022	0.144	±	0.017
63-Eu-151	0.333	±	0.017	0.312	±	0.014	0.49	±	0.11
63-Eu-152	6.8E-08	±	2.0E-08	0.0000001 52	±	0.0000000 41	0.000059	±	0.000021
63-Eu-154	0.0000078	±	0.0000022	0.0000306	±	0.0000096	0.00208	±	0.00067
63-Eu-155	0.0214	±	0.0060	0.0351	±	0.0053	0.067	±	0.011

C-3.3. U-235 cumulative 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/endf00.htm, 6 May 2008;
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-3.3. U-235 cumulative fission yields for selected fission products.

Fission product	Thermal fission yields [% per fission]			Fast fission yields [% per fission]			14 MeV fission yields [% per fission]		
1- H- 1	0.00171	±	0.00018	0.00269	±	0.00044	0.00264	±	0.00045
1- H- 2	0.00084	±	0.00015	0.00082	±	0.00012	0.00081	±	0.00012
1- H- 3	0.01080	±	0.00040	0.01080	±	0.00040	0.0174	±	0.0036
2-He- 3	0.01080	±	0.00040	0.01080	±	0.00040	0.0174	±	0.0036
2-He- 4	0.1702	±	0.0049	0.1700	±	0.0049	0.1667	±	0.0088
35-Br- 85	1.304	±	0.012	1.309	±	0.043	1.64	±	0.31
36-Kr- 82	0.000285	±	0.000076	0.00044	±	0.00016	0.038	±	0.012
36-Kr- 85	0.286	±	0.021	0.286	±	0.026	0.47	±	0.10
36-Kr- 85m	1.303	±	0.012	1.307	±	0.043	1.65	±	0.31
38-Sr- 90	5.73	±	0.13	5.22	±	0.18	4.41	±	0.18
40-Zr- 95	6.502	±	0.072	6.349	±	0.083	5.07	±	0.19
41-Nb- 94	0.00000042	±	0.00000011	2.90E-08	±	0.77E-08	0.000040	±	0.000015
41-Nb- 95	6.498	±	0.072	6.345	±	0.083	5.07	±	0.19
41-Nb- 95m	0.0702	±	0.0067	0.0686	±	0.0071	0.0548	±	0.0072
42-Mo- 92	0.	±	0.	0.	±	0.	0.	±	0.
42-Mo- 94	8.7E-10	±	3.2E-10	0.	±	0.	6.2E-08	±	2.5E-08
42-Mo- 96	0.00042	±	0.00015	0.000069	±	0.000025	0.0033	±	0.0015
42-Mo- 99	6.132	±	0.092	5.80	±	0.13	5.02	±	0.13
43-Tc- 99	6.132	±	0.092	5.80	±	0.13	5.02	±	0.13
44-Ru-103	3.103	±	0.084	3.248	±	0.042	3.14	±	0.11
44-Ru-106	0.410	±	0.011	0.469	±	0.036	2.15	±	0.59
45-Rh-106	0.410	±	0.011	0.469	±	0.036	2.15	±	0.59
50-Sn-121m	0.00106	±	0.00011	0.00390	±	0.00091	0.142	±	0.023
51-Sb-122	0.000000366	±	0.000000098	0.00000040	±	0.00000014	0.00193	±	0.00068
51-Sb-124	0.000089	±	0.000021	0.000112	±	0.000034	0.027	±	0.010
51-Sb-125	0.0260	±	0.0014	0.067	±	0.011	1.42	±	0.42
52-Te-132	4.276	±	0.043	4.639	±	0.065	3.85	±	0.16
53- I-129	0.706	±	0.032	1.03	±	0.26	1.59	±	0.18
53- I-131	2.878	±	0.032	3.365	±	0.054	4.11	±	0.14
53- I-133	6.59	±	0.11	6.61	±	0.13	5.42	±	0.40
53- I-135	6.39	±	0.22	6.01	±	0.18	4.8	±	1.4
54-Xe-128	0.	±	0.	0.	±	0.	0.00108	±	0.00048
54-Xe-130	0.0000380	±	0.0000098	0.000152	±	0.000055	0.038	±	0.014
54-Xe-131m	0.0313	±	0.0030	0.0365	±	0.0031	0.0470	±	0.0049
54-Xe-133	6.60	±	0.11	6.61	±	0.13	5.57	±	0.41
54-Xe-133m	0.189	±	0.015	0.190	±	0.015	0.281	±	0.049

Table C-3.3. U-235 cumulative fission yields for selected fission products.

Fission product	Thermal fission yields [% per fission]			Fast fission yields [% per fission]			14 MeV fission yields [% per fission]		
54-Xe-135	6.61	±	0.22	6.32	±	0.18	6.4	±	1.8
54-Xe-135m	1.22	±	0.12	1.23	±	0.13	2.17	±	0.66
55-Cs-134	0.0000121	±	0.0000032	0.0000279	±	0.0000073	0.0132	±	0.0035
55-Cs-137	6.221	±	0.069	5.889	±	0.096	5.6	±	1.3
56-Ba-140	6.314	±	0.095	5.959	±	0.048	4.474	±	0.081
57-La-140	6.315	±	0.095	5.960	±	0.048	4.508	±	0.081
58-Ce-141	5.86	±	0.15	5.795	±	0.081	4.44	±	0.20
58-Ce-144	5.474	±	0.055	5.094	±	0.076	3.154	±	0.038
59-Pr-144	5.474	±	0.055	5.094	±	0.076	3.155	±	0.038
60-Nd-142	6.3E-09	±	1.7E-09	1.70E-09	±	0.48E-09	0.0000137	±	0.0000049
60-Nd-144	5.475	±	0.055	5.094	±	0.076	3.155	±	0.038
60-Nd-147	2.232	±	0.040	2.148	±	0.028	1.657	±	0.045
61-Pm-147	2.232	±	0.040	2.148	±	0.028	1.657	±	0.045
61-Pm-148	5.0E-08	±	1.7E-08	7.4E-09	±	2.5E-09	0.00000130	±	0.00000042
61-Pm-148m	0.000000104	±	0.000000039	1.78E-08	±	0.66E-08	0.0000048	±	0.0000018
61-Pm-149	1.053	±	0.021	1.064	±	0.030	0.557	±	0.090
61-Pm-151	0.4204	±	0.0071	0.431	±	0.015	0.388	±	0.061
62-Sm-148	0.000000149	±	0.000000041	2.43E-08	±	0.68E-08	0.0000058	±	0.0000018
62-Sm-150	0.000061	±	0.000022	0.0000201	±	0.0000077	0.00045	±	0.00018
62-Sm-151	0.4204	±	0.0071	0.431	±	0.015	0.388	±	0.061
62-Sm-153	0.1477	±	0.0071	0.1512	±	0.0097	0.230	±	0.015
63-Eu-151	0.4204	±	0.0071	0.431	±	0.015	0.388	±	0.061
63-Eu-152	3.24E-10	±	0.85E-10	0.	±	0.	3.3E-08	±	1.1E-08
63-Eu-154	0.000000195	±	0.000000064	4.0E-08	±	1.1E-08	0.0000033	±	0.0000011
63-Eu-155	0.0308	±	0.0013	0.044	±	0.010	0.088	±	0.014

C-3.4. U-238 cumulative 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/endf00.htm, 6 May 2008;
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-3.4. U-238 cumulative fission yields for selected fission products.

Fission product	Fast fission yields [% per fission]			14 MeV fission yields [% per fission]		
1- H- 1	0.00235	±	0.00040	0.00130	±	0.00024
1- H- 2	0.00072	±	0.00011	0.000398	±	0.000068
1- H- 3	0.0103	±	0.0010	0.0065	±	0.0014
2-He- 3	0.0103	±	0.0010	0.0065	±	0.0014
2-He- 4	0.1488	±	0.0086	0.0823	±	0.0078
35-Br- 85	0.85	±	0.11	1.051	±	0.066
36-Kr- 82	0.0000089	±	0.0000030	0.000044	±	0.000016
36-Kr- 85	0.182	±	0.030	0.227	±	0.026
36-Kr- 85m	0.85	±	0.11	1.050	±	0.066
38-Sr- 90	3.11	±	0.14	3.07	±	0.16
40-Zr- 95	5.188	±	0.089	4.594	±	0.056
41-Nb- 94	1.89E-09	±	0.51E-09	3.4E-08	±	1.1E-08
41-Nb- 95	5.185	±	0.089	4.591	±	0.056
41-Nb- 95m	0.0561	±	0.0069	0.0496	±	0.0056
42-Mo- 92	0.	±	0.	0.	±	0.
42-Mo- 94	0.	±	0.	0.	±	0.
42-Mo- 96	0.0000063	±	0.0000024	0.000053	±	0.000026
42-Mo- 99	6.181	±	0.099	5.737	±	0.040
43-Tc- 99	6.181	±	0.099	5.737	±	0.040
44-Ru-103	6.029	±	0.096	4.495	±	0.085
44-Ru-106	2.52	±	0.11	2.56	±	0.13
45-Rh-106	2.52	±	0.11	2.56	±	0.13
50-Sn-121m	0.00125	±	0.00026	0.091	±	0.019
51-Sb-122	9.7E-10	±	3.1E-10	0.00000283	±	0.00000096
51-Sb-124	0.00000068	±	0.00000019	0.000270	±	0.000080
51-Sb-125	0.0210	±	0.0038	1.277	±	0.063
52-Te-132	4.76	±	0.17	4.679	±	0.066
53- I-129	0.622	±	0.034	1.66	±	0.19
53- I-131	3.321	±	0.083	3.62	±	0.17
53- I-133	6.71	±	0.23	5.74	±	0.17
53- I-135	6.42	±	0.27	5.32	±	0.12
54-Xe-128	0.	±	0.	2.9E-10	±	1.2E-10
54-Xe-130	3.1E-10	±	1.3E-10	0.0000149	±	0.0000057
54-Xe-131m	0.0361	±	0.0036	0.0393	±	0.0045
54-Xe-133	6.71	±	0.23	5.74	±	0.17

Table C-3.4. U-238 cumulative fission yields for selected fission products.

Fission product	Fast fission yields [% per fission]			14 MeV fission yields [% per fission]		
54-Xe-133m	0.191	±	0.017	0.164	±	0.016
54-Xe-135	6.43	±	0.27	5.45	±	0.12
54-Xe-135m	1.07	±	0.11	0.99	±	0.10
55-Cs-134	0.000000113	±	0.000000030	0.0000086	±	0.0000024
55-Cs-137	6.02	±	0.15	5.62	±	0.68
56-Ba-140	5.972	±	0.084	4.619	±	0.037
57-La-140	5.972	±	0.084	4.620	±	0.037
58-Ce-141	5.93	±	0.45	4.418	±	0.080
58-Ce-144	4.67	±	0.11	3.58	±	0.14
59-Pr-144	4.67	±	0.11	3.58	±	0.14
60-Nd-142	0.	±	0.	1.21E-08	±	0.36E-08
60-Nd-144	4.67	±	0.11	3.58	±	0.14
60-Nd-147	2.677	±	0.046	2.134	±	0.041
61-Pm-147	2.677	±	0.046	2.134	±	0.041
61-Pm-148	1.13E-10	±	0.37E-10	0.000000129	±	0.000000043
61-Pm-148m	2.72E-10	±	0.99E-10	0.00000048	±	0.00000018
61-Pm-149	1.683	±	0.067	1.358	±	0.080
61-Pm-151	0.810	±	0.012	0.800	±	0.057
62-Sm-148	3.7E-10	±	1.0E-10	0.00000058	±	0.00000018
62-Sm-150	0.00000084	±	0.00000032	0.00032	±	0.00016
62-Sm-151	0.810	±	0.012	0.800	±	0.057
62-Sm-153	0.367	±	0.014	0.395	±	0.021
63-Eu-151	0.810	±	0.012	0.800	±	0.057
63-Eu-152	0.	±	0.	5.3E-09	±	2.0E-09
63-Eu-154	1.90E-09	±	0.51E-09	0.0000044	±	0.0000015
63-Eu-155	0.127	±	0.021	0.174	±	0.030

C-3.5. Pu-239 cumulative 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/endf00.htm, 6 May 2008; 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-3.5. Pu-239 cumulative fission yields for selected fission products.

Fission product	Thermal fission yields [% per fission]			Fast fission yields [% per fission]		
1- H- 1	0.00408	±	0.00041	0.00346	±	0.00057
1- H- 2	0.00135	±	0.00019	0.00106	±	0.00016
1- H- 3	0.01420	±	0.00070	0.01420	±	0.00070
2-He- 3	0.01420	±	0.00070	0.01420	±	0.00070
2-He- 4	0.2192	±	0.0090	0.2190	±	0.0090
35-Br- 85	0.574	±	0.026	0.617	±	0.049
36-Kr- 82	0.00175	±	0.00060	0.00055	±	0.00020
36-Kr- 85	0.136	±	0.014	0.138	±	0.017
36-Kr- 85m	0.576	±	0.026	0.617	±	0.049
38-Sr- 90	2.013	±	0.054	2.031	±	0.057
40-Zr- 95	4.949	±	0.099	4.682	±	0.098
41-Nb- 94	0.0000168	±	0.0000045	0.00000255	±	0.00000069
41-Nb- 95	4.946	±	0.099	4.680	±	0.098
41-Nb- 95m	0.0535	±	0.0066	0.0506	±	0.0062
42-Mo- 92	0.	±	0.	0.	±	0.
42-Mo- 94	3.6E-08	±	1.3E-08	4.8E-09	±	1.7E-09
42-Mo- 96	0.0051	±	0.0018	0.00170	±	0.00062
42-Mo- 99	6.185	±	0.056	5.82	±	0.13
43-Tc- 99	6.184	±	0.056	5.82	±	0.13
44-Ru-103	6.948	±	0.083	6.59	±	0.16
44-Ru-106	4.188	±	0.092	4.13	±	0.24
45-Rh-106	4.188	±	0.092	4.13	±	0.24
50-Sn-121m	0.0052	±	0.0011	0.0053	±	0.0012
51-Sb-122	0.0000240	±	0.0000063	0.0000153	±	0.0000050
51-Sb-124	0.00228	±	0.00049	0.00154	±	0.00043
51-Sb-125	0.117	±	0.015	0.138	±	0.022
52-Te-132	5.095	±	0.094	4.92	±	0.32
53- I-129	1.407	±	0.086	1.31	±	0.13
53- I-131	3.724	±	0.078	4.09	±	0.12
53- I-133	6.97	±	0.13	6.99	±	0.33
53- I-135	6.33	±	0.23	6.24	±	0.22
54-Xe-128	0.00000234	±	0.00000085	0.0000025	±	0.0000012
54-Xe-130	0.00166	±	0.00056	0.00231	±	0.00085
54-Xe-131m	0.0405	±	0.0040	0.0444	±	0.0044
54-Xe-133	6.99	±	0.13	7.03	±	0.33
54-Xe-133m	0.216	±	0.016	0.223	±	0.021

Table C-3.5. Pu-239 cumulative fission yields for selected fission products.

Fission product	Thermal fission yields [% per fission]			Fast fission yields [% per fission]		
54-Xe-135	7.36	±	0.24	7.50	±	0.23
54-Xe-135m	1.78	±	0.21	1.97	±	0.25
55-Cs-134	0.00067	±	0.00018	0.00115	±	0.00030
55-Cs-137	6.588	±	0.080	6.35	±	0.12
56-Ba-140	5.322	±	0.059	5.303	±	0.074
57-La-140	5.333	±	0.059	5.324	±	0.075
58-Ce-141	5.205	±	0.073	5.01	±	0.16
58-Ce-144	3.755	±	0.030	3.504	±	0.053
59-Pr-144	3.756	±	0.030	3.505	±	0.053
60-Nd-142	0.00000145	±	0.00000040	0.00000251	±	0.00000072
60-Nd-144	3.756	±	0.030	3.505	±	0.053
60-Nd-147	2.044	±	0.039	1.929	±	0.046
61-Pm-147	2.044	±	0.039	1.929	±	0.046
61-Pm-148	0.0000056	±	0.0000019	0.0000120	±	0.0000040
61-Pm-148m	0.0000118	±	0.0000044	0.000029	±	0.000011
61-Pm-149	1.263	±	0.032	1.275	±	0.056
61-Pm-151	0.776	±	0.018	0.796	±	0.037
62-Sm-148	0.0000168	±	0.0000046	0.000039	±	0.000011
62-Sm-150	0.00227	±	0.00078	0.0051	±	0.0019
62-Sm-151	0.776	±	0.018	0.797	±	0.037
62-Sm-153	0.380	±	0.030	0.40	±	0.18
63-Eu-151	0.776	±	0.018	0.797	±	0.037
63-Eu-152	0.000000195	±	0.000000050	0.00000048	±	0.00000014
63-Eu-154	0.000049	±	0.000012	0.000127	±	0.000043
63-Eu-155	0.174	±	0.030	0.171	±	0.054

C-3.6. Pu-241 cumulative 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/endf00.htm, 6 May 2008; 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-3.6. Pu-241 cumulative fission yields for selected fission products.

Fission product	Thermal fission yields [% per fission]			Fast fission yields [% per fission]		
1- H- 1	0.00294	±	0.00048	0.00294	±	0.00048
1- H- 2	0.00090	±	0.00013	0.00090	±	0.00013
1- H- 3	0.01410	±	0.00061	0.01410	±	0.00061
2-He- 3	0.01410	±	0.00061	0.01410	±	0.00061
2-He- 4	0.1860	±	0.0071	0.1860	±	0.0071
35-Br- 85	0.429	±	0.069	0.400	±	0.021
36-Kr- 82	0.000124	±	0.000059	0.000071	±	0.000033
36-Kr- 85	0.094	±	0.018	0.0870	±	0.0090
36-Kr- 85m	0.429	±	0.069	0.400	±	0.021
38-Sr- 90	1.510	±	0.074	1.502	±	0.041
40-Zr- 95	3.91	±	0.15	3.84	±	0.10
41-Nb- 94	0.000000301	±	0.000000090	0.000000127	±	0.000000033
41-Nb- 95	3.91	±	0.15	3.840	±	0.100
41-Nb- 95m	0.0423	±	0.0048	0.0415	±	0.0047
42-Mo- 92	0.	±	0.	0.	±	0.
42-Mo- 94	6.2E-10	±	2.5E-10	2.38E-10	±	0.85E-10
42-Mo- 96	0.00033	±	0.00013	0.000177	±	0.000066
42-Mo- 99	5.61	±	0.25	4.1	±	2.3
43-Tc- 99	5.61	±	0.25	4.1	±	2.3
44-Ru-103	6.54	±	0.32	5.9	±	2.7
44-Ru-106	5.95	±	0.70	6.12	±	0.19
45-Rh-106	5.95	±	0.70	6.12	±	0.19
50-Sn-121m	0.0065	±	0.0017	0.00127	±	0.00048
51-Sb-122	0.00000040	±	0.00000015	0.000000134	±	0.000000061
51-Sb-124	0.000172	±	0.000061	0.000069	±	0.000029
51-Sb-125	0.249	±	0.065	0.092	±	0.020
52-Te-132	4.512	±	0.095	4.56	±	0.13
53- I-129	1.28	±	0.36	1.67	±	0.36
53- I-131	3.076	±	0.074	3.164	±	0.085
53- I-133	6.61	±	0.18	6.67	±	0.19
53- I-135	6.84	±	0.23	6.96	±	0.19
54-Xe-128	1.27E-10	±	0.69E-10	1.04E-10	±	0.48E-10
54-Xe-130	0.000023	±	0.000010	0.000093	±	0.000032
54-Xe-131m	0.0334	±	0.0036	0.0344	±	0.0035
54-Xe-133	6.61	±	0.18	6.67	±	0.19
54-Xe-133m	0.189	±	0.017	0.191	±	0.018

Table C-3.6. Pu-241 cumulative fission yields for selected fission products.

Fission product	Thermal fission yields [% per fission]			Fast fission yields [% per fission]		
54-Xe-135	7.01	±	0.24	7.26	±	0.20
54-Xe-135m	1.25	±	0.13	1.38	±	0.14
55-Cs-134	0.0000092	±	0.0000026	0.000038	±	0.000010
55-Cs-137	6.28	±	0.14	6.37	±	0.18
56-Ba-140	5.76	±	0.11	5.36	±	0.14
57-La-140	5.76	±	0.11	5.36	±	0.14
58-Ce-141	4.90	±	0.12	4.63	±	0.62
58-Ce-144	4.123	±	0.095	4.18	±	0.11
59-Pr-144	4.123	±	0.095	4.18	±	0.11
60-Nd-142	3.7E-09	±	1.0E-09	2.30E-08	±	0.64E-08
60-Nd-144	4.123	±	0.095	4.18	±	0.11
60-Nd-147	2.252	±	0.095	2.228	±	0.062
61-Pm-147	2.252	±	0.095	2.228	±	0.062
61-Pm-148	4.2E-08	±	1.4E-08	0.000000222	±	0.000000072
61-Pm-148m	8.9E-08	±	3.2E-08	0.00000053	±	0.00000019
61-Pm-149	1.454	±	0.071	1.452	±	0.041
61-Pm-151	0.86	±	0.24	0.910	±	0.025
62-Sm-148	0.000000127	±	0.000000034	0.00000073	±	0.00000020
62-Sm-150	0.000079	±	0.000031	0.00033	±	0.00012
62-Sm-151	0.86	±	0.24	0.910	±	0.025
62-Sm-153	0.40	±	0.23	0.45	±	0.19
63-Eu-151	0.86	±	0.24	0.910	±	0.025
63-Eu-152	6.2E-10	±	1.7E-10	4.4E-09	±	1.1E-09
63-Eu-154	0.00000089	±	0.00000034	0.0000042	±	0.0000011
63-Eu-155	0.19	±	0.35	0.231	±	0.084

D-1. Half-lives and branching fractions for activation products.

References

LNHB: Laboratoire National Henri Becquerel, Recommended Data, http://www.nucleide.org/DDEP_WG/DDEPdata.htm, 5 June 2008.

ENSDF: Evaluated Nuclear Structure Data File, http://www-nds.iaea.org/ensdf/, 5 June 2008.

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 Scientific and Technical Information report STI/PUB/1287, May 2007, International Atomic Energy Agency, Vienna, Austria, ISBN 92-0-

Table D-1. Half-lives and branching fractions for activation products.

Nuclide	Half-life $T_{1/2}$	Units	Decay mode	Branching Fraction	Source	Notes
1-H-3	12.312 ± 0.025	y	β^-	1.0	LNHB	
4-Be-10	(1.51 ± 0.06) × 10^6	y	β^-	1.0	ENSDF	
6-C-14	(5.70 ± 0.03) × 10^3	y	β^-	1.0	LNHB	
6-C-15	2.449 ± 0.005	s	β^-	1.0	ENSDF	
7-N-16	7.13 ± 0.02	s	β^-	1.0	ENSDF	
8-O-19	26.88 ± 0.05	s	β^-	1.0	ENSDF	
11-Na-22	950.57 ± 0.23	d	β^+ EC	0.8989 ± 0.0002 0.1011 ± 0.0002	IAEA-CRP-XG	[1]
11-Na-24	0.62329 ± 0.00006	d	β^-	1.0	IAEA-CRP-XG	
12-Mg-27	9.458 ± 0.012	m	β^-	1.0	ENSDF	
13-Al-26	(7.17 ± 0.24) × 10^5	y	β^+ EC	0.8175 ± 0.0023 0.1825 ± 0.0023	LNHB	[2]
16-S-35	87.32 ± 0.16	d	β^-	1.0	LNHB	
17-Cl-36	(3.01 ± 0.03) × 10^5	y	β^- EC	0.981 ± 0.001 0.019 ± 0.001	LNHB	
18-Ar-39	269. ± 3.	y	β^-	1.0	ENSDF	
18-Ar-41	109.61 ± 0.04	m	β^-	1.0	ENSDF	
19-K-40	(4.563 ± 0.013) × 10^{11}	d	β^- EC	0.8914 ± 0.0013 0.1086 ± 0.0013	IAEA-CRP-XG	[1]
19-K-42	12.360 ± 0.012	h	β^-	1.0	ENSDF	
20-Ca-41	(1.02 ± 0.07) × 10^5	y	EC	1.0	ENSDF	

Table D-1. Half-lives and branching fractions for activation products.

Nuclide	Half-life $T_{1/2}$	Units	Decay mode	Branching Fraction	Source	Notes
20-Ca-45	162.61 ± 0.09	d	β^-	1.0	ENSDF	
21-Sc-47	3.3492 ± 0.0006	d	β^-	1.0	ENSDF	
21-Sc-48	43.67 ± 0.09	h	β^-	1.0	ENSDF	
24-Cr-51	27.7009 ± 0.0020	d	EC	1.0	IAEA-CRP-XG	
25-Mn-54	312.29 ± 0.26	d	EC	1.0	IAEA-CRP-XG	
25-Mn-56	0.107449 ± 0.000019	d	β^-	1.0	IAEA-CRP-XG	
26-Fe-55	(1.0027 ± 0.0023) × 10^3	d	EC	1.0	IAEA-CRP-XG	
26-Fe-59	44.494 ± 0.013	d	β^-	1.0	IAEA-CRP-XG	
27-Co-57	271.80 ± 0.05	d	EC	1.0	IAEA-CRP-XG	
27-Co-58	70.86 ± 0.06	d	EC β^+	0.8500 ± 0.002 0.1500 ± 0.002	IAEA-CRP-XG	[1]
27-Co-60	(1.92523 ± 0.00027) × 10^3	d	β^-	1.0	IAEA-CRP-XG	
28-Ni-59	(7.6 ± 0.5) × 10^4	y	EC	1.0	ENSDF	
28-Ni-63	98.7 ± 2.4	y	β^-	1.0	LNHB	
28-Ni-65	2.51719 ± 0.00026	h	β^-	1.0	ENSDF	
29-Cu-64	0.52929 ± 0.00018	d	β^- β^+ EC	0.390 ± 0.003 0.179 ± 0.002 0.431 ± 0.005	IAEA-CRP-XG	[1]
29-Cu-66	5.120 ± 0.014	m	β^-	1.0	ENSDF	
30-Zn-65	243.86 ± 0.20	d	EC β^+	0.9858 ± 0.0001 0.0142 ± 0.0001	IAEA-CRP-XG	[1]
41-Nb-93m	(5.73 ± 0.22) × 10^3	d	IT	1.0	IAEA-CRP-XG	
42-Mo-93	(4.0 ± 0.8) × 10^3	y	EC	1.0	ENSDF	
43-Tc-99m	0.250281 ± 0.000022	d	β^- IT	0.000037 ± 0.000006 0.999963 ± 0.000006	IAEA-CRP-XG	[1]
47-Ag-110m	249.85 ± 0.10	d	β^- IT	0.9864 ± 0.0008 0.0136 ± 0.0008	IAEA-CRP-XG	[1]
49-In-115m	4.486 ± 0.004	h	IT β^-	0.950 ± 0.008 0.050 ± 0.008	ENSDF	
53-I-126	12.93 ± 0.05	d	EC β^-	0.527 ± 0.006 0.473 ± 0.006	ENSDF	
72-Hf-175	70. ± 2.	d	EC	1.0	ENSDF	
72-Hf-181	42.39 ± 0.06	d	β^-	1.0	ENSDF	

Table D-1. Half-lives and branching fractions for activation products.

Nuclide	Half-life $T_{1/2}$			Units	Decay mode	Branching Fraction	Source	Notes
73-Ta-182	114.43	±	0.04	d	β^-	1.0	ENSDF	
74-W-181	121.2	±	0.2	d	EC	1.0	ENSDF	
74-W-185	75.1	±	0.3	d	β^-	1.0	ENSDF	
74-W-187	23.72	±	0.06	h	β^-	1.0	ENSDF	
79-Au-198	2.6950	±	0.0007	d	β^-	1.0	IAEA-CRP-XG	
80-Hg-197	64.14	±	0.05	h	EC	1.0	ENSDF	
80-Hg-203	46.594	±	0.012	d	β^-	1.0	IAEA-CRP-XG	

[1] Branching fractions from LNHB database.
[2] Branching fractions renormalised to sum to 1.0.

D-2. Gamma-ray energies and emission probabilities for activation products.

References

LNHB: Laboratoire National Henri Becquerel, Recommended Data, http://www.nucleide.org/DDEP_WG/DDEPdata.htm, 5 June 2008.

ENSDF: Evaluated Nuclear Structure Data File, http://www-nds.iaea.org/ensdf/, 5 June 2008.

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 Scientific and Technical Information report STI/PUB/1287, May 2007, International Atomic Energy Agency, Vienna, Austria, ISBN 92-0-113606-4.

Table D-2. Gamma-ray energies and emission probabilities for activation products.

Nuclide	Half-life $T_{1/2}$	Units	Energy [keV]			Emission probability [% decay]			Source	Notes
6-C-15	2.449 ± 0.005	s	5297.817	±	0.014	63.2	±	0.8	ENSDF	
7-N-16	7.13 ± 0.02	s	6128.63	±	0.04	67.0	±	0.6	ENSDF	
			7115.15	±	0.14	4.9	±	0.4		
8-O-19	26.88 ± 0.05	s	109.894	±	0.005	2.54	±	0.10	ENSDF	
			197.142	±	0.004	95.9	±	2.1		
			1356.843	±	0.008	50.4	±	1.1		
			1444.085	±	0.010	2.64	±	0.06		
			1553.970	±	0.008	1.39	±	0.03		
11-Na-22	950.57 ± 0.23	d	511.			179.8	±	0.2	IAEA-CRP-XG	[1]
			1274.537	±	0.003	99.940	±	0.014		
11-Na-24	0.62329 ± 0.00006	d	1368.626	±	0.005	99.9935	±	0.0005	IAEA-CRP-XG	
			2754.007	±	0.011	99.872	±	0.008		
12-Mg-27	9.458 ± 0.012	m	170.686	±	0.015	0.8	±	0.1	ENSDF	
			843.76	±	0.03	71.8	±	0.4		
			1014.44	±	0.04	28.0	±	0.4		
13-Al-26	$(7.17 \pm 0.24) \times 10^5$	y	511.			163.5	±	0.4	LNHB	[1]
			1129.67	±	0.10	2.5	±	0.2		
			1808.65	±	0.07	99.76	±	0.04		
			2938.	±	1.	0.24	±	0.04		
18-Ar-41	109.61 ± 0.04	m	1293.64	±	0.04	99.160	±	0.020	ENSDF	
19-K-40	$(4.563 \pm 0.013) \times 10^{11}$	d	1460.822	±	0.006	10.66	±	0.13	IAEA-CRP-XG	
19-K-42	12.360 ± 0.012	h	312.60	±	0.25	0.34	±	0.02	ENSDF	
			1524.6	±	0.3	18.08	±	0.09		
21-Sc-47	3.3492 ± 0.0006	d	159.381	±	0.015	68.3	±	0.4	ENSDF	
21-Sc-48	43.67 ± 0.09	h	175.361	±	0.005	7.48	±	0.10	ENSDF	
			983.526	±	0.012	100.0	±	0.6		
			1037.522	±	0.012	97.6	±	0.7		
			1212.880	±	0.012	2.38	±	0.04		
			1312.120	±	0.012	100.0	±	0.7		
24-Cr-51	27.7009 ± 0.0020	d	320.0835	±	0.0004	9.87	±	0.05	IAEA-CRP-XG	
25-Mn-54	312.29 ± 0.26	d	834.838	±	0.005	99.9746	±	0.0011	IAEA-CRP-XG	

Table D-2. Gamma-ray energies and emission probabilities for activation products.

Nuclide	Half-life $T_{1/2}$	Units	Energy [keV]			Emission probability [% decay]			Source	Notes
25-Mn-56	0.107449 ± 0.000019	d	846.7638	±	0.0019	98.85	±	0.03	IAEA-CRP-XG	
			1810.726	±	0.004	26.9	±	0.4		
			2113.092	±	0.006	14.2	±	0.3		
			2523.06	±	0.05	1.02	±	0.02		
26-Fe-59	44.494 ± 0.013	d	142.651	±	0.002	0.972	±	0.015	IAEA-CRP-XG	
			192.349	±	0.005	2.92	±	0.03		
			1099.245	±	0.003	56.59	±	0.21		
			1291.590	±	0.006	43.21	±	0.25		
27-Co-57	271.80 ± 0.05	d	122.06065	±	0.00012	85.51	±	0.06	IAEA-CRP-XG	
			136.47356	±	0.00029	10.71	±	0.15		
27-Co-58	70.86 ± 0.06	d	511.			30.0	±	0.4	IAEA-CRP-XG	[1]
			810.759	±	0.002	99.45	±	0.01		
27-Co-60	$(1.92523 \pm 0.00027) \times 10^3$	d	1173.228	±	0.003	99.85	±	0.03	IAEA-CRP-XG	
			1332.492	±	0.004	99.9826	±	0.0006		
28-Ni-65	2.51719 ± 0.00026	h	366.27	±	0.03	4.81	±	0.06	ENSDF	
			507.9	±	0.1	0.293	±	0.005		
			1115.53	±	0.04	15.43	±	0.13		
			1481.84	±	0.05	23.59	±	0.14		
			1623.42	±	0.06	0.498	±	0.014		
			1724.92	±	0.06	0.399	±	0.012		
29-Cu-64	0.52929 ± 0.00018	d	511.			35.72	±	0.28	IAEA-CRP-XG	[1]
			1345.77	±	0.16	0.475	±	0.010		
29-Cu-66	5.120 ± 0.014	m	833.0	±	1.0	0.220	±	0.004	ENSDF	
			1039.2	±	0.2	9.23	±	0.09		
30-Zn-65	243.86 ± 0.20	d	511.			2.84	±	0.04	IAEA-CRP-XG	[1]
			1115.539	±	0.002	50.60	±	0.22		
43-Tc-99m	0.250281 ± 0.000022	d	140.511	±	0.001	88.5	±	0.2	IAEA-CRP-XG	
			42.683	±	0.001	0.023	±	0.002		
47-Ag-110m	249.85 ± 0.10	d	446.812	±	0.003	3.65	±	0.05	IAEA-CRP-XG	[2]
			620.3553	±	0.0017	2.72	±	0.08		
			657.7600	±	0.0011	94.38	±	0.08		
			677.6217	±	0.0012	10.56	±	0.06		
			687.0091	±	0.0018	6.45	±	0.03		
			706.6760	±	0.0015	16.48	±	0.08		
			744.2755	±	0.0018	4.71	±	0.03		
			763.9424	±	0.0017	22.31	±	0.09		
			818.0244	±	0.0018	7.33	±	0.04		
			884.6781	±	0.0013	74.0	±	1.2		
			937.483	±	0.003	34.51	±	0.27		
			1384.2931	±	0.0020	24.7	±	0.5		
			1475.7792	±	0.0023	4.03	±	0.05		
			1505.0280	±	0.0020	13.16	±	0.16		
			1562.294	±	0.018	1.21	±	0.03		

Table D-2. Gamma-ray energies and emission probabilities for activation products.

Nuclide	Half-life $T_{1/2}$	Units	Energy [keV]			Emission probability [% decay]			Source	Notes
49-In-115m	4.486 ± 0.004	h	336.241	±	0.025	45.9	±	2.3	ENSDF	
53-I-126	12.93 ± 0.05	d	388.633	±	0.011	35.6	±	0.6	ENSDF	[3]
			491.243	±	0.011	2.88	±	0.05		[3]
			666.331	±	0.012	32.9	±	0.8		[4]
			753.819	±	0.013	4.15	±	0.10		[4]
			879.876	±	0.013	0.744	±	0.017		[3]
			1420.19	±	0.03	0.304	±	0.010		[4]
72-Hf-175	70. ± 2.	d	89.36	±	0.01	2.40	±	0.20	ENSDF	
			113.81	±	0.02	0.29	±	0.03		
			229.6	±	0.6	0.68	±	0.03		
			343.40	±	0.08	84.	±	3.		
			353.3	±	0.2	0.228	±	0.019		
			433.0	±	0.5	1.44	±	0.06		
72-Hf-181	42.39 ± 0.06	d	133.021	±	0.019	43.3	±	0.5	ENSDF	
			136.260	±	0.018	5.85	±	0.19		
			136.86	±	0.04	0.86	±	0.19		
			345.93	±	0.06	15.12	±	0.12		
			475.99	±	0.09	0.703	±	0.007		
			482.18	±	0.09	80.5	±	0.4		
			615.17	±	0.11	0.233	±	0.018		
73-Ta-182	114.43 ± 0.04	d	65.72201	±	0.00018	2.92	±	0.07	ENSDF	
			67.75001	±	0.00019	41.2	±	0.9		
			84.68080	±	0.00024	2.65	±	0.07		
			100.1065	±	0.0003	14.1	±	0.3		
			113.6725	±	0.0003	1.88	±	0.04		
			116.4186	±	0.0007	0.431	±	0.009		
			152.4308	±	0.0003	6.93	±	0.13		
			156.3876	±	0.0003	2.64	±	0.05		
			179.3945	±	0.0003	3.08	±	0.06		
			198.3532	±	0.0003	1.44	±	0.03		
			222.1096	±	0.0004	7.49	±	0.14		
			229.3220	±	0.0009	3.63	±	0.07		
			264.0752	±	0.0003	3.61	±	0.07		
			927.992	±	0.002	0.619	±	0.013		
			959.7296	±	0.0019	0.348	±	0.008		
			1001.6950	±	0.0019	2.07	±	0.04		
			1044.4099	±	0.0019	0.237	±	0.006		
			1113.40	±	0.05	0.446	±	0.009		
			1121.3008	±	0.0017	34.9	±	0.6		
			1157.3127	±	0.0018	0.59	±	0.11		
			1158.0817	±	0.0019	0.40	±	0.06		
			1189.0503	±	0.0017	16.2	±	0.3		
			1221.4066	±	0.0017	27.0	±	0.5		
			1223.8033	±	0.0019	0.23	±	0.08		
			1231.0157	±	0.0017	11.44	±	0.20		
			1257.4185	±	0.0018	1.49	±	0.03		
			1273.7305	±	0.0017	0.651	±	0.011		
			1289.1561	±	0.0017	1.35	±	0.02		
			1342.72	±	0.05	0.251	±	0.005		
			1373.8363	±	0.0017	0.218	±	0.004		
74-W-181	121.2 ± 0.2	d	136.28	±	0.02	0.0311	±	0.0010	ENSDF	
			152.32	±	0.02	0.083	±	0.003		
74-W-185	75.1 ± 0.3	d	125.358	±	0.003	0.0192	±	0.0007	ENSDF	

Table D-2. Gamma-ray energies and emission probabilities for activation products.

Nuclide	Half-life $T_{1/2}$	Units	Energy [keV]			Emission probability [% decay]			Source	Notes
74-W-187	23.72 ± 0.06	h	72.002	±	0.004	11.1	±	0.4	ENSDF	
			134.247	±	0.007	8.8	±	0.3		
			479.550	±	0.022	21.8	±	0.7		
			551.52	±	0.04	5.08	±	0.17		
			618.26	±	0.04	6.28	±	0.21		
			625.519	±	0.010	1.09	±	0.04		
			685.73	±	0.04	27.3	±	0.9		
			772.89	±	0.05	4.12	±	0.13		
79-Au-198	2.6950 ± 0.0007	d	411.80205	±	0.00017	95.54	±	0.07	IAEA-CRP-XG	
			675.8836	±	0.0007	0.806	±	0.007		
			1087.6842	±	0.0007	0.159	±	0.003		
80-Hg-197	64.14 ± 0.05	h	77.351	±	0.002	18.7	±	0.4	ENSDF	
			191.364	±	0.015	0.632	±	0.022		
80-Hg-203	46.594 ± 0.012	d	279.1952	±	0.0010	81.48	±	0.08	IAEA-CRP-XG	

[1] Annihilation radiation.

[2] With ^{110}Ag.

[3] Gamma emission arises from β^- decay mode.

[4] Gamma emission arises from electron-capture decay mode.

D-3. X-ray energies and emission probabilities for activation products.

References

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Table D-3. X-ray energies and emission probabilities for activation products.

Nuclide	Half-life $T_{1/2}$	Units	Decay mode	Origin		Energy [keV]	Emission probability [% decay]	Source
13-Al-26	$(7.17 \pm 0.24) \times 10^5$	y	β^+	Mg	$K\alpha_2$	1.2536	0.160 ± 0.006	LNHB
			EC		$K\alpha_1$	1.2536	0.318 ± 0.011	
19-K-40	$(4.563 \pm 0.013) \times 10^{11}$	d	EC	Ar	K	2.96 – 3.19	0.997 ± 0.022	IAEA-CRP-XG
24-Cr-51	27.7009 ± 0.0020	d	EC	V	Kα	4.94 – 4.95	20.2 ± 0.3	IAEA-CRP-XG
					Kβ	5.43 – 5.46	2.69 ± 0.07	
25-Mn-54	312.29 ± 0.26	d	EC	Cr	Kα	5.405 – 5.415	0.227 ± 0.003	IAEA-CRP-XG
					Kβ	5.947	0.0305 ± 0.0007	
26-Fe-55	$(1.0027 \pm 0.0023) \times 10^3$	d	EC	Mn	$K\alpha_2$	5.8877	8.45 ± 0.14	IAEA-CRP-XG
					$K\alpha_1$	5.8988	16.56 ± 0.27	
					$K'\beta_1$	6.49 – 6.54	3.40 ± 0.07	
26-Fe-59	44.494 ± 0.013	d	β^-	Co	Kα	6.92	0.0177 ± 0.0003	IAEA-CRP-XG
27-Co-57	271.80 ± 0.05	d	EC	Fe	$K\alpha_2$	6.39084	16.8 ± 0.3	IAEA-CRP-XG
					$K\alpha_1$	6.40384	33.2 ± 0.5	
					$K'\beta_1$	7.058 – 7.108	7.1 ± 0.2	
27-Co-58	70.86 ± 0.06	d	EC	Fe	Kα	6.40	23.5 ± 0.3	IAEA-CRP-XG
			β^+		Kβ	7.06	3.20 ± 0.10	
27-Co-60	$(1.92523 \pm 0.00027) \times 10^3$	d	β^-	Ni	Kα	7.46 – 7.48	0.0098 ± 0.0003	IAEA-CRP-XG
					Kβ	8.26 – 8.33	0.00136 ± 0.00005	
29-Cu-64	0.52929 ± 0.00018	d	β^+	Ni	Kα	7.46 – 7.48	14.15 ± 0.17	IAEA-CRP-XG
			EC		Kβ	8.26 – 8.33	1.95 ± 0.04	
30-Zn-65	243.86 ± 0.20	d	EC	Cu	Kα	8.03 – 8.05	34.7 ± 0.3	IAEA-CRP-XG
			β^+		Kβ	8.90 – 8.98	4.82 ± 0.07	
41-Nb-93m	$(5.73 \pm 0.22) \times 10^3$	d	IT	Nb	$K\alpha_2$	16.5213	3.16 ± 0.07	IAEA-CRP-XG
					$K\alpha_1$	16.6152	6.04 ± 0.12	
					$K'\beta_1$	18.618	1.56 ± 0.05	
					$K'\beta_2$	18.953	0.23 ± 0.01	
43-Tc-99m	0.250281 ± 0.000022	d	IT	Tc	$K\alpha_2$	18.2510	2.22 ± 0.07	IAEA-CRP-XG
					$K\alpha_1$	18.3672	4.21 ± 0.12	
					$K'\beta_1$	20.60 – 20.79	1.12 ± 0.04	
					$K'\beta_2$	21.00 – 21.04	0.177 ± 0.008	

Table D-3. X-ray energies and emission probabilities for activation products.

Nuclide	Half-life $T_{1/2}$	Units	Decay mode	Origin		Energy [keV]	Emission probability [% decay]	Source
47-Ag-110m	249.85 ± 0.10	d	IT	Ag	$K\alpha_2$	21.9906	0.198 ± 0.012	IAEA-CRP-XG
					$K\alpha_1$	22.1632	0.372 ± 0.022	
					$K'\beta_1$	24.912 – 25.146	0.103 ± 0.007	
					$K'\beta_2$	25.457 – 25.512	0.0179 ± 0.0012	
47-Ag-110m	249.85 ± 0.10	d	β^-	Cd	$K\alpha_2$	22.9843	0.153 ± 0.009	
					$K\alpha_1$	23.1738	0.288 ± 0.016	
					$K'\beta_1$	26.061 – 26.304	0.080 ± 0.005	
					$K'\beta_2$	26.64 – 26.70	0.0146 ± 0.0009	
79-Au-198	2.6950 ± 0.0007	d	β^-	Hg	L	8.72 – 14.85	1.20 ± 0.05	IAEA-CRP-XG
					$K\alpha_2$	68.8952 ± 0.0012	0.809 ± 0.008	
					$K\alpha_1$	70.8196 ± 0.0012	1.372 ± 0.012	
					$K'\beta_1$	79.82 – 80.76	0.466 ± 0.008	
					$K'\beta_2$	82.43 – 83.03	0.136 ± 0.004	
80-Hg-203	46.594 ± 0.012	d	β^-	Tl	L	8.953 – 14.738	5.43 ± 0.09	IAEA-CRP-XG
					$K\alpha_2$	70.8325 ± 0.0008	3.75 ± 0.04	
					$K\alpha_1$	72.8725 ± 0.0008	6.33 ± 0.06	
					$K'\beta_1$	82.118 – 83.115	2.15 ± 0.04	
					$K'\beta_2$	84.838 – 85.530	0.64 ± 0.02	

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