UKPADD6.12: An Evaluated Decay Data Library for Nuclear Applications

Authors: A L Nichols, R J Perry

Date: March 2013

From: AMEC

Our Reference: AMEC/TS/006301.10.01/002 Issue 1

Alternative References JEF/DOC-1494, UKNSF(2013)P251

This page is intentionally left blank to allow double-sided pagination.

Title	UKPADD6.12: An Evaluated Decay Data Library for Nuclear Applications
Authors	A L Nichols and R J Perry
Our Reference	AMEC/TS/006301.10.01/002 Issue 1
Confidentiality, copyright & reproduction	UNCLASSIFIED To minimise our impact on the environment, AMEC uses paper from sustainable sources

Contact Details

AMEC
Kimmeridge House
Dorset Green Technology Park
Winfrith Newburgh
Dorchester, Dorset
DT2 8ZB

Telephone 01305 851200
Facsimile 01305 851105
E-mail: ray.perry@amec.com

amec.com

	Name	Signature	Date
Author(s)	R J Perry	[signature]	14/03/13
Reviewed by	G A Wright	George A. Wright	19/3/13
Approved by	S K Hammond	[signature]	28/3/13

This page is intentionally left blank to allow double-sided pagination.

Executive Summary

A detailed description is given of the latest version of the UKPADD decay data library, identified previously as the UK Activation Product Decay Data Library and re-assembled for general use in March 2013 as UKPADD6.12.

The decay data of various radionuclides have been evaluated on the basis of a series of well-defined specifications. These radionuclides are predominantly activation products of immediate relevance to the European Fusion Programme and to the operation, decommissioning and disposal of fission-based reactor facilities, along with various standards that are commonly used to calibrate gamma-ray spectrometers. Recommended data include half-lives, branching fractions, alpha, beta and gamma-ray energies and emission probabilities, total decay energies, mean and/or average alpha, beta and gamma energies, internal conversion coefficients, internal-pair formation coefficients, and all associated uncertainties. Computer based files have been generated, including lists of the references used to produce the proposed decay schemes and comments that identify any observed inadequacies. The evaluated data have been processed through the COGEND code to yield complete and verified evaluated decay data files in ENDF-6 format. Various additional decay data were calculated from the evaluated inputs by means of a series of sub-routines contained within COGEND:

(i) mean alpha, beta and gamma energies,

(ii) conversion-electron energies and emission probabilities,

(iii) K-, L- and M-shell capture ratios in electron-capture decay,

(iv) K-, L- and M-shell Auger-electron energies and emission probabilities,

(v) K-, L- and M-shell X-ray energies and emission probabilities,

(vi) energy of recoil in alpha decay,

(vii) internal bremsstrahlung associated with beta decay.

Verification has included processing with the codes STANEF, CHECKR and FIZCON, and confirming the overall consistency of the energy release by summing the emission by quanta and comparing with the total emission by decay mode.

All evaluations for UKPADD6.12 were carried out by Dr A L Nichols[1] whilst COGEND processing and verification were performed by AMEC. During the course of 2012/13, complex decay schemes and extensive data sets for Xe-139 and Cs-140 were evaluated for their inclusion within UKPADD6.12, and minor adjustments made to the existing contents of the Rb-90 file. The resulting UKPADD6.12 decay data library in ENDF-6 format replaces all previous versions of UKPADD, including UKPADD6.11 as assembled and made available in March/April 2012.

Historically, the evaluation work and assembly of many of the earlier files has also been funded by BNFL plc, Sellafield, and the UK Department of Trade and Industry and Euratom (UK Atomic Energy Authority/Euratom Fusion Association).

[1] Consultant and Visiting Researcher, Faculty of Engineering and Physical Sciences, University of Surrey, Guildford, Surrey GU2 7XH, UK.

This page is intentionally left blank to allow double-sided pagination.

Contents

This page is intentionally left blank to allow double-sided pagination.

1 Introduction

UKPADD was first released in 1977 as the UK Activation Product Decay Data Library (1). Improvements in the available decay data through various spectroscopic measurements led to a comprehensive evaluation of the decay data for 236 radionuclides, and these improved data were released as UKPADD2 in 1993 (2). A significant fraction of the UKPADD2 decay-data library was incorporated into version 2 of the Joint Evaluated File JEF-2.2 (3). Subsequent reviews of JEF-2.2 data highlighted the need for further developments in the recommended data for fission and fusion applications. Hence, UKPADD6 was developed incrementally, and released in 1999 (4).

Between 1999 and 2010, a programme of decay data evaluation was sponsored primarily by the UK Atomic Energy Authority (UKAEA) in support of the European Fusion Programme. The aim of the evaluation programme was to produce and maintain the recommended libraries of relevant nuclear data and this long-term initiative led to significant improvements and extensions to the UKPADD library. Specific nuclides requiring improved decay data were identified by R A Forrest (formerly of UKAEA Fusion, Culham) and A L Nichols (5). Over the period from 1999 to early 2012, approximately 185 radionuclides were newly evaluated or re-evaluated, and details of this set of work programmes was published in a series of UK Nuclear Science Forum papers (6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16). All evaluations have been carried out by A L Nichols. UKPADD libraries are made available to the international community via the NEA Data Bank, and new evaluations are also submitted for possible inclusion in the JEFF-3 decay data library.

The most recent version of the UKPADD library (UKPADD6.12), released in April 2013, is described in this paper. This latest library contains evaluations for 595 radionuclides, and supersedes all previous versions of the UKPADD database. Complex decay data for two nuclides have been newly evaluated by A L Nichols in preparation for the release of UKPADD6.12 (^{139}Xe and ^{140}Cs). The evaluation procedure and contents of UKPADD6.12 are summarized in the following sections.

2 Decay Data

UKPADD6.12 contains recommended data for the following parameters (see also Section 4.3):

(i) half-lives,

(ii) total decay energies (Q-values),

(iii) branching fractions,

(iv) alpha-particle energies and emission probabilities,

(v) beta-particle energies, emission probabilities and transition types (also equivalent data for β^+/electron-capture (EC) transitions),

(vi) gamma-ray energies, emission probabilities, and internal-conversion and internal-pair formation coefficients,

(vii) neutron energies and emission probabilities,

(viii) spontaneous fission data including prompt gamma-ray spectra.

The spin and parity of the decaying nuclide are defined, and uncertainties have been assigned to all evaluated data. Other data in UKPADD6.12 (mean/average energies, discrete electrons, X-rays) were derived from the above data by using the processing code COGEND (17). The component contributions to the average energies (light particle, electromagnetic and heavy particle) are derived from the evaluated input data by COGEND. The code also contains data libraries of fluorescence yields, Auger-electron energies, mean x-ray energies and electron-wave-function ratios from which capture ratios can be calculated.

The library has been generated in ENDF-6 format (18). There is a general information section for each nuclide which contains:

(i) name of the evaluator and date of the evaluation (month and year),

(ii) list of references used to construct the recommended data set,

(iii) detailed comments associated with the evaluation,

(iv) consistency check of the evaluated data.

The recommended decay data are contained within the main data section. Every effort has been made to produce consistent and comprehensive data sets. When necessary, theoretical internal-conversion and internal-pair formation coefficients have been used in conjunction with the evaluated gamma-ray data. X-ray data were derived from the energy and emission probability data held within COGEND (19, 20).

All of the energy data are in eV, and the absolute emission probabilities are expressed as fractions of the decay (calculated from the spectral normalisation factor and relative emission probabilities). The data in UKPADD6.12 are listed as described in Reference 18, and summaries of the contents of the updated library are given in Tables 1 and 2.

The consistency of the recommended data has been determined by calculating the percentage deviation between the effective Q-value and the calculated Q-value:

$$\text{effective Q-value} = \sum_{i=1}^{\text{all BF}} Q_i.BF_i \quad (1)$$

where Q_i and BF_i are the Q-value and branching faction of the i^{th} decay mode (i.e. weighted sum of the evaluated Q-values of the radionuclide),

$$\text{calculated Q-value} = \sum_{i}^{\text{all }\alpha} E_{\alpha_i}P_{\alpha_i} + \sum_{j}^{\text{all }\beta} E_{\beta_j}P_{\beta_j} + \sum_{k}^{\text{all }\gamma} E_{\gamma_k}P_{\gamma_k} + \sum_{l}^{\text{all x-rays}} E_{x_l}P_{x_l} + \text{etc.} \quad (2)$$

where $E_{\alpha_i}, E_{\beta_j}, E_{\gamma_k}, E_{x_l}$, etc., and $P_{\alpha_i}, P_{\beta_j}, P_{\gamma_k}, P_{x_l}$, etc.

are the energies and emission probabilities of the i^{th} alpha particle, j^{th} beta particle, k^{th} gamma ray, l^{th} x ray, etc. of the individual decay process.

The percentage deviations of the data in the UKPADD6.12 library are given in Table 1. Percentage deviations above 5% would be regarded as high and imply a poorly defined decay scheme; a value of less than 5% indicates the construction of a reasonably consistent decay scheme.

3 Evaluation Procedure

3.1 Overview

An initial decay scheme was constructed for each radionuclide from a suitable combination of the various data sources. The evaluation procedure was as follows:

(i) assess the status of the existing data,

(ii) identify data discrepancies,

(iii) evaluate and recommend decay data.

The emission probabilities have been expressed as the absolute probability of the transition (α, β, conversion electron, X-ray or γ ray) per decay. All available measurements were generally taken into account during an evaluation, including experimental data from laboratory reports and written private communications. Comprehensive statements of the precise evaluation procedure were prepared after each assessment, as well as details of any changes made to the reported data. Under specific circumstances, the evaluations involved the determination of a weighted mean for each parameter. No individual measurement was allowed to contribute more than 50% to the sum of weights when more than one value of the same parameter was reported, and the uncertainty of the datum was increased if necessary. If the set of accepted experimental data proved to be inconsistent, one of several possibilities was adopted:

(i) recommend the unweighted mean,

(ii) reject some measured values on the basis of objective or subjective judgements (e.g. inappropriate calibration procedure or ill-defined measurement techniques employed by the metrologist),

(iii) change the weights.

An appropriate method of changing weights was preferred rather than outright rejection of data. Any serious problems encountered during an evaluation are described in the Comments Section associated with each nuclide in the library. If the resulting decay scheme has any outstanding problems, a statement was made to the effect that better measurements are required.

3.2 Procedures and Consistency Checks

The following procedures and consistency checks form the basis of the evaluation strategy used to update and improve the UKPADD library.

(i) Every effort was made to ensure that there was a reasonable transition-probability balance between the population and de-population of all excited levels in the decay scheme.

(ii) All decay modes of each radioactive nuclide were completely specified in terms of both the branching ratios and the Q-values. The Q-value, defined as the energy difference between the initial and final states, takes account of the energies of any metastable states which are involved in the decay.

(iii) The sum of all α, β^-, β^+/electron-capture and isomeric gamma-emission probabilities were consistent with the corresponding branching fractions.

(iv) Gamma-ray emission probabilities must be the photon probabilities per disintegration and were listed as percentages in the data files. This means that relative photon probabilities were normalised in a consistent manner.

(v) Internal-conversion and internal-pair formation coefficients for gamma-ray transitions were consistent with both the photon and total transition probabilities, i.e. (photon + conversion electron + internal-pair formation) emission probabilities = total transition probability.

(vi) When the internal conversion and internal-pair formation of a gamma-ray transition were significant, theoretical internal-conversion and internal-pair formation coefficients were adopted if experimental data were unavailable. This procedure ensured that the transition energy was appropriately shared between the electromagnetic and electron components.

(vii) The nature of the beta transition was taken into account in the calculation of mean beta energies from the evaluated end points. This information was inferred from the spin and parity assignments proposed for the levels involved.

(viii) Energies and emission probabilities of conversion electrons, Auger electrons, X rays and annihilation radiation were derived in a consistent manner.

(ix) Uncertainties were estimated for all of the parameters incorporated into UKPADD6.

(x) Each evaluation was fully documented. The evaluated ENDF-6 files include a descriptive section that includes comments on inconsistencies and any assumptions made by the evaluator to deal with such problems.

3.3 Production Procedure

(i) The evaluation is undertaken and the initial input data are prepared by the evaluator.

(ii) The evaluation is converted into a form suitable for input to COGEND.

(iii) COGEND input data are checked against the original evaluation.

(iv) The COGEND code is run and the input file and ENDF-6 output file are sent to the evaluator for checking.

(v) Any corrections and improvements are defined by the evaluator, and COGEND is rerun until he/she is satisfied with the results.

COGEND generates an ENDF-6 format file. The computer codes STANEF (21), CHECKR (21) and FIZCON (22) are applied to the file. Any diagnostic reports from these codes are reported to the evaluator who directs any further change necessary.

4 UKPADD6.12

4.1 New Evaluations

Two nuclides were evaluated during 2012/13 in response to the postulated accident study described in JEF/DOC-1291 (23). These were important fission products that either contained no spectral data in existing JEFF evaluation (Xe-139), or exhibited significant differences in the emitted gamma-ray dose between JEF2.2 and JEFF3.1.1 (Cs-140). Minor adjustments were also made to the existing ENDF-6 decay-data file of Rb-90, which arose from an error in the original calculation of the average gamma energy as determined from the relevant tabulation in Greenwood *et al*. (24). All resulting recommended decay data were prepared in ENDF-6 format.

Evaluated β^- and γ data derived from discrete γ-ray measurements have been adopted in both the Xe-139 and Cs-140 files. Furthermore, the recommended total average (or mean) gamma and beta energies for Xe-139 were also derived from the discrete gamma-ray measurements, whereas the mean gamma and beta energies for Cs-140 were determined from the TAGS studies of Greenwood *et al*. (24) rather than from the gross $\beta\gamma$ spectral measurements of Rudstam *et al*. (25). These resulting mean energies for Cs-140 have replaced the equivalent data calculated from the discrete gamma-ray studies in the mean energy data section located at the beginning of the recommended decay-data file (denoted as MT = 457); the mean antineutrino energy was also re-calculated to maintain the overall energy balance. While this particular set of component data is recommended for decay-heat calculations, the mean gamma and beta data derived from the discrete spectra remain in the relevant sub-sections for use in radiation shielding studies. Full details of the selection of source data for each of the evaluations are described in Appendix 1.

The resulting quality of the recommended decay data was based on the subjective judgement of the evaluator, and a well-defined consistency check of the proposed data set, as outlined in the Comments Sections of the files. All such detailed comments have been assembled in Appendix 2 for each evaluation. These newly evaluated decay-data files have been assembled with all others from previous versions of UKPADD to create the UKPADD6.12 library in ENDF-6 format, giving a grand total of 595 radionuclides.

4.2 Consistency Checks

All the files within UKPADD6.12 were checked using CHECKR7.02 (21) and FIZCON (22).

Six nuclides produced a warning statement when processed through CHECKR that the material number (MAT) was inconsistent with the ZA number (Cs-123, Cs-123m, Tb-146, Tb-146m, Tl-193 and Tl-193m). This warning arose because the MAT numbers for these nuclides exceed the standard ENDF-6 numbering scheme. For example, the first stable isotope of Tl is Tl-203 which is assigned the MAT number 8125. The MAT number for Tl-193 is 3 x 10 less than this value, i.e. 8095. Thus the first two digits do not match the Z number and produce a warning message from CHECKR.

FIZCON produced diagnostic messages for a number of nuclides, as described below.

elis not in range 0.00000E+00 to 0.00000E+00

This message is present for all metastable nuclides. The parameter ELIS is the excitation energy (18), and is non-zero for metastable nuclides. FIZCON checks that this parameter is between zero and EMAX, the upper energy of the evaluation. EMAX is zero for decay data files, and therefore the message does not apply to decay data files and can be ignored.

ft value too small

This message occurred for Mg-28, Br-77, Rb-93, Y-97m, Rh-104, Ag-115m, Cd-107, I-138, Ho-160, Ta-177, Os-180, Ir-190, Hg-190 and Pb-201. FIZCON checks that the ft value for beta transitions is within certain limits dependent on the transition type. Beta transitions that fail this test had been individually assessed at the time of evaluation, and the evaluator believed that this condition could not be averted.

total energy release sumup failure

Evaluations have been derived theoretically for 35 fission products important at short cooling times in decay-heat calculations (see Section 4.3). The theoretical spectra are given only in continuum form, resulting in the associated antineutrino energy not being included in the files except as part of the Q value for the decay mode. This causes the total energy sum-up test to fail. There is no practicable way to prevent this process happening, and FIZCON prints the following message.

```
warning: continuum spectrum for beta-radiation.
         fizcon cannot calculate antineutrino energy
         for total energy release.
```

Two additional nuclides also failed the total energy sum-up test (In-116 and Po-208), although the discrepancy is rather small for Po-208 (-0.0380%). The reasons for these two failures are not clear.

gamma ray needed, source mode= 4

This message was present for Li-8 and indicates that the discrete energy of the single alpha particle (plus recoil) is less than the Q value for the decay mode, and therefore an associated gamma emission is expected. As there are no gamma data present, this warning is issued.

ris usually is 0. for stype 0.0

This message was present for Kr-90, Rb-90, Sr-94, I-136, I-136m and Cs-140, and relates to the inclusion of internal-pair formation coefficients for these nuclides. This does not indicate a problem with these particular evaluated files.

gamma energy (ge) sumup failure
and
gamma spectrum calculated average energy inconsistent with component data

The mean/average gamma and beta energies for both Rb-90 and Cs-140, and for I-136m, as given in the average energy component data, were adopted from Greenwood *et al*. (24) and Rudstam *et al*. (25) respectively, and were therefore no longer consistent with the mean energies calculated from the discrete gamma-ray data.

Various messages relating to energy sum-up discrepancies were also obtained for the incomplete evaluations of Cs-136m, Pm-155 and Ho-163.

4.3 Contents of the Library

The UKPADD6.12 evaluated decay data library has been assembled in the internationally-accepted ENDF-6 format adopted for nuclear applications, as described in Reference 18. Comprehensive decay scheme data are presented for 595 radionuclides.

A General Information/Descriptive Data Section is defined for each nuclide (MF = 1, MT = 451) that contains the following information:

(i) radionuclide, date of evaluation, name of evaluator, date of distribution (month, year) and most recent date of issue (year, month and day);

(ii) library name (UKPADD6.12), file identifier (material number), data type (radioactive decay data) and format type (ENDF-6);

(iii) list of references used to determine the recommended data set;

(iv) detailed comments concerning the evaluation;

(v) specific decay data not contained in the main decay data section, including beta-particle transition parameters;

(vi) consistency check of the recommended data set.

The recommended decay data are contained within the primary data section (MF = 8, MT = 457), and are defined as follows:

(i) spin and parity of the decaying radionuclide;

(ii) half-life;

(iii) average energy per disintegration for three general radiation types (light particles, electromagnetic radiations and heavy particles), followed by the individual components of these types for evaluations undertaken since September 2002;

(iv) decay modes, Q-values and branching fractions;

(v) radiation decay data, including gamma-ray, beta-particle, electron-capture, alpha-particle, neutron, discrete electron and x-ray transitions;

(vi) spontaneous fission decay data.

The decay parameters of the majority of radionuclides in UKPADD6.12 have been reasonably well defined in the published literature, and were evaluated with good precision and confidence to produce consistent decay schemes.

Various decay parameters and continuum spectra have been theoretically derived for 35 neutron-rich nuclides deemed to be important at short cooling times in decay-heat calculations (denoted by

in Table 1). While each of these fission products contributes significantly to the decay heat of irradiated fuel (> 0.01 of the fractional cumulative yield), they have proved extremely difficult (if not impossible) to prepare, isolate and study experimentally. The US ENDF/B-VI decay-data library contains files of theoretical data for 33 of these nuclides (26), and they were considered as possible candidates for incorporation into UKPADD, with supportive data from Takahashi *et al.* (27) and Audi *et al.* (28). Furthermore, the relevant data for nine other radionuclides proved insufficient to evaluate and recommend complete decay schemes at the time of their evaluation. These nine troublesome radionuclides are He-8, Li-9, V-54, Sb-129m, Cs-136m, Pm-155, Ho-163, Au-198m and Tl-201.

There are 595 full evaluations in UKPADD6.12, of which 35 files are assembled from theoretical data and 9 are defined as being incomplete data sets. The remaining 551 radionuclides have been evaluated to give reasonably consistent decay schemes. All of the data files are judged to be suitable for a wide range of applications in the nuclear industry and for research purposes.

5 Conclusions

Sets of recommended decay scheme and emission probability data have been derived for a series of radionuclides identified predominantly as activation products and calibrants. The resulting evaluated data sets represent significant improvements in the quality of the derived decay parameters.

Decay data for Xe-139 and Cs-140 have been newly evaluated in 2012/13, and entries corrected for Rb-90 to give good to excellent consistency. The total mean/average gamma and beta energies derived from the discrete gamma-ray studies have been replaced in the component mean energy section of both the Rb-90 and Cs-140 data files with the equivalent data derived from Greenwood *et al*. (24). While these particular data are recommended for decay-heat calculations, the total mean/average gamma and beta data derived from the discrete gamma spectra remain in their relevant sub-sections with the discrete data for application in radiation shielding studies. The complete set of recommended decay data for Xe-139 has been fully derived from the discrete gamma-ray spectral studies.

All of the evaluated decay data have been assembled with other files from previous versions of UKPADD to create the UKPADD6.12 library in ENDF-6 format (595 radionuclides, as listed in Table 1). Rigorous consistency checks have been undertaken to confirm the validity and completeness of the data before releasing the updated library. Comprehensive details of each evaluation can be found within the Comments Section of each individual ENDF-6 file.

The structure of all the evaluated files has been updated to ensure the files are consistent with modern standards and can be assimilated into JEFF-3 and future libraries. UKPADD6.12 is available via the NEA Data Bank, and all the decay data comprising UKPADD6.12 have been submitted for possible inclusion in the JEFF-3 Decay Data Library.

6 Acknowledgements

JoAnn Totans (NNDC, BNL, USA) and Kira Nathani (IAEA-NDS, Vienna, Austria) assisted greatly in the accumulation of the necessary, and sometimes obscure, references required to undertake the decay-data evaluations.

Both authors would also like to thank and pay tribute to Christopher Dean (ex-UKAEA and Serco, Winfrith Newburgh, UK) for his significant input during the long-term discussions and preparation of technical arguments to justify the work described in this report, along with his support over the course of much of the evaluation work reported above, prior to his sad death in May 2012.

7 References

1 A L Nichols
Radioactive Decay Data for Reactor Calculations: Activation Products and Related Isotopes.
UKAEA Harwell Report AERE-R 8903
1977

2 A L Nichols
Activation Product Decay Data: UKPADD2 Data Files.
AEA-RS-5449
March 1993

3 JEF-2.2 Radioactive Decay Data.
JEF Report 13
http://db.nea.fr/html/dbdata/nds_jefreports/jefreport-13.pdf
August 1994

4 A L Nichols, C J Dean, A P Neill, R J Perry
UKPADD6: Evaluated Decay Data Library.
AEAT-5281
March 1999

5 A L Nichols
Assessment and Evaluation of Decay Data for EAF – 1999/2000.
UKNSF(99)P130
1999

6 A L Nichols
Assessment and Evaluation of Decay Data for EAF – 2000/2001.
UKNSF(2001)P144
2001

7 A L Nichols
Assessment and Evaluation of Decay Data for EAF – 2001/02.
UKNSF(2001)P151
2001

8 A L Nichols, R J Perry
Assessment and Evaluation of Decay Data for EAF – 2002/04.
UKNSF(2003)P175
2003

9 A L Nichols, R J Perry
Assessment and Evaluation of Decay Data for EAF – 2004/05.
UKNSF(2005)P188, JEF/DOC-1072
2005

10 A L Nichols, R J Perry
Assessment and Evaluation of Decay Data for EAF – 2005/06.
UKNSF(2006)P200, JEF/DOC-1128
2006

11 A L Nichols, R J Perry
Assessment and Evaluation of Decay Data for EAF – 2006/07.
UKNSF(2007)P214, JEF/DOC-1167
2007

12 A L Nichols, R J Perry
Activation Product Decay Data: UKPADD6.7.
SA/NST/18923/W001 Issue 1, UKNSF(2007)P212, JEF/DOC-1165
February 2007

13 A L Nichols, R J Perry
Activation Product Decay Data: UKPADD6.8.
SERCO/TAS/000343/W003 Issue 1, UKNSF(2008)P226, JEF/DOC-1227
March 2008

14 A L Nichols, R J Perry
Activation Product Decay Data: UKPADD6.9.
SERCO/TAS/002856/W001 Issue 1, UKNSF(2009)P233, JEF/DOC-1270
March 2009

15 A L Nichols, R J Perry
Activation Product Decay Data: UKPADD6.10.
SERCO/003962/001 Issue 1, UKNSF(2010)P240, JEF/DOC-1317
March 2010

16 A L Nichols, R J Perry
Activation Product Decay Data: UKPADD6.11.
SERCO/TCS/005398.25/002 Issue 1, UKNSF(2012)P248, JEF/DOC-1424
April 2012

17 R J Perry, C J Dean (originally A Tobias)
COGEND: A Code to Generate Nuclear Decay Scheme Data in ENDF-6 Format.
UKNSF(04)P190, JEF/DOC-1083
2004

18 A Trkov, M Herman, D A Brown, and members of the Cross Sections Evaluation Working Group
ENDF-6 Formats Manual
Data Formats and Procedures for the Evaluated Nuclear Data Files ENDF/B-VI and ENDF/B-VII.
CSEWG Document ENDF-102, Report BNL-90365-2009, Rev. 2
Revised December 2011
http://www.nndc.bnl.gov/csewg/docs/endf-manual.pdf

19 C M Lederer, V S Shirley (Editors)
K X-rays: Energies, Relative Intensities and Fluorescence Yields.
Table of Isotopes, 7th Edition, APPENDIX III, Table 10
John Wiley and Sons Inc, New York
1978

20 S I Salem, S L Panossian, R A Krause
Experimental K and L Relative X-ray Emission Rates.
At. Data Nucl. Data Tables, 14(2), 91-109
1974

21 C L Dunford
ENDF Utility Codes Release 7.01/02.
May 2005

22 R J Perry, M J Grimstone, C J Dean
Specification and Maintenance Document for Decay Data Checking in FIZCON.
JEF/DOC-959, UKNSF(2003)P160
March 2003

23 C Dean, G Wright, R Perry
Need for Spectra in JEFF3.1.1 Decay Data.
JEF/DOC-1291
2009

24 R C Greenwood, R G Helmer, M H Putnam, K D Watts
Measurement of β^--decay Intensity Distributions of Several Fission-product Isotopes Using a Total Absorption γ-ray Spectrometer.
Nucl. Instrum. Methods Phys. Res., A390, 95-154
1997

25 G Rudstam, P I Johansson, O Tengblad, P Aagaard, J Eriksen
Beta and Gamma Spectra of Short-lived Fission Products.
At. Data Nucl. Data Tables, 45(2), 239-320
1990

26 C L Dunford
Evaluated Nuclear Data File ENDF/B-VI.
pp 788-792 in Proc. Int. Conf. Nucl. Data for Science and Technology
Editor: S M Qaim, Springer-Verlag, Berlin, Germany
1992

27 K Takahashi, M Yamada, T Kondoh
Beta-decay Half-lives Calculated on the Gross Theory.
At. Data Nucl. Data Tables, 12(1), 101-142
1973

28 G Audi, O Bersillon, J Blachot, A H Wapstra
The NUBASE Evaluation of Nuclear and Decay Properties.
Nucl. Phys., A624, 1-124
1997

Table 1. Decay Data Summary

Nuclide	Evaluation Date	$T_{1/2}$	Decay Modes	Q % Deviation
1-H - 3	OCT82	12.330y	β–	0.0000
2-He- 6	OCT82	0.808s	β–	0.0000
2-He- 8	FEB03	0.122s	β– (0.88), β–n (0.12)	Incomplete
3-Li- 8	APR92	0.838s	β–α	0.0419
3-Li- 9	APR92	0.178s	β– (0.505), β–n (0.495)	Incomplete
4-Be- 7	OCT82	53.240d	EC	0.0111
4-Be- 8	APR92	7.000E-17s	α	-0.0092
4-Be- 10	OCT82	1.600E+06y	β–	0.0000
4-Be- 11	DEC90	13.810s	β– (0.97), β–α (0.03)	0.0915
5-B - 12	OCT82	0.020s	β– (0.9842), β–α (0.0158)	0.0002
5-B - 13	FEB03	0.017s	β– (0.99724), β–n (0.00276)	0.0244
6-C - 14	OCT82	5.730E+03y	β–	0.0000
6-C - 15	OCT82	2.449s	β–	-0.0733
7-N - 13	DEC94	9.965m	EC	0.0000
7-N - 16	JAN02	7.130s	β– (0.9999880), β–α (1.2000E-05)	0.0577
7-N - 17	JAN02	4.170s	β– (0.05), β–n (0.9499750), β–α (2.5000E-05)	0.0700
8-O - 19	OCT82	26.910s	β–	-0.1655
9-F - 18	DEC94	1.828h	EC	0.0000
9-F - 20	OCT82	11.030s	β–	0.0051
9-F - 21	OCT05	4.158s	β–	0.0666
10-Ne- 23	OCT82	37.200s	β–	0.0183
11-Na- 22	OCT92	2.603y	EC	0.0018
11-Na- 24	OCT92	14.965h	β–	0.0068
11-Na- 24m	NOV82	0.020s	β– (0.005), IT (0.995)	0.0003
11-Na- 25	OCT82	59.600s	β–	0.1602
11-Na- 26	NOV82	1.080s	β–	-0.0077
12-Mg- 27	NOV82	9.458m	β–	0.0001
12-Mg- 28	NOV82	20.9h	β–	0.1597
13-Al- 26	NOV82	7.200E+05y	EC	0.0250
13-Al- 26m	DEC94	6.345s	EC	0.0000
13-Al- 28	NOV82	2.241m	β–	0.0022
13-Al- 29	NOV82	6.560m	β–	-0.0207
13-Al- 30	NOV82	3.650s	β–	-0.0638
14-Si- 31	NOV82	2.620h	β–	-0.0014

Nuclide	Evaluation Date	$T_{1/2}$	Decay Modes	Q % Deviation
14-Si- 32	NOV82	330.0y	β–	0.0000
15-P - 32	NOV82	14.270d	β–	0.0000
15-P - 33	NOV82	25.4d	β–	0.0000
15-P - 34	DEC94	12.4s	β–	-0.0062
16-S - 35	NOV82	87.5d	β–	0.0000
16-S - 37	NOV82	4.990m	β–	-0.0801
17-Cl- 34	DEC94	1.526s	EC	0.0000
17-Cl- 34m	DEC94	32.1m	EC (0.52), IT (0.48)	-0.0474
17-Cl- 36	SEP01	3.070E+05y	β– (0.981), EC (0.019)	0.0001
17-Cl- 38	DEC82	37.2m	β–	-0.0079
17-Cl- 38m	NOV82	0.715s	IT	-0.0640
17-Cl- 39	OCT05	55.6m	β–	-0.0153
18-Ar- 37	DEC82	35.0d	EC	-0.0007
18-Ar- 39	DEC82	269.0y	β–	0.0000
18-Ar- 41	JAN83	1.827h	β–	-0.0384
18-Ar- 42	DEC82	33.00y	β–	0.0000
19-K - 38	DEC94	7.610m	EC	0.0013
19-K - 38m	DEC94	0.924s	EC	0.0000
19-K - 40	DEC82	1.280E+09y	β– (0.893), EC (0.107)	-0.0011
19-K - 42	FEB83	12.370h	β–	0.0066
19-K - 43	DEC82	22.2h	β–	-0.0474
19-K - 44	MAR90	22.130m	β–	0.1283
20-Ca- 41	DEC82	1.030E+05y	EC	0.0035
20-Ca- 45	JAN92	162.7d	β–	0.0000
20-Ca- 47	APR92	4.538d	β–	0.1213
20-Ca- 49	DEC82	8.720m	β–	-0.0229
21-Sc- 44	JAN83	3.927h	EC	0.0171
21-Sc- 44m	JAN83	2.442d	EC (0.0123), IT (0.9877)	0.0391
21-Sc- 45m	NOV07	0.325s	IT	-0.0903
21-Sc- 46	OCT92	83.790d	β–	-0.0028
21-Sc- 46m	FEB83	18.7s	IT	0.4710
21-Sc- 47	DEC91	3.346d	β–	0.0017
21-Sc- 48	FEB83	1.820d	β–	0.0226
21-Sc- 49	DEC82	57.2m	β–	0.0000
21-Sc- 50	JAN92	1.708m	β–	-0.0075
21-Sc- 50m	JAN92	0.350s	β– (0.0125), IT (0.9875)	-0.0276
22-Ti- 45	APR92	3.080h	EC	0.0022
22-Ti- 51	JAN92	5.8m	β–	0.0073
23-V - 48	FEB83	15.974d	EC	-0.2125

Nuclide	Evaluation Date	$T_{1/2}$	Decay Modes	Q % Deviation
23-V - 49	FEB83	330.0d	EC	0.0029
23-V - 52	JAN92	3.745m	β–	-0.0006
23-V - 53	APR92	1.620m	β–	-0.2563
23-V - 54	APR92	49.8s	β–	Incomplete
24-Cr- 49	JAN83	41.9m	EC	-0.0171
24-Cr- 51	AUG89	27.706d	EC	0.0053
24-Cr- 55	FEB92	3.540m	β–	0.0000
25-Mn- 53	NOV93	3.680E+06y	EC	0.0042
25-Mn- 54	DEC91	312.3d	EC	-0.0001
25-Mn- 56	JAN92	2.579h	β–	-0.0179
25-Mn- 58	APR97	1.087m	β–	-0.3450
25-Mn- 58m	APR97	2.7s	β–	0.1037
26-Fe- 53	JAN92	8.510m	EC	-0.2021
26-Fe- 53m	JAN92	2.580m	IT	0.1882
26-Fe- 55	JAN92	2.735y	EC	-0.0020
26-Fe- 59	DEC91	44.502d	β–	-0.0172
26-Fe- 60	JAN94	1.500E+06y	β–	0.0000
26-Fe- 63	DEC00	6.1s	β–	0.0119
27-Co- 55	FEB92	17.530h	EC	0.0305
27-Co- 56	APR92	77.260d	EC	0.5072
27-Co- 57	JAN92	271.790d	EC	0.0020
27-Co- 58	JUL91	70.860d	EC	-0.0023
27-Co- 58m	JUL91	8.940h	IT	-0.3171
27-Co- 60	DEC91	5.272y	β–	0.0053
27-Co- 60m	JAN94	10.470m	β– (0.0025), IT (0.9975)	0.0838
28-Ni- 57	JAN92	1.487d	EC	-0.0314
28-Ni- 59	DEC91	7.600E+04y	EC	-0.0056
28-Ni- 63	JUL90	99.0y	β–	0.0000
28-Ni- 65	DEC91	2.520h	β–	0.0352
28-Ni- 66	AUG93	2.267d	β–	0.0000
28-Ni- 67	JUL01	21.0s	β–	0.0093
29-Cu- 62	FEB92	9.750m	EC	0.0001
29-Cu- 64	JAN92	12.70h	β– (0.3886), EC (0.6114)	-0.0007
29-Cu- 66	JAN92	5.1m	β–	0.0166
29-Cu- 67	AUG93	2.579d	β–	0.0171
30-Zn- 63	MAR91	38.4m	EC	0.0286
30-Zn- 65	JAN90	244.260d	EC	-0.0075
30-Zn- 69	NOV05	56.4m	β–	0.0000
30-Zn- 69m	NOV05	13.780h	β– (0.00033), IT (0.99967)	-0.0071
31-Ga- 67	NOV08	3.261d	EC	-0.0255

Nuclide	Evaluation Date	$T_{1/2}$	Decay Modes	Q % Deviation
31-Ga- 70	NOV07	21.140m	β- (0.9959), EC (0.0041)	-0.0002
31-Ga- 77	JUL99	13.0s	β–	-0.4724
32-Ge- 71	OCT07	11.430d	EC	-0.0402
32-Ge- 71m	JAN08	0.0204s	IT	-0.0361
32-Ge- 73m	JUN06	0.5s	IT	-0.3557
32-Ge- 75	DEC07	1.380h	β-	-0.0284
32-Ge- 75m	DEC07	48.00s	β- (0.00033), IT (0.99967)	-0.033
32-Ge- 80	FEB05	27.0s	β–	-0.0204
33-As- 73	JUN06	80.3d	EC	-0.0344
33-As- 74	OCT90	17.780d	β– (0.34), EC (0.66)	-0.2919
33-As- 76	NOV06	1.092d	β-	0.0406
33-As- 82	JUL99	20.0s	β–	-0.0231
33-As- 82m	JUL99	13.6s	β–	-0.7379
33-As- 85	SEP97	2.040s	β– (0.78), β–n (0.22)	0.0988
34-Se- 75	JAN90	119.640d	EC	-0.1033
34-Se- 77m	JUL06	17.550s	IT	-0.1025
34-Se- 79	OCT07	3.770E+05y	β-	0.0000
34-Se- 79m	JUN01	3.9m	IT (0.99944), β– (0.00056)	-0.0743
34-Se- 81	AUG03	18.390m	β–	0.0027
34-Se- 81m	AUG03	57.280m	β– (0.00068), IT (0.99932)	0.1410
35-Br- 72	AUG03	1.310m	EC	-0.2821
35-Br- 72m	AUG03	10.6s	IT	0.2164
35-Br- 77	DEC09	2.3765d	EC(gd) (0.9794), EC(m) (0.0206)	0.0255
35-Br- 79m	FEB90	4.880s	IT	-0.0283
35-Br- 80	SEP90	17.6m	β– (0.917), EC (0.083)	-0.0134
35-Br- 80m	SEP90	4.410h	IT	-0.1960
35-Br- 82	DEC89	1.472d	β–	0.0729
35-Br- 82m	DEC89	6.090m	β– (0.024), IT (0.976)	0.5001
35-Br- 87	NOV98	55.7s	β– (0.9749), β–n (0.0251)	-0.1976
35-Br- 88	OCT97	16.5s	β– (0.933), β–n (0.067)	0.2554
35-Br- 89	OCT97	4.370s	β– (0.859), β–n (0.141)	0.0534
35-Br- 90	MAR97	1.9s	β– (0.754), β–n (0.246)	0.1331
35-Br- 91	SEP97	0.538s	β– (0.80), β–n (0.20)	0.0274
36-Kr- 79	JAN90	1.460d	EC	-0.0466
36-Kr- 79m	JAN90	50.0s	IT	-0.0728
36-Kr- 81	MAY94	2.100E+05y	EC	-0.0300
36-Kr- 81m	MAY94	13.2s	EC (2.5000E-05), IT (0.9999750)	0.0187
36-Kr- 83m	OCT08	1.83h	IT	-0.6199
36-Kr- 85	APR94	10.730y	β–	-0.0001

Nuclide	Evaluation Date	$T_{1/2}$	Decay Modes	Q % Deviation
36-Kr- 85m	APR94	4.480h	β– (0.789), IT (0.211)	0.0483
36-Kr- 90	JUL11	32.32s	β–(gd) (0.872), β–(m) (0.128)	-0.3831
37-Rb- 83	OCT93	86.2d	EC(gd) (0.25), EC(m) (0.75)	-0.0760
37-Rb- 84	FEB94	33.5d	β– (0.032), EC (0.968)	0.0319
37-Rb- 84m	AUG93	20.4m	IT	0.1151
37-Rb- 86	APR94	18.630d	β– (0.9999480), EC (5.2000E-05)	0.0049
37-Rb- 86m	APR94	1.017m	IT	0.0034
37-Rb- 89	AUG01	15.4m	β–	-0.0750
37-Rb- 90	AUG11	157s	β–	-0.6699##
37-Rb- 93	FEB03	5.8s	β– (0.986), β–n (0.014)	-0.0182
37-Rb- 94	JUN98	2.702s	β– (0.899), β–n (0.101)	-0.0527
37-Rb- 95	FEB98	0.381s	β– (0.914), β–n (0.086)	-0.2394
38-Sr- 83	OCT93	1.350d	EC	0.3553
38-Sr- 83m	OCT93	4.950s	IT	-0.0428
38-Sr- 85	FEB92	64.849d	EC	-0.0051
38-Sr- 85m	FEB92	1.127h	EC (0.134), IT (0.866)	0.0031
38-Sr- 87m	OCT06	2.816h	EC (0.003), IT (0.997)	-0.0120
38-Sr- 89	JAN91	50.520d	β–(gd) (0.9999040), β–(m) (9.6400E-05)	0.0000
38-Sr- 90	MAY94	28.869y	β–	0.0000
38-Sr- 92	JUN01	2.710h	β–	-0.0061
38-Sr- 94	SEP11	75.3s	β–	0.0312
39-Y - 87	JUL06	3.325d	EC	0.0077
39-Y – 87m	JUL06	13.370h	EC (0.0157), IT (0.9843)	-0.0408
39-Y - 88	MAR90	106.630d	EC	0.0531
39-Y - 89m	JAN91	16.050s	IT	0.0024
39-Y - 90	NOV07	2.667d	β-	0.0089
39-Y – 90m	NOV07	3.190h	β- (2.1000E-05), IT (0.999979)	-0.002
39-Y - 91	APR94	58.7d	β–	0.0000
39-Y - 91m	APR94	49.720m	IT	-0.0041
39-Y - 96	FEB96	5.370s	β–	-0.0151
39-Y - 96m	FEB96	9.620s	β–	0.0079
39-Y - 97	FEB05	3.750s	β– (0.99945), β–n (0.00055)	0.0105
39-Y - 97m	FEB05	1.170s	β– (0.9925), IT (0.007), β–n (0.0005)	-0.0227
39-Y - 97n	FEB05	0.142s	β– (0.016), IT (0.984)	-0.0264
39-Y - 98	FEB97	0.590s	β– (0.9973), β–n (0.0027)	-0.0432
39-Y - 98m	FEB97	2.0s	β– (0.9656), β–n (0.0344)	-0.2944
39-Y - 99	NOV97	1.477s	β– (0.983), β–n (0.017)	-0.0741
39-Y -104	MAR98	0.130s	β– (0.912230), β–n (0.087769)	#

Nuclide	Evaluation Date	$T_{1/2}$	Decay Modes	Q % Deviation
39-Y -105	MAR98	0.150s	β– (0.80247), β–n (0.19753)	#
40-Zr- 88	MAY94	83.4d	EC	0.0149
40-Zr- 89	JAN91	3.267d	EC(gd) (0.0013), EC(m) (0.9987)	0.0513
40-Zr- 89m	JAN91	4.180m	EC (0.0666), IT (0.9334)	-0.0317
40-Zr- 90m	NOV07	0.808s	IT	-0.0421
40-Zr- 93	OCT08	1.53E+06y	β–(gd) (0.03), β–(m) (0.97)	0.0000
40-Zr- 95	NOV90	64.030d	β–(gd) (0.989), β–(m) (0.011)	-0.0121
40-Zr- 99	AUG03	2.2s	β–(gd) (0.632), β–(m) (0.368)	-0.0510
40-Zr-105	JAN98	0.6s	β– (0.986), β–n (0.014)	#
40-Zr-106	MAR98	0.9s	β– (0.984760), β–n (0.015242)	#
40-Zr-107	MAR98	0.240s	β– (0.962870), β–n (0.037127)	#
41-Nb- 90	NOV07	14.590h	EC(gd) (0.019), EC(m) (0.981)	-0.0108
41-Nb- 90m	NOV07	18.810s	IT	0.0185
41-Nb- 90n	NOV07	6.220E-03s	IT	0.0158
41-Nb- 91	APR94	680.016y	EC	-0.0021
41-Nb- 91m	APR94	60.9d	IT (0.976), EC (0.024)	-0.1628
41-Nb- 92	SEP93	3.500E+07y	EC	0.0187
41-Nb- 92m	SEP93	10.150d	EC	-0.0254
41-Nb- 93m	OCT08	16.120y	IT	-0.2611
41-Nb- 94	JAN90	1.998E+04y	β–	-0.0014
41-Nb- 94m	JAN90	6.260m	β– (0.005), IT (0.995)	-0.0290
41-Nb- 95	NOV90	34.975d	β–	0.0025
41-Nb- 95m	NOV90	3.608d	β– (0.034), IT (0.966)	-0.0661
41-Nb- 96	OCT05	23.350h	β–	0.0239
41-Nb-100	DEC96	1.4s	β–	0.0733
41-Nb-100m	DEC96	2.9s	β–	-0.0167
41-Nb-109	MAR98	0.190s	β– (0.87347), β–n (0.12653)	#
42-Mo- 93	MAR90	3.011E+03y	EC(gd) (0.15), EC(m) (0.85)	-0.0074
42-Mo- 93m	MAR90	6.850h	EC (0.0012), IT (0.9988)	0.0162
42-Mo- 99	OCT90	2.748d	β–(gd) (0.119), β–(m) (0.881)	-0.0098
42-Mo-103	AUG01	1.132m	β–	-0.0096
42-Mo-109	MAR98	0.5s	β– (0.9947), β–n (0.0053)	#
42-Mo-111	MAR98	0.5s	β– (0.9897), β–n (0.0103030)	#
42-Mo-112	MAR98	1.0s	β– (0.97921), β–n (0.0207880)	#
43-Tc- 97	FEB96	2.600E+06y	EC	-0.0047
43-Tc- 97m	FEB96	90.2d	IT	0.0621
43-Tc- 98	JUL08	4.300E+06y	β–	0.0097
43-Tc- 99m	JUL90	6.010h	β– (3.7000E-05), IT (0.9999630)	0.0470
43-Tc-113	MAR98	0.130s	β– (0.928140), β–n (0.071864)	#

Nuclide	Evaluation Date	$T_{1/2}$	Decay Modes	Q % Deviation
43-Tc-114	MAR98	0.2s	β– (0.934640), β–n (0.065358)	#
43-Tc-115	MAR98	0.270s	β– (0.85663), β–n (0.14337)	#
43-Tc-116	MAR98	0.120s	β– (0.87777), β–n (0.12223)	#
43-Tc-99	JUL90	2.113E+05y	β–	0.0000
44-Ru-103	MAY90	39.260d	β–(gd) (0.0115), β–(m) (0.9885)	-0.0914
44-Ru-115	MAR98	0.7s	β– (0.997720), β–n (0.002276)	#
44-Ru-116	MAR98	1.7s	β– (0.989190), β–n (0.010811)	#
44-Ru-117	MAR98	0.340s	β– (0.979490), β–n (0.020509)	#
44-Ru-118	MAR98	0.7s	β– (0.958910), β–n (0.041092)	#
44-Ru-119	JAN02	0.190s	β– (0.95642), β–n (0.04358)	#
45-Rh-101	NOV08	3.2y	EC	-0.0017
45-Rh-101m	NOV08	4.35d	EC (0.9256), IT (0.0744)	-0.0119
45-Rh-102	DEC90	2.902y	EC	-0.4531
45-Rh-102m	DEC90	208.0d	β– (0.20), EC (0.75), IT (0.05)	0.0748
45-Rh-103m	MAY94	56.115m	IT	-0.3866
45-Rh-104	JUN90	42.3s	β– (0.9955), EC (0.0045)	0.0233
45-Rh-104m	JUN90	4.340m	β– (0.0013), IT (0.9987)	-0.1843
45-Rh-105	JAN94	1.474d	β–	-0.0546
45-Rh-105m	JAN94	40.0s	IT	-0.0461
45-Rh-106	AUG96	30.1s	β–	-0.0243
45-Rh-106m	AUG96	2.2h	β–	-0.0487
45-Rh-110	SEP03	28.5s	β–	0.0172
45-Rh-110m	SEP03	3.2s	β–	0.1721
45-Rh-111	SEP04	12.0s	β–	0.0125
45-Rh-118	MAR98	0.320s	β– (0.970830), β–n (0.029167)	#
45-Rh-120	MAR98	0.170s	β– (0.940720), β–n (0.059282)	#
45-Rh-121	MAR98	0.250s	β– (0.86432), β–n (0.13568)	#
46-Pd-103	MAY94	16.980d	EC(gd) (0.00026), EC(m) (0.99974)	-0.0398
46-Pd-107	NOV93	6.500E+06y	β–	0.0000
46-Pd-107m	NOV93	21.3s	IT	0.0330
46-Pd-109	MAR98	13.460h	β–(gd) (0.00046), β–(m) (0.99954)	0.0090
46-Pd-109m	FEB98	4.710m	IT	0.0367
46-Pd-112	JAN97	20.3h	β–	-0.0306
46-Pd-113	OCT04	1.517m	β–(gd) (0.050), β–(m) (0.950)	-0.1194
46-Pd-113m	OCT04	0.3s	IT	0.3404
46-Pd-121	MAR98	0.6s	β– (0.99728), β–n (0.0027220)	#
47-Ag-105	JAN94	41.3d	EC	-0.0536
47-Ag-105m	JAN94	7.230m	EC (0.0034), IT (0.9966)	-0.6547
47-Ag-106	JAN94	24.0m	β– (0.005), EC (0.995)	-0.0051

Nuclide	Evaluation Date	$T_{1/2}$	Decay Modes	Q % Deviation
47-Ag-106m	JAN94	8.460d	EC	0.9682
47-Ag-107m	JAN97	44.1s	IT	-0.0525
47-Ag-108	OCT90	2.4m	β– (0.971), EC (0.029)	0.0204
47-Ag-108m	JAN92	418.010y	EC (0.913), IT (0.087)	-0.0190
47-Ag-109m	JUL06	39.7s	IT	-0.0051
47-Ag-110	NOV91	24.7s	β– (0.997), EC (0.003)	-0.0009
47-Ag-110m	NOV91	249.791d	β– (0.9873), IT (0.0127)	-0.3356
47-Ag-111	JUL94	7.450d	β–	0.0002
47-Ag-111m	JUL94	1.080m	β– (0.005), IT (0.995)	-0.1750
47-Ag-114	OCT98	4.7s	β–	-0.1883
47-Ag-114m	OCT98	1.500E-03s	IT	0.0039
47-Ag-115	MAY98	20.5m	β–(gd) (0.88), β–(m) (0.12)	0.0434
47-Ag-115m	FEB03	18.6s	β–(gd) (0.767), β–(m) (0.023), IT (0.21)	0.1918
48-Cd-107	FEB03	6.520h	EC(gd) (0.00064), EC(m) (0.99936)	-0.0289
48-Cd-109	MAR90	1.267y	EC	0.0330
48-Cd-111m	NOV09	48.74m	IT	-0.0121
48-Cd-113	DEC07	7.800E+15y	β-	0.0000
48-Cd-113m	DEC07	14.600y	β- (0.9988), IT (0.0012)	0.0000
48-Cd-115	AUG08	2.228d	β–(gd) (0.0000007), β–(m) (0.9999993),	0.0269
48-Cd-115m	AUG08	44.45d	β–(gd) (0.999897), β–(m) (0.000103)	-0.0407
49-In-111	JAN91	2.805d	EC(gd) (0.9999140), EC(m) (8.6000E-05)	0.0372
49-In-111m	JAN91	7.9m	IT	-0.0507
49-In-112	JAN97	14.7m	β– (0.44), EC (0.56)	0.1052
49-In-112m	JAN97	20.7m	IT	-0.1202
49-In-113m	FEB91	1.658h	IT	0.0014
49-In-114	FEB92	1.198m	β– (0.995), EC (0.005)	-0.0031
49-In-114m	FEB92	50.0d	EC (0.035), IT (0.965)	-0.1894
49-In-114n	FEB92	0.043s	IT	-0.0062
49-In-115	MAR90	4.410E+14y	β–	0.0000
49-In-115m	MAY94	4.486h	β– (0.0505), IT (0.9495)	0.0066
49-In-116	JAN92	14.2s	β–	0.6261
49-In-116m	JAN92	54.6m	β–	0.1921
49-In-116n	JAN92	2.170s	IT	0.0632
50-Sn-110	DEC00	4.1h	EC	0.0064
50-Sn-113	FEB91	115.0d	EC(gd) (0.0001), EC(m) (0.9999)	0.0204
50-Sn-113m	FEB91	20.9m	EC (0.089), IT (0.911)	-0.2109
50-Sn-117m	JAN90	13.6d	IT	-0.0006

Nuclide	Evaluation Date	$T_{1/2}$	Decay Modes	Q % Deviation
50-Sn-119m	JAN92	293.0d	IT	-0.1028
50-Sn-121	NOV07	1.125d	β-	0.0000
50-Sn-121m	NOV07	43.90y	β- (0.224), IT (0.776)	-0.0914
50-Sn-123	APR91	129.2d	β–	-0.0042
50-Sn-123m	APR91	40.1m	β–	-0.0694
50-Sn-125	OCT91	9.640d	β–	-0.0725
50-Sn-125m	NOV09	9.53m	β-	-0.0032
50-Sn-126	NOV09	2.30E+05y	β- (m)(0.331), β- (n)(0.669)	0.0980
50-Sn-129	SEP04	2.230m	β–	-0.0200
50-Sn-129m	SEP04	7.2m	β–(gd) (0.69), β–(m) (0.31)	-0.0531
50-Sn-130	JAN05	3.730m	β–	-0.0085
50-Sn-130m	JAN05	1.7m	β–(gd) (0.84), β–(m) (0.16)	0.0458
51-Sb-119	NOV93	1.596d	EC	0.0186
51-Sb-120	NOV93	15.9m	EC	-0.1123
51-Sb-120m	NOV93	5.760d	EC	-0.0684
51-Sb-122	JUL91	2.696d	β– (0.9763), EC (0.0237)	0.0041
51-Sb-122m	JUL91	4.190m	IT	-0.0135
51-Sb-124	DEC90	60.240d	β–	-0.0495
51-Sb-124m	DEC90	1.550m	β– (0.25), IT (0.75)	-0.3407
51-Sb-124n	DEC90	20.2m	IT	-0.4979
51-Sb-125	JAN92	2.759y	β–(gd) (0.764), β–(m) (0.236)	0.0434
51-Sb-126	JUL01	12.410d	β–	-0.0635
51-Sb-126m	JUL01	19.1m	IT (0.14), β– (0.86)	-0.1708
51-Sb-126n	JUL01	11.0s	IT	-0.5031
51-Sb-127	OCT96	3.840d	β–(gd) (0.832), β–(m) (0.168)	-0.0431
51-Sb-129	MAR92	4.360h	β–(gd) (0.834), β–(m) (0.166)	-0.6673
51-Sb-129m	MAR92	17.7m	β–(gd) (0.02), β–(m) (0.83), IT (0.15)	Incomplete
51-Sb-135	JUL98	1.740s	β– (0.843), β–n (0.157)	-0.0198
51-Sb-141	MAR98	0.3s	β– (0.869), β–n (0.131)	#
52-Te-121	JUL01	19.160d	EC	0.0226
52-Te-121m	JUL01	154.0d	EC (0.113), IT (0.887)	-0.1799
52-Te-125m	JUL91	58.0d	IT	-0.0051
52-Te-127	OCT96	9.350h	β–	-0.0037
52-Te-127m	OCT96	109.0d	IT (0.976), β– (0.024)	-0.0908
52-Te-129	JUN92	1.160h	β–	-0.0619
52-Te-129m	NOV09	33.6d	β- (0.363), IT (0.637)	-0.0088
52-Te-132	OCT96	3.230d	β–	0.1077
53-I -125	JAN92	59.430d	EC	0.0709

Nuclide	Evaluation Date	$T_{1/2}$	Decay Modes	Q % Deviation
53-I -126	OCT90	12.980d	β– (0.437), EC (0.563)	0.0678
53-I -132	DEC96	2.283h	β–	-0.0832
53-I -132m	NOV96	1.383h	IT (0.86), β– (0.14)	-0.3723
53-I -137	DEC97	24.510s	β– (0.935), β–n (0.065)	0.1276
53-I -136	OCT11	83.5s	β–	-0.0091
53-I -136m	NOV11	47s	β–	-0.0482##
53-I -138	FEB03	6.460s	β– (0.947), β–n (0.053)	-0.1955
53-I -139	NOV97	2.3s	β– (0.902), β–n (0.098)	-0.0552
54-Xe-125	OCT91	16.9h	EC	-0.0292
54-Xe-125m	OCT91	56.0s	IT	0.0606
54-Xe-127	MAR91	36.440d	EC	-0.1451
54-Xe-127m	MAR91	1.160m	IT	-0.0383
54-Xe-129m	DEC08	8.88d	IT	0.1423
54-Xe-131m	SEP94	11.870d	IT	0.0676
54-Xe-133	SEP93	5.243d	β–	0.0299
54-Xe-133m	SEP93	2.190d	IT	0.0213
54-Xe-134m	NOV08	0.290s	IT	0.0088
54-Xe-139	JUL12	39.69s	β–	0.1475
55-Cs-123	MAR05	5.910m	EC	-0.0424
55-Cs-123m	MAR05	1.7s	IT	-0.0020
55-Cs-129	SEP94	1.342d	EC	0.0670
55-Cs-131	SEP94	9.690d	EC	0.0477
55-Cs-132	AUG94	6.530d	β– (0.018), EC (0.982)	0.0165
55-Cs-134	MAR92	2.065y	β– (0.9999970), EC (3.0000E-06)	0.0823
55-Cs-134m	MAR92	2.908h	IT	-0.0812
55-Cs-135	JUL91	2.400E+06y	β–	0.0000
55-Cs-135m	JUL91	53.0m	IT	-0.0280
55-Cs-136	OCT91	13.030d	β–	-0.2422
55-Cs-136m	OCT91	19.0s	β– (0.50), IT (0.50)	Incomplete
55-Cs-137	NOV90	30.172y	β–(gd) (0.054), β–(m) (0.946)	0.0000
55-Cs-140	DEC12	64.0s	β–	0.0062##
56-Ba-126	JAN01	1.667h	EC	-0.1958
56-Ba-129	FEB96	2.380h	EC	-0.0730
56-Ba-129m	FEB96	2.140h	EC	0.0550
56-Ba-131	NOV94	11.550d	EC	-0.0195
56-Ba-131m	NOV94	14.6m	IT	0.1392
56-Ba-133	JAN92	10.574y	EC	0.0810
56-Ba-133m	MAR92	1.592d	EC (0.0001010), IT (0.9998990)	-0.0816
56-Ba-137m	NOV90	2.553m	IT	0.0176
57-La-137	JUN01	6.000E+04y	EC	0.0353

Nuclide	Evaluation Date	$T_{1/2}$	Decay Modes	Q % Deviation
57-La-140	OCT96	1.679d	β–	-0.0108
57-La-152	MAR98	0.280s	β– (0.93961), β–n (0.0603930)	#
58-Ce-139	MAY92	137.650d	EC	0.1622
58-Ce-139m	MAY92	56.1s	IT	0.0029
58-Ce-145	JUL01	2.950m	β–	0.1188
58-Ce-147	NOV96	57.0s	β–	0.0269
58-Ce-149	OCT04	5.3s	β–	0.0777
58-Ce-153	MAR98	1.5s	β– (0.99378), β–n (0.0062190)	#
58-Ce-154	MAR98	2.0s	β– (0.99363), β–n (0.0063730)	#
58-Ce-158	MAR98	1.0s	β– (0.9945), β–n (0.0055)	#
59-Pr-143	SEP96	13.560d	β–	0.0000
59-Pr-144	SEP96	17.280m	β–	0.0382
59-Pr-144m	SEP96	6.9m	IT (0.9993), β– (0.0007)	-0.0860
59-Pr-150	DEC96	6.1s	β–	-0.6261
59-Pr-156	MAR98	0.5s	β– (0.97283), β–n (0.02717)	#
59-Pr-157	MAR98	0.3s	β– (0.936130), β–n (0.063874)	#
60-Nd-140	NOV93	3.370d	EC	0.1286
60-Nd-141	OCT08	2.487h	EC	0.0176
60-Nd-141m	OCT08	1.033m	EC (0.00032), IT (0.99968)	0.0006
60-Nd-147	JUN94	11.02d	β–	0.0450
60-Nd-157	MAR98	2.5s	β–	#
60-Nd-158	MAR98	0.7s	β– (0.99995), β–n (5.3000E-05)	#
60-Nd-159	MAR98	0.5s	β– (0.99764), β–n (0.0023610)	#
60-Nd-160	MAR98	0.3s	β– (0.99053), β–n (0.0094690)	#
61-Pm-143	NOV93	266.0d	EC	0.0493
61-Pm-144	AUG93	363.0d	EC	0.0484
61-Pm-145	JUL91	17.7y	EC (1.00), α (2.8000E-09)	0.1990
61-Pm-146	JUL94	5.531y	β– (0.34), EC (0.66)	-0.3961
61-Pm-147	JUN94	2.622y	β–	0.0000
61-Pm-148	OCT93	5.368d	β–	0.0064
61-Pm-148m	OCT93	41.05d	β– (0.95), IT (0.05)	-0.0147
61-Pm-149	FEB94	2.212d	β–	0.2080
61-Pm-151	AUG94	1.171d	β–	0.4059
61-Pm-152	JAN97	4.120m	β–	-0.3799
61-Pm-152m	JAN97	7.5m	β–	-0.7796
61-Pm-152n	JAN97	14.4m	β–	-0.0401
61-Pm-155	MAR05	41.5s	β–	Incomplete
61-Pm-159	MAR98	3.0s	β– (0.999820), β–n (0.000185)	#
61-Pm-160	MAR98	2.0s	β– (0.997320), β–n (0.002676)	#

Nuclide	Evaluation Date	$T_{1/2}$	Decay Modes	Q % Deviation
62-Sm-145	JUL91	340.0d	EC	0.0659
62-Sm-146	JUL90	1.000E+08y	α	-0.0199
62-Sm-147	SEP96	1.060E+11y	α	-0.0023
62-Sm-151	FEB94	90.00y	β–	-0.0009
62-Sm-153	AUG94	1.929d	β–	0.1640
63-Eu-149	FEB94	93.1d	EC	0.1254
63-Eu-150	NOV94	36.359y	EC	0.0823
63-Eu-150m	NOV94	12.8h	β– (0.88), EC (0.12)	0.5503
63-Eu-152	JUL92	13.523y	β– (0.28), EC (0.72)	-0.1502
63-Eu-152m	JUL92	9.275h	β– (0.72), EC (0.28)	-0.6753
63-Eu-152n	JUL92	1.6h	IT	0.0207
63-Eu-154	MAY92	8.593y	β– (0.9998), EC (0.0002)	0.0416
63-Eu-154m	MAY92	46.4m	IT	0.0927
63-Eu-155	DEC91	4.846y	β–	0.1705
63-Eu-156	OCT94	15.2d	β–	-0.2787
64-Gd-148	NOV09	75y	α	-0.0034
64-Gd-150	DEC94	1.820E+06y	α	0.0119
64-Gd-151	FEB94	124.0d	EC (1.00), α (1.0000E-08)	-0.1917
64-Gd-153	AUG94	240.5d	EC	-0.0495
64-Gd-163	SEP04	1.133m	β–	0.0550
65-Tb-146	JAN05	8.0s	EC	-0.0027
65-Tb-146m	JAN05	24.0s	EC	-0.1118
65-Tb-156	FEB96	5.170d	EC	-0.3867
65-Tb-156m	FEB96	1.017d	IT	0.5785
65-Tb-156n	FEB96	5.1h	EC (0.0019), IT (0.9981)	-0.0964
65-Tb-157	MAR91	99.00y	EC	1.2277
65-Tb-158	DEC05	180.0y	β– (0.168), EC (0.832)	-0.0411
65-Tb-158m	DEC05	10.8s	IT	0.1545
65-Tb-160	NOV05	72.3d	β–	0.0185
65-Tb-161	OCT96	6.890d	β–	-0.0324
66-Dy-157	OCT91	8.140h	EC	-0.0226
66-Dy-159	APR91	144.4d	EC	0.0906
66-Dy-166	NOV07	3.400d	β-	0.0542
67-Ho-160	FEB03	25.3m	EC	-0.2337
67-Ho-160m	MAR96	5.0h	IT (0.65), EC (0.35)	-0.502
67-Ho-160n	MAR96	2.9s	IT	0.2220
67-Ho-161	OCT96	2.480h	EC	0.0565
67-Ho-161m	OCT96	6.770s	IT	0.1297
67-Ho-162	DEC09	14m	EC	-0.0196
67-Ho-162m	DEC09	1.117h	EC (0.45), IT (0.55)	-0.0152

Nuclide	Evaluation Date	$T_{1/2}$	Decay Modes	Q % Deviation
67-Ho-163	JUN01	4.570E+03y	EC	Incomplete
67-Ho-163m	JUN01	1.1s	IT	0.0373
67-Ho-164	DEC00	28.6m	β– (0.517), EC (0.483)	0.0101
67-Ho-164m	DEC00	37.6m	IT	0.0498
67-Ho-170	AUG99	2.780m	β–	-0.4097
67-Ho-170m	AUG99	43.0s	β–	-0.3870
68-Er-167m	JUL06	2.270s	IT	0.0743
68-Er-172	JAN01	2.054d	β–	0.2611
69-Tm-167	DEC08	9.25d	EC(gd) (0.0175), EC(m) (0.9825)	0.1375
69-Tm-168	DEC06	90.0d	β– (0.0001), EC (0.9999)	0.0759
69-Tm-170	NOV07	128.60d	β- (0.99862),EC (0.00138)	0.0041
69-Tm-171	JAN06	1.917y	β–	0.0017
69-Tm-172	NOV05	2.650d	β–	0.1605
70-Yb-175	NOV94	4.185d	β–	-0.0012
70-Yb-176m	NOV07	11.40s	IT	-0.0071
71-Lu-171	MAR94	8.250d	EC	0.4900
71-Lu-171m	NOV93	1.3m	IT	-0.0305
71-Lu-172	DEC93	6.7d	EC	-0.4760
71-Lu-172m	NOV93	3.7m	IT	-0.0295
71-Lu-173	JUL94	1.336y	EC	-0.2844
71-Lu-174	NOV93	3.559y	EC	-0.1885
71-Lu-174m	NOV93	142.0d	EC (0.0058), IT (0.9942)	0.2587
71-Lu-177	FEB94	6.7d	β–	0.0612
71-Lu-177m	MAY94	160.3d	β– (0.774), IT (0.226)	0.2669
72-Hf-173	JUL94	23.9h	EC	0.0977
72-Hf-174	JUL91	2.000E+15y	α	0.0155
72-Hf-175	FEB92	70.0d	EC	0.0337
72-Hf-177m	FEB94	1.080s	IT	0.5106
72-Hf-177n	FEB94	51.4m	IT	-0.2990
72-Hf-178m	AUG98	4.0s	IT	0.0013
72-Hf-178n	AUG98	31.00y	IT	0.1450
72-Hf-179m	OCT05	18.670s	IT	0.0568
72-Hf-179n	OCT05	25.1d	IT	0.0382
72-Hf-180m	AUG98	5.5h	β– (0.0031), IT (0.9969)	-0.2523
72-Hf-181	JAN92	42.380d	β–	0.0975
73-Ta-177	SEP94	2.350d	EC	-0.0203
73-Ta-179	MAR91	1.610y	EC	0.8418
73-Ta-180	MAR91	8.080h	β– (0.181), EC (0.819)	0.0321
73-Ta-180m	MAR91	1.800E+15y	β– (0.20), EC (0.80)	0.1639
73-Ta-182	DEC91	114.7d	β–	-0.0057

Nuclide	Evaluation Date	$T_{1/2}$	Decay Modes	Q % Deviation
73-Ta-182m	DEC91	0.283s	IT	0.1654
73-Ta-182n	DEC91	15.840m	IT	0.8531
73-Ta-183	JUN94	5.090d	β–(gd) (0.966), β–(m) (0.034)	0.0328
74-W -176	SEP03	2.5h	EC	0.1347
74-W -178	SEP94	21.6d	EC	1.2871
74-W -181	AUG91	120.980d	EC	0.0684
74-W -183m	JUN94	5.250s	IT	0.0409
74-W -185	JAN91	75.1d	β–	0.0001
74-W -185m	JAN91	1.667m	IT	-0.1514
74-W -187	OCT91	23.850h	β–	0.0631
74-W -188	OCT05	69.780d	β–	0.0013
75-Re-183	JAN09	70.0d	EC	0.1119
75-Re-183m	NOV06	1.030E-03s	IT	0.1037
75-Re-184	NOV07	35.400d	EC	0.0468
75-Re-184m	NOV05	168.0d	EC (0.252), IT (0.748)	0.1530
75-Re-186	JUN06	3.750d	β– (0.9313), EC (0.0687)	0.0046
75-Re-186m	JUN06	1.900E+05y	IT	-0.4061
75-Re-191	MAR96	9.7m	β–	0.0000
75-Re-192	MAR96	6.2s	β–	0.0566
76-Os-180	OCT03	21.5m	EC	0.0346
76-Os-185	SEP98	93.8d	EC	0.0570
76-Os-189m	NOV07	5.810h	IT	-0.2464
76-Os-190m	SEP98	9.9m	IT	0.0011
76-Os-191	NOV05	15.3d	β–	0.0000
76-Os-191m	NOV05	13.1h	IT	-0.0030
76-Os-194	JUL06	6.0y	β–	-0.1669
76-Os-195	APR96	6.5m	β–	-0.0396
76-Os-196	AUG03	34.9m	β–	-0.0177
77-Ir-187	OCT00	10.5h	EC	-0.0621
77-Ir-189	DEC08	13.2d	EC(gd) (0.925), EC(m) (0.075)	0.1686
77-Ir-190	FEB03	12.0d	EC	-0.1063
77-Ir-190m	SEP98	1.120h	IT	-0.0849
77-Ir-190n	SEP98	3.087h	IT (0.086), EC (0.914)	0.0893
77-Ir-191m	NOV05	4.9s	IT	0.0772
77-Ir-191n	OCT00	5.5s	IT	0.0097
77-Ir-192	SEP03	73.822d	β– (0.952), EC (0.048)	0.1323
77-Ir-192m	SEP03	1.440m	β– (0.0001750), IT (0.9998250)	-0.0780
77-Ir-192n	SEP03	241.0y	IT	0.0069
77-Ir-193m	AUG08	10.53d	IT	-0.0699
77-Ir-194m	DEC08	0.03183s	IT	0.3813

Nuclide	Evaluation Date	$T_{1/2}$	Decay Modes	Q % Deviation
77-Ir-194n	DEC08	171.0d	β–	-0.0393
77-Ir-197	OCT00	5.8m	β–	-0.2184
77-Ir-197m	OCT00	8.9m	β– (0.9975), IT (0.0025)	0.0004
78-Pt-190	JAN08	6.50E+11y	α	-0.0157
78-Pt-193	FEB96	50.00y	EC	2.0682
78-Pt-193m	FEB96	4.340d	IT	-0.3390
78-Pt-195m	OCT06	4.1d	IT	0.2207
78-Pt-197	NOV00	19.892h	β–	0.1082
78-Pt-197m	NOV00	1.588h	β– (0.033), IT (0.967)	0.1698
78-Pt-202	AUG03	1.833d	β–	0.0000
79-Au-192m	SEP03	0.029s	IT	0.3330
79-Au-192n	SEP03	0.160s	IT	0.0100
79-Au-195	OCT06	186.0d	EC	0.8595
79-Au-195m	OCT06	30.5s	IT	0.0121
79-Au-197m	NOV00	7.740s	IT	-0.0267
79-Au-198	DEC87	2.694d	β–	0.0018
79-Au-198m	APR92	2.3d	IT	Incomplete
79-Au-199	JUN01	3.139d	β–	-0.0640
80-Hg-190	FEB03	20.0m	EC	0.5330
80-Hg-194	JUL06	444.00y	EC	2.4780
80-Hg-197	NOV00	2.692d	EC	0.1223
80-Hg-197m	NOV00	23.9h	EC (0.086), IT (0.914)	0.0878
80-Hg-199m	AUG98	42.1m	IT	0.0441
80-Hg-203	MAR91	46.595d	β–	0.0271
80-Hg-205	JUL01	5.2m	β–	-0.0431
81-Tl-193	JAN01	21.8m	EC	-0.0502
81-Tl-193m	JAN01	2.110m	EC (0.25), IT (0.75)	-0.0042
81-Tl-201	SEP93	3.041d	EC	Incomplete
81-Tl-202	APR94	12.240d	EC	0.0885
81-Tl-204	NOV91	3.790y	β– (0.978), EC (0.022)	0.0033
82-Pb-201	FEB03	9.4h	EC	0.3405
82-Pb-201m	OCT98	1.017m	IT	0.1220
82-Pb-202	DEC93	5.300E+04y	EC	1.6745
82-Pb-202m	DEC93	3.570h	EC (0.091), IT (0.909)	-0.3569
82-Pb-203	MAR94	2.162d	EC	0.0605
82-Pb-203m	MAR94	6.290s	IT	-0.0116
82-Pb-203n	MAR94	0.480s	IT	0.0625
82-Pb-204	NOV91	1.400E+17y	α	-0.0097
82-Pb-204m	NOV91	1.125h	IT	0.0780
82-Pb-205	DEC93	1.530E+07y	EC	1.9227

Nuclide	Evaluation Date	$T_{1/2}$	Decay Modes	Q % Deviation
82-Pb-205m	JAN10	5.10E-03s	IT	-0.0528
82-Pb-207m	NOV08	0.806s	IT	0.0054
83-Bi-201m	NOV09	55.8m	EC (0.932), IT (0.068), α (3.0000E-05)	0.0087
83-Bi-205	JAN10	15.31d	EC(gd) (0.86), EC(m) (0.14)	-0.1112
83-Bi-207	AUG91	31.760y	EC	0.1833
83-Bi-208	FEB96	3.680E+05y	EC	0.0635
84-Po-208	FEB96	2.930y	EC (1.8100E-05), α (0.9999820)	-0.0380
86-Rn-223	DEC92	24.2m	$\beta-$	-0.3329
90-Th-228	SEP02	1.913y	α	-0.0175
90-Th-231	MAR95	1.063d	$\beta-$	-0.7156
93-Np-239	MAY91	2.355d	$\beta-$	-0.1364
95-Am-241	FEB01	432.808y	α (1.00), SF (3.7700E-12)	0.2443
95-Am-243	FEB03	7.365E+03y	α (1.00), SF (3.7000E-11)	-0.0218

\# Decay data measurements were unavailable, and therefore theoretical data were adopted from a combination of US ENDF/B-VI (26), Takahashi *et al.* (27) and Audi *et al.* (28).

\## Although gross beta-gamma or TAGS data have been adopted to quantify the average beta and gamma energies inserted into the average energies section of the data file, the consistency check applies only to equivalent energy data derived primarily from discrete gamma-ray studies.

Incomplete files are described in Section 4.3 of the main text.

Table 2. Summary of Spectral Data

Continuum spectra are indicated by the letter ‘c’ following the number of discrete spectral lines. Thus, ‘15c’ indicates that there are 15 discrete lines followed by a continuum spectrum, and ‘0c’ indicates that only a continuum spectrum is present.

Nuclide	$T_{1/2}$ (s)	Mean Decay Energies (keV)			Number of Spectral Lines								
		Light Particle	Electro-magnetic	Heavy Particle	γ	β^-	EC/β^+	α	n	SF*	p	e^-	X-ray
1-H - 3	3.89105E+08	5.71	0.00	0.00	-	1	-	-	-	-	-	-	-
2-He- 6	8.08100E-01	1561.31	5.64	0.00	-	1	-	-	-	-	-	-	-
2-He- 8	1.22000E-01	4448.62	884.97	141.37	1	2	-	-	1	-	-	-	-
3-Li- 8	8.38000E-01	6204.62	32.98	3125.25	-	1	-	1	-	-	-	-	-
3-Li- 9	1.78300E-01	5696.25	29.90	0.00	-	5	-	-	-	-	-	-	-
4-Be- 7	4.59994E+06	0.00	49.30	0.00	1	-	2	-	-	-	-	-	-
4-Be- 8	7.00000E-17	0.00	0.00	91.90	-	-	-	1	-	-	-	-	-
4-Be- 10	5.04922E+13	252.21	0.00	0.00	-	1	-	-	-	-	-	-	-
4-Be- 11	1.38100E+01	4647.31	1418.78	36.27	8	6	-	1	-	-	-	-	-
5-B - 12	2.02000E-02	6308.41	90.56	6.64	1	4	-	2	-	-	-	-	-
5-B - 13	1.73300E-02	6278.30	313.53	9.76	1	5	-	-	4	-	-	-	-
6-C - 14	1.80825E+11	49.48	0.00	0.00	-	1	-	-	-	-	-	-	-
6-C - 15	2.44900E+00	2856.16	3621.81	0.00	5	6	-	-	-	-	-	-	-
7-N - 13	5.97900E+02	490.11	1020.70	0.00	-	-	1	-	-	-	-	1	2
7-N - 16	7.13000E+00	2679.45	4621.50	0.03	10	7	-	3	-	-	-	-	-
7-N - 17	4.17000E+00	1697.81	44.51	901.13	2	9	-	2	6	-	-	-	-
8-O - 19	2.69100E+01	1709.60	1004.57	0.00	8	3	-	-	-	-	-	-	-
9-F - 18	6.58200E+03	241.49	987.27	0.00	-	-	1	-	-	-	-	1	2
9-F - 20	1.10300E+01	2467.27	1644.68	0.00	2	2	-	-	-	-	-	-	-
9-F - 21	4.15800E+00	2341.83	556.87	0.00	15	7	-	-	-	-	-	4	1

UNCLASSIFIED

Nuclide	$T_{1/2}$ (s)	Mean Decay Energies (keV)			Number of Spectral Lines								
		Light Particle	Electro-magnetic	Heavy Particle	γ	β^-	EC/β^+	α	n	SF*	p	e^-	X-ray
10-Ne- 23	3.72000E+01	1890.05	172.79	0.00	5	4	-	-	-	-	-	-	-
11-Na- 22	8.21444E+07	195.76	2198.92	0.00	1	-	2	-	-	-	-	4	2
11-Na- 24	5.38756E+04	553.60	4122.24	0.00	6	3	-	-	-	-	-	5	2
11-Na- 24m	2.02000E-02	13.77	470.00	0.00	1	1	-	-	-	-	-	-	-
11-Na- 25	5.96000E+01	1496.49	436.90	0.00	10	5	-	-	-	-	-	-	-
11-Na- 26	1.08000E+00	3329.45	2180.29	0.00	19	9	-	-	-	-	-	-	-
12-Mg- 27	5.67480E+02	699.62	894.99	0.00	3	2	-	-	-	-	-	-	-
12-Mg- 28	7.52400E+04	197.86	1379.96	0.00	8	3	-	-	-	-	-	5	3
13-Al- 26	2.27215E+13	446.15	2678.09	0.00	3	-	2	-	-	-	-	2	3
13-Al- 26m	6.34500E+00	1433.75	1026.13	0.00	-	-	1	-	-	-	-	2	3
13-Al- 28	1.34460E+02	1237.60	1782.85	0.00	1	1	-	-	-	-	-	-	-
13-Al- 29	3.93600E+02	972.76	1380.92	0.00	7	4	-	-	-	-	-	-	-
13-Al- 30	3.65000E+00	2290.18	3512.41	0.00	17	7	-	-	-	-	-	-	-
14-Si- 31	9.43200E+03	593.74	2.17	0.00	1	2	-	-	-	-	-	-	-
14-Si- 32	1.04140E+10	64.68	0.00	0.00	-	1	-	-	-	-	-	-	-
15-P - 32	1.23293E+06	692.92	1.71	0.00	-	1	-	-	-	-	-	-	-
15-P - 33	2.19456E+06	76.57	0.00	0.00	-	1	-	-	-	-	-	-	-
15-P - 34	1.24000E+01	2284.55	347.48	0.00	6	5	-	-	-	-	-	-	-
16-S - 35	7.56000E+06	48.83	0.00	0.00	-	1	-	-	-	-	-	-	-
16-S - 37	2.99400E+02	793.24	2936.91	0.00	4	4	-	-	-	-	-	-	-
17-Cl- 34	1.52600E+00	2043.76	1029.20	0.00	-	-	1	-	-	-	-	2	4
17-Cl- 34m	1.92600E+03	441.40	1979.11	0.00	9	-	5	-	-	-	-	8	7
17-Cl- 36	9.68818E+12	246.09	0.03	0.00	-	1	1	-	-	-	-	2	4
17-Cl- 38	2.23200E+03	1522.99	1493.73	0.00	3	3	-	-	-	-	-	-	-
17-Cl- 38m	7.15000E-01	0.43	671.30	0.00	1	-	-	-	-	-	-	5	3

Nuclide	$T_{1/2}$ (s)	Mean Decay Energies (keV)			Number of Spectral Lines								
		Light Particle	Electro-magnetic	Heavy Particle	γ	β^-	EC/β^+	α	n	SF*	p	e^-	X-ray
17-Cl- 39	3.33600E+03	822.65	1454.37	0.00	19	7	-	-	-	-	-	12	3
18-Ar- 37	3.02746E+06	2.36	0.32	0.00	-	-	1	-	-	-	-	3	3
18-Ar- 39	8.48899E+09	218.65	0.00	0.00	-	1	-	-	-	-	-	-	-
18-Ar- 41	6.57600E+03	463.60	1284.47	0.00	2	3	-	-	-	-	-	6	3
18-Ar- 42	1.04140E+09	232.82	0.00	0.00	-	1	-	-	-	-	-	-	-
19-K - 38	4.56600E+02	1201.32	3190.50	0.00	3	-	2	-	-	-	-	3	4
19-K - 38m	9.24000E-01	2312.41	1030.62	0.00	-	-	1	-	-	-	-	3	4
19-K - 40	4.03937E+16	521.75	157.20	0.00	1	1	2	-	-	-	-	3	4
19-K - 42	4.45320E+04	1417.12	296.38	0.00	8	5	-	-	-	-	-	-	-
19-K - 43	7.99200E+04	309.56	966.16	0.00	10	5	-	-	-	-	-	12	3
19-K - 44	1.32780E+03	1436.10	2391.27	0.00	122	33	-	-	-	-	-	72	3
20-Ca- 41	3.25043E+12	2.84	0.44	0.00	-	-	1	-	-	-	-	3	3
20-Ca- 45	1.40573E+07	77.22	0.00	0.00	1	2	-	-	-	-	-	6	3
20-Ca- 47	3.92083E+05	344.61	1060.41	0.00	7	4	-	-	-	-	-	6	3
20-Ca- 49	5.23200E+02	869.51	3167.14	0.00	11	6	-	-	-	-	-	-	-
21-Sc- 44	1.41372E+04	595.65	2136.46	0.00	5	-	3	-	-	-	-	6	4
21-Sc- 44m	2.10960E+05	32.82	275.27	0.00	4	-	1	-	-	-	-	12	6
21-Sc- 45m	3.25000E-01	11.71	0.70	0.00	1	-	-	-	-	-	-	6	3
21-Sc- 46	7.23946E+06	112.24	2009.54	0.00	3	2	-	-	-	-	-	9	3
21-Sc- 46m	1.87000E+01	58.90	82.96	0.00	1	-	-	-	-	-	-	6	3
21-Sc- 47	2.89094E+05	162.53	108.53	0.00	1	2	-	-	-	-	-	6	3
21-Sc- 48	1.57212E+05	219.59	3349.60	0.00	5	2	-	-	-	-	-	-	-
21-Sc- 49	3.43200E+03	819.88	3.34	0.00	2	3	-	-	-	-	-	-	-
21-Sc- 50	1.02500E+02	1624.13	3198.10	0.00	10	8	-	-	-	-	-	-	-
21-Sc- 50m	3.50000E-01	40.69	264.40	0.00	2	1	-	-	-	-	-	6	3

Nuclide	$T_{1/2}$ (s)	Mean Decay Energies (keV)			Number of Spectral Lines								
		Light Particle	Electro-magnetic	Heavy Particle	γ	β^-	EC/β^+	α	n	SF*	p	e^-	X-ray
22-Ti- 45	1.10880E+04	373.34	871.84	0.00	15	-	6	-	-	-	-	6	4
22-Ti- 51	3.48000E+02	868.93	364.55	0.00	3	2	-	-	-	-	-	6	3
23-V - 48	1.38015E+06	149.28	2915.94	0.00	9	-	6	-	-	-	-	3	4
23-V - 49	2.85120E+07	3.58	0.95	0.00	-	-	1	-	-	-	-	3	3
23-V - 52	2.24700E+02	1064.34	1448.36	0.00	14	8	-	-	-	-	-	15	3
23-V - 53	9.72000E+01	1005.11	1041.59	0.00	7	3	-	-	-	-	-	-	-
23-V - 54	4.98000E+01	1357.52	4097.54	0.00	24	8	-	-	-	-	-	-	-
24-Cr- 49	2.51400E+03	596.49	1047.24	0.00	12	-	8	-	-	-	-	12	4
24-Cr- 51	2.39380E+06	3.85	32.75	0.00	1	-	2	-	-	-	-	6	3
24-Cr- 55	2.12400E+02	1096.51	4.24	0.00	7	5	-	-	-	-	-	6	3
25-Mn- 53	1.16132E+14	4.00	1.42	0.00	-	-	1	-	-	-	-	3	3
25-Mn- 54	2.69827E+07	4.21	836.04	0.00	1	-	1	-	-	-	-	9	6
25-Mn- 56	9.28440E+03	823.81	1700.66	0.00	10	7	-	-	-	-	-	-	-
25-Mn- 58	6.52000E+01	1711.42	2382.19	0.00	39	14	-	-	-	-	-	27	3
25-Mn- 58m	2.70000E+00	2828.39	120.07	0.00	9	4	-	-	-	-	-	9	3
26-Fe- 53	5.10600E+02	1106.98	1184.25	0.00	10	-	8	-	-	-	-	6	4
26-Fe- 53m	1.54800E+02	0.00	3034.68	0.00	6	-	-	-	-	-	-	-	-
26-Fe- 55	8.63136E+07	4.22	1.67	0.00	-	-	1	-	-	-	-	3	3
26-Fe- 59	3.84497E+06	117.89	1189.21	0.00	8	5	-	-	-	-	-	18	3
26-Fe- 60	4.73364E+13	87.67	0.00	0.00	-	1	-	-	-	-	-	-	-
26-Fe- 63	6.10000E+00	2604.28	317.73	0.00	19	14	-	-	-	-	-	21	3
27-Co- 55	6.31080E+04	436.58	2007.03	0.00	23	-	10	-	-	-	-	24	4
27-Co- 56	6.67526E+06	121.02	3589.76	0.00	45	-	13	-	-	-	-	30	4
27-Co- 57	2.34827E+07	20.01	123.99	0.00	10	-	2	-	-	-	-	33	3
27-Co- 58	6.12230E+06	34.31	976.20	0.00	3	-	3	-	-	-	-	12	4

Nuclide	$T_{1/2}$ (s)	Mean Decay Energies (keV)			Number of Spectral Lines								
		Light Particle	Electro-magnetic	Heavy Particle	γ	β^-	EC/β^+	α	n	SF*	p	e^-	X-ray
27-Co- 58m	3.21840E+04	23.15	1.82	0.00	1	-	-	-	-	-	-	6	3
27-Co- 60	1.66363E+08	96.71	2503.95	0.00	6	3	-	-	-	-	-	15	3
27-Co- 60m	6.28200E+02	56.50	6.79	0.00	4	2	-	-	-	-	-	15	6
28-Ni- 57	1.28520E+05	162.12	1960.02	0.00	24	-	9	-	-	-	-	18	4
28-Ni- 59	2.39838E+12	4.62	2.54	0.00	-	-	1	-	-	-	-	3	4
28-Ni- 63	3.12420E+09	17.14	0.00	0.00	-	1	-	-	-	-	-	-	-
28-Ni- 65	9.07200E+03	629.70	549.93	0.00	10	5	-	-	-	-	-	18	3
28-Ni- 66	1.95840E+05	65.24	0.00	0.00	-	1	-	-	-	-	-	-	-
28-Ni- 67	2.10000E+01	1523.24	50.25	0.00	7	6	-	-	-	-	-	-	-
29-Cu- 62	5.85000E+02	1282.90	1011.69	0.00	16	-	10	-	-	-	-	3	4
29-Cu- 64	4.57272E+04	125.75	190.56	0.00	1	1	2	-	-	-	-	3	4
29-Cu- 66	3.06000E+02	1070.64	81.86	0.00	3	4	-	-	-	-	-	-	-
29-Cu- 67	2.22840E+05	155.67	115.41	0.00	6	4	-	-	-	-	-	21	3
30-Zn- 63	2.30400E+03	916.73	1104.23	0.00	64	-	20	-	-	-	-	33	4
30-Zn- 65	2.11041E+07	6.98	582.52	0.00	3	-	2	-	-	-	-	6	4
30-Zn- 69	3.38400E+03	322.90	0.01	0.00	2	3	-	-	-	-	-	9	3
30-Zn- 69m	4.96080E+04	22.38	416.43	0.00	2	1	-	-	-	-	-	12	6
31-Ga- 67	2.81768E+05	35.98	159.15	0.00	10	-	5	-	-	-	-	33	3
31-Ga- 70	1.26840E+03	640.49	9.18	0.00	3	3	1	-	-	-	-	12	8
31-Ga- 77	1.30000E+01	2111.68	457.02	0.00	14	9	-	-	-	-	-	21	5
32-Ge- 71	9.87552E+05	5.14	4.2	0.00	-	-	1	-	-	-	-	3	3
32-Ge- 71m	2.04000E-02	33.27	165.17	0.00	2	-	-	-	-	-	-	9	5
32-Ge- 73m	5.00000E-01	55.61	11.35	0.00	2	-	-	-	-	-	-	9	5
32-Ge- 75	4.96680E+03	419.78	34.73	0.00	11	5	-	-	-	-	-	18	5
32-Ge- 75m	4.80000E+01	81.87	58.06	0.00	14	1	-	-	-	-	-	48	10
32-Ge- 80	2.70000E+01	949.23	342.75	0.00	17	9	-	-	-	-	-	33	5

Nuclide	$T_{1/2}$ (s)	Mean Decay Energies (keV)			Number of Spectral Lines								
		Light Particle	Electro-magnetic	Heavy Particle	γ	$β^-$	EC/$β^+$	α	n	SF*	p	e^-	X-ray
33-As- 73	6.93792E+06	5.23	4.76	0.00	-	-	1	-	-	-	-	3	5
33-As- 74	1.53619E+06	268.31	759.66	0.00	14	3	6	-	-	-	-	15	11
33-As- 76	9.43920E+04	1063.82	419.75	0.00	61	22	-	-	-	-	-	69	5
33-As- 82	2.00000E+01	3156.07	343.10	0.00	17	13	-	-	-	-	-	9	5
33-As- 82m	1.36000E+01	2037.24	2969.60	0.00	13	6	-	-	-	-	-	15	5
33-As- 85	2.04000E+00	3380.98	358.54	151.84	10	14	-	-	11	-	-	24	5
34-Se- 75	1.03369E+07	14.65	390.20	0.00	20	-	9	-	-	-	-	36	5
34-Se- 77m	1.75500E+01	73.28	88.81	0.00	1	-	-	-	-	-	-	6	5
34-Se- 79	1.18970E+13	52.55	0.00	0.00	-	1	-	-	-	-	-	-	-
34-Se- 79m	2.34000E+02	81.87	13.96	0.00	1	1	-	-	-	-	-	6	5
34-Se- 81	1.10340E+03	609.06	8.55	0.00	11	7	-	-	-	-	-	30	5
34-Se- 81m	3.43680E+03	85.40	18.03	0.00	8	2	-	-	-	-	-	30	10
35-Br- 72	7.86000E+01	2716.91	2921.83	0.00	35	-	13	-	-	-	-	57	6
35-Br- 72m	1.06000E+01	50.88	50.00	0.00	1	-	-	-	-	-	-	6	5
35-Br- 77	2.05326E+05	7.97	318.88	0.00	60	-	14	-	-	-	-	161	6
35-Br- 79m	4.88000E+00	50.00	157.16	0.00	1	-	-	-	-	-	-	6	5
35-Br- 80	1.05600E+03	724.04	77.00	0.00	6	4	3	-	-	-	-	24	12
35-Br- 80m	1.58760E+04	61.76	24.26	0.00	2	-	-	-	-	-	-	9	5
35-Br- 82	1.27152E+05	142.69	2638.03	0.00	34	6	-	-	-	-	-	60	6
35-Br- 82m	3.65400E+02	70.09	8.18	0.00	26	11	-	-	-	-	-	33	11
35-Br- 87	5.57000E+01	1576.66	3089.26	3.78	374	181	-	-	24	-	-	51	6
35-Br- 88	1.65000E+01	2393.53	3112.18	8.07	167	66	-	-	2	-	-	75	6
35-Br- 89	4.37000E+00	2572.12	1711.12	6.48	116	60	-	-	5	-	-	27	6
35-Br- 90	1.90000E+00	3290.29	1537.77	21.91	75	47	-	-	6	-	-	12	6
35-Br- 91	5.38000E-01	3908.96	451.19	10.00	4	6	-	-	1	-	-	15	6

Nuclide	$T_{1/2}$ (s)	Mean Decay Energies (keV)			Number of Spectral Lines								
		Light Particle	Electro-magnetic	Heavy Particle	γ	β^-	EC/β^+	α	n	SF*	p	e^-	X-ray
36-Kr- 79	1.26144E+05	24.63	257.77	0.00	41	-	11	-	-	-	-	57	6
36-Kr- 79m	5.00000E+01	90.06	39.80	0.00	1	-	-	-	-	-	-	6	6
36-Kr- 81	6.62710E+12	5.39	7.37	0.00	1	-	2	-	-	-	-	6	5
36-Kr- 81m	1.32000E+01	58.77	131.72	0.00	1	-	1	-	-	-	-	9	11
36-Kr- 83m	6.58800E+03	39.12	2.70	0.00	2	-	-	-	-	-	-	8	6
36-Kr- 85	3.38602E+08	250.65	2.23	0.00	3	2	-	-	-	-	-	12	6
36-Kr- 85m	1.61280E+04	255.51	157.18	0.00	7	3	-	-	-	-	-	27	12
36-Kr- 90	3.23000E+01	1331.96	1282.49	0.00	102	25	-	-	-	-	-	42	6
37-Rb- 83	7.44768E+06	8.64	496.07	0.00	11	-	6	-	-	-	-	35	6
37-Rb- 84	2.89440E+06	144.04	887.23	0.00	3	1	3	-	-	-	-	3	7
37-Rb- 84m	1.22400E+03	80.18	382.88	0.00	3	-	-	-	-	-	-	12	6
37-Rb- 86	1.60963E+06	665.79	96.75	0.00	1	2	1	-	-	-	-	3	6
37-Rb- 86m	6.10000E+01	9.96	546.02	0.00	1	-	-	-	-	-	-	6	6
37-Rb- 89	9.24000E+02	929.24	2234.21	0.00	62	22	-	-	-	-	-	114	6
37-Rb- 90	1.57000E+02	1904.00	2280.00	0.00	95	26	-	-	-	-	-	45	6
37-Rb- 93	5.80000E+00	2117.68	2602.36	4.15	272	92	-	-	27	-	-	48	6
37-Rb- 94	2.70200E+00	3101.54	2747.43	10.05	161	87	-	-	8	-	-	72	6
37-Rb- 95	3.81000E-01	2828.94	2642.12	7.85	252	88	-	-	15	-	-	60	6
38-Sr- 83	1.16676E+05	148.99	776.22	0.00	120	-	23	-	-	-	-	122	7
38-Sr- 83m	4.95000E+00	31.17	228.09	0.00	1	-	-	-	-	-	-	6	6
38-Sr- 85	5.60295E+06	9.16	518.50	0.00	7	-	3	-	-	-	-	15	6
38-Sr- 85m	4.05660E+03	13.25	215.91	0.00	11	-	4	-	-	-	-	26	12
38-Sr- 87m	1.01376E+04	66.56	320.89	0.00	1	-	1	-	-	-	-	9	12
38-Sr- 89	4.36493E+06	582.30	1.29	0.00	-	2	-	-	-	-	-	-	-
38-Sr- 90	9.11002E+08	195.71	0.00	0.00	-	1	-	-	-	-	-	-	-
38-Sr- 92	9.75600E+03	179.90	1380.97	0.00	9	3	-	-	-	-	-	15	6

Nuclide	$T_{1/2}$ (s)	Mean Decay Energies (keV)			Number of Spectral Lines								
		Light Particle	Electro-magnetic	Heavy Particle	γ	β^-	EC/β^+	α	n	SF*	p	e^-	X-ray
38-Sr- 94	7.53000E+01	831.28	1433.13	0.00	16	7	-	-	-	-	-	45	6
39-Y - 87	2.87280E+05	7.2	461.66	0.00	1	-	2	-	-	-	-	6	7
39-Y – 87m	4.81320E+04	78.65	308.17	0.00	1	-	1	-	-	-	-	9	13
39-Y - 88	9.21283E+06	6.77	2696.62	0.00	7	-	4	-	-	-	-	9	7
39-Y - 89m	1.60500E+01	7.71	901.36	0.00	1	-	-	-	-	-	-	6	6
39-Y - 90	2.30400E+05	930.62	2.87	0.00	3	3	-	-	-	-	-	3	-
39-Y – 90m	1.14840E+04	46.44	635.23	0.00	3	1	-	-	-	-	-	12	6
39-Y - 91	5.07168E+06	602.41	5.00	0.00	1	2	-	-	-	-	-	-	-
39-Y - 91m	2.98320E+03	27.99	527.61	0.00	1	-	-	-	-	-	-	6	6
39-Y - 96	5.37000E+00	3179.25	95.61	0.00	64	43	-	-	-	-	-	48	6
39-Y - 96m	9.62000E+00	1851.14	4486.45	0.00	59	15	-	-	-	-	-	117	6
39-Y - 97	3.75000E+00	2135.04	1845.99	0.12	25	11	-	-	1	-	-	30	6
39-Y - 97m	1.17000E+00	2317.49	2110.63	0.14	63	24	-	-	1	-	-	54	12
39-Y - 97n	1.42000E-01	120.75	2807.45	0.00	47	1	-	-	-	-	-	84	12
39-Y - 98	5.90000E-01	2779.90	2613.36	1.04	32	12	-	-	0c	-	-	54	6
39-Y - 98m	2.00000E+00	2788.18	3294.44	15.76	28	9	-	-	0c	-	-	54	6
39-Y - 99	1.47700E+00	2948.70	916.74	7.36	117	39	-	-	0c	-	-	213	6
39-Y -104	1.30000E-01	3494.00	3750.00	49.48	0c	0c	-	-	0c	-	-	-	-
39-Y -105	1.50000E-01	3325.00	2372.00	123.48	0c	0c	-	-	0c	-	-	-	-
40-Zr- 88	7.20576E+06	16.09	391.81	0.00	1	-	1	-	-	-	-	6	6
40-Zr- 89	2.82240E+05	92.78	253.88	0.00	4	-	5	-	-	-	-	3	7
40-Zr- 89m	2.50800E+02	32.74	638.03	0.00	2	-	2	-	-	-	-	9	13
40-Zr- 90m	8.08200E-01	16.2	2303.78	0.00	5	-	-	-	-	-	-	12	6
40-Zr- 93	4.82821E+13	19.18	0.00	0.00	-	2	-	-	-	-	-	-	-
40-Zr- 95	5.53219E+06	118.03	730.54	0.00	2	4	-	-	-	-	-	-	-
40-Zr- 99	2.20000E+00	1538.96	841.41	0.00	14	6	-	-	-	-	-	42	6

Nuclide	$T_{1/2}$ (s)	Mean Decay Energies (keV)			Number of Spectral Lines								
		Light Particle	Electro-magnetic	Heavy Particle	γ	β^-	EC/β^+	α	n	SF*	p	e^-	X-ray
40-Zr-105	6.00000E-01	2662.00	1764.00	4.47	0c	0c	-	-	0c	-	-	-	-
40-Zr-106	9.00000E-01	2138.00	1091.00	5.80	0c	0c	-	-	0c	-	-	-	-
40-Zr-107	2.40000E-01	2982.00	2201.00	17.51	0c	0c	-	-	0c	-	-	-	-
41-Nb- 90	5.25240E+04	391.77	1960.33	0.00	33	-	9	-	-	-	-	45	7
41-Nb- 90m	1.88100E+01	42.3	82.38	0.00	2	-	-	-	-	-	-	7	6
41-Nb- 90n	6.22000E-03	38.7	218.55	0.00	1	-	-	-	-	-	-	6	6
41-Nb- 91	2.14592E+10	5.88	12.57	0.00	-	-	1	-	-	-	-	3	7
41-Nb- 91m	5.26176E+06	93.46	38.03	0.00	2	-	1	-	-	-	-	9	12
41-Nb- 92	1.10452E+15	7.93	1503.31	0.00	2	-	1	-	-	-	-	9	6
41-Nb- 92m	8.76960E+05	6.45	970.38	0.00	6	-	5	-	-	-	-	15	7
41-Nb- 93m	5.08698E+08	28.85	2.05	0.00	1	-	-	-	-	-	-	6	6
41-Nb- 94	6.30720E+11	168.27	1571.53	0.00	2	1	-	-	-	-	-	9	6
41-Nb- 94m	3.75600E+02	35.09	12.27	0.00	4	3	-	-	-	-	-	15	6
41-Nb- 95	3.02184E+06	44.60	764.35	0.00	3	3	-	-	-	-	-	12	6
41-Nb- 95m	3.11760E+05	173.65	71.68	0.00	5	4	-	-	-	-	-	12	12
41-Nb- 96	8.40600E+04	250.16	2445.75	0.00	39	8	-	-	-	-	-	93	6
41-Nb-100	1.40000E+00	2443.19	744.36	0.00	40	19	-	-	-	-	-	66	6
41-Nb-100m	2.90000E+00	2047.30	2064.43	0.00	22	7	-	-	-	-	-	69	6
41-Nb-109	1.90000E-01	3158.00	2263.00	68.40	0c	0c	-	-	0c	-	-	-	-
42-Mo- 93	9.50400E+10	5.65	10.94	0.00	-	-	2	-	-	-	-	3	6
42-Mo- 93m	2.46600E+04	107.21	2317.51	0.00	13	-	2	-	-	-	-	15	12
42-Mo- 99	2.37420E+05	392.36	146.76	0.00	35	12	-	-	-	-	-	42	6
42-Mo-103	6.79000E+01	1316.28	636.20	0.00	43	17	-	-	-	-	-	90	6
42-Mo-109	5.00000E-01	2675.00	1876.00	0.91	0c	0c	-	-	0c	-	-	-	-
42-Mo-111	5.00000E-01	3098.00	2413.00	3.57	0c	0c	-	-	0c	-	-	-	-
42-Mo-112	1.00000E+00	2552.00	1354.00	7.96	0c	0c	-	-	0c	-	-	-	-

Nuclide	$T_{1/2}$ (s)	Mean Decay Energies (keV)			Number of Spectral Lines								
		Light Particle	Electro-magnetic	Heavy Particle	γ	β^-	EC/β^+	α	n	SF*	p	e^-	X-ray
43-Tc- 97	8.20498E+13	5.65	11.68	0.00	-	-	1	-	-	-	-	3	6
43-Tc- 97m	7.79328E+06	87.04	9.50	0.00	1	-	-	-	-	-	-	6	6
43-Tc- 98	1.35695E+14	122.72	1394.91	0.00	2	1	-	-	-	-	-	9	6
43-Tc- 99m	2.16360E+04	16.13	126.48	0.00	6	3	-	-	-	-	-	22	12
43-Tc-113	1.30000E-01	2732.00	1822.00	33.53	0c	0c	-	-	0c	-	-	-	-
43-Tc-114	2.00000E-01	3578.00	3257.00	32.88	0c	0c	-	-	0c	-	-	-	-
43-Tc-115	2.70000E-01	2995.00	2162.00	79.74	0c	0c	-	-	0c	-	-	-	-
43-Tc-116	1.20000E-01	3693.00	3495.00	71.73	0c	0c	-	-	0c	-	-	-	-
43-Tc-99	6.66812E+12	100.98	0.00	0.00	1	2	-	-	-	-	-	6	6
44-Ru-103	3.39206E+06	66.45	497.68	0.00	18	6	-	-	-	-	-	57	6
44-Ru-115	7.00000E-01	2538.00	1806.00	0.61	0c	0c	-	-	0c	-	-	-	-
44-Ru-116	1.70000E+00	1843.00	986.00	3.61	0c	0c	-	-	0c	-	-	-	-
44-Ru-117	3.40000E-01	2697.00	2026.00	8.31	0c	0c	-	-	0c	-	-	-	-
44-Ru-118	7.00000E-01	2094.00	1118.00	17.80	0c	0c	-	-	0c	-	-	-	-
44-Ru-119	1.90000E-01	2920.00	2311.00	20.66	0c	0c	-	-	0c	-	-	-	-
45-Rh-101	1.00982E+08	28.04	312.04	0.00	8	-	3	-	-	-	-	27	6
45-Rh-101m	3.75840E+05	20.17	305.55	0.00	10	-	2	-	-	-	-	36	12
45-Rh-102	9.15840E+07	12.16	2122.05	0.00	16	-	2	-	-	-	-	33	6
45-Rh-102m	1.79712E+07	173.60	493.17	0.00	30	2	7	-	-	-	-	57	19
45-Rh-103m	3.36690E+03	38.21	1.70	0.00	1	-	-	-	-	-	-	6	6
45-Rh-104	4.23000E+01	980.49	15.02	0.00	17	7	3	-	-	-	-	30	13
45-Rh-104m	2.60400E+02	86.20	45.52	0.00	22	7	-	-	-	-	-	27	12
45-Rh-105	1.27368E+05	153.21	78.04	0.00	5	4	-	-	-	-	-	18	6
45-Rh-105m	4.00000E+01	95.24	34.60	0.00	1	-	-	-	-	-	-	6	6
45-Rh-106	3.01000E+01	1401.28	218.09	0.00	87	36	-	-	-	-	-	48	6

Nuclide	$T_{1/2}$ (s)	Mean Decay Energies (keV)			Number of Spectral Lines								
		Light Particle	Electro-magnetic	Heavy Particle	γ	β^-	EC/β^+	α	n	SF*	p	e^-	X-ray
45-Rh-106m	7.92000E+03	321.63	2759.22	0.00	40	5	-	-	-	-	-	84	6
45-Rh-110	2.85000E+01	1182.14	2553.61	0.00	25	5	-	-	-	-	-	45	6
45-Rh-110m	3.20000E+00	2266.23	335.96	0.00	8	6	-	-	-	-	-	27	6
45-Rh-111	1.20000E+01	1389.42	357.05	0.00	43	13	-	-	-	-	-	96	6
45-Rh-118	3.20000E-01	3094.00	2494.00	12.16	0c	0c	-	-	0c	-	-	-	-
45-Rh-120	1.70000E-01	3261.00	2837.00	29.19	0c	0c	-	-	0c	-	-	-	-
45-Rh-121	2.50000E-01	2671.00	1852.00	74.06	0c	0c	-	-	0c	-	-	-	-
46-Pd-103	1.46707E+06	5.88	14.68	0.00	8	-	4	-	-	-	-	27	6
46-Pd-107	2.05124E+14	9.40	0.00	0.00	-	1	-	-	-	-	-	-	-
46-Pd-107m	2.13000E+01	62.99	151.84	0.00	1	-	-	-	-	-	-	6	6
46-Pd-109	4.84560E+04	359.82	1.05	0.00	31	12	-	-	-	-	-	84	6
46-Pd-109m	2.82600E+02	77.49	111.43	0.00	1	-	-	-	-	-	-	6	6
46-Pd-112	7.30800E+04	89.90	5.25	0.00	1	1	-	-	-	-	-	4	2
46-Pd-113	9.10000E+01	1330.18	127.55	0.00	33	14	-	-	-	-	-	90	6
46-Pd-113m	3.00000E-01	59.42	21.40	0.00	1	-	-	-	-	-	-	6	6
46-Pd-121	6.00000E-01	2335.00	1638.00	0.75	0c	0c	-	-	0c	-	-	-	-
47-Ag-105	3.56832E+06	19.93	530.41	0.00	62	-	9	-	-	-	-	120	6
47-Ag-105m	4.33800E+02	25.34	1.22	0.00	20	-	9	-	-	-	-	34	8
47-Ag-106	1.44000E+03	503.52	705.98	0.00	36	1	17	-	-	-	-	30	7
47-Ag-106m	7.30944E+05	12.27	2754.44	0.00	57	-	5	-	-	-	-	87	6
47-Ag-107m	4.41000E+01	80.67	12.51	0.00	1	-	-	-	-	-	-	6	6
47-Ag-108	1.44000E+02	605.53	22.83	0.00	13	2	6	-	-	-	-	24	13
47-Ag-108m	1.31911E+10	16.04	1630.06	0.00	5	-	1	-	-	-	-	21	12
47-Ag-109m	3.97000E+01	76.74	11.30	0.00	1	-	-	-	-	-	-	6	6
47-Ag-110	2.47000E+01	1174.85	34.77	0.00	15	11	2	-	-	-	-	24	12

Nuclide	$T_{1/2}$ (s)	Mean Decay Energies (keV)			Number of Spectral Lines								
		Light Particle	Electro-magnetic	Heavy Particle	γ	β^-	EC/β^+	α	n	SF*	p	e^-	X-ray
47-Ag-110m	2.15819E+07	69.02	2760.64	0.00	61	9	-	-	-	-	-	46	12
47-Ag-111	6.43680E+05	353.29	26.34	0.00	14	7	-	-	-	-	-	45	6
47-Ag-111m	6.48000E+01	56.01	6.88	0.00	11	4	-	-	-	-	-	39	12
47-Ag-114	4.70000E+00	2096.51	271.79	0.00	43	26	-	-	-	-	-	36	6
47-Ag-114m	1.50000E-03	101.88	97.12	0.00	4	-	-	-	-	-	-	15	6
47-Ag-115	1.23000E+03	779.22	1132.27	0.00	145	44	-	-	-	-	-	93	6
47-Ag-115m	1.86000E+01	844.05	454.99	0.00	25	10	-	-	-	-	-	66	12
48-Cd-107	2.34720E+04	6.27	21.24	0.00	35	-	12	-	-	-	-	81	7
48-Cd-109	3.99686E+07	5.71	15.15	0.00	-	-	1	-	-	-	-	3	6
48-Cd-111m	2.92440E+03	109.59	286.67	0.00	2	-	-	-	-	-	-	9	6
48-Cd-113	2.46144E+23	92.59	0.00	0.00	-	1	-	-	-	-	-	-	-
48-Cd-113m	4.60731E+08	184.49	0.07	0.00	1	1	-	-	-	-	-	6	6
48-Cd-115	1.92456E+05	317.32	192.90	0.00	16	7	-	-	-	-	-	39	6
48-Cd-115m	3.84048E+06	602.48	33.63	0.00	25	8	-	-	-	-	-	60	6
49-In-111	2.42326E+05	33.49	406.47	0.00	2	-	2	-	-	-	-	9	6
49-In-111m	4.74000E+02	67.84	469.64	0.00	1	-	-	-	-	-	-	6	6
49-In-112	8.82000E+02	245.21	290.19	0.00	16	1	9	-	-	-	-	30	7
49-In-112m	1.24200E+03	122.20	34.56	0.00	1	-	-	-	-	-	-	6	6
49-In-113m	5.96880E+03	131.33	260.35	0.00	1	-	-	-	-	-	-	6	6
49-In-114	7.19000E+01	769.23	4.37	0.00	3	2	2	-	-	-	-	3	7
49-In-114m	4.32000E+06	140.90	88.99	0.00	3	-	1	-	-	-	-	9	12
49-In-114n	4.30000E-02	33.96	277.66	0.00	1	-	-	-	-	-	-	6	6
49-In-115	1.39169E+22	207.88	0.00	0.00	-	1	-	-	-	-	-	-	-
49-In-115m	1.61496E+04	170.99	162.50	0.00	2	2	-	-	-	-	-	12	12
49-In-116	1.42000E+01	1356.65	5.27	0.00	11	8	-	-	-	-	-	21	6
49-In-116m	3.27600E+03	312.60	2490.78	0.00	40	7	-	-	-	-	-	114	6

Nuclide	$T_{1/2}$ (s)	Mean Decay Energies (keV)			Number of Spectral Lines								
		Light Particle	Electro-magnetic	Heavy Particle	γ	β^-	EC/β^+	α	n	SF*	p	e^-	X-ray
49-In-116n	2.17000E+00	94.12	68.17	0.00	1	-	-	-	-	-	-	6	6
50-Sn-110	1.47600E+04	14.17	290.43	0.00	1	-	1	-	-	-	-	6	6
50-Sn-113	9.94378E+06	6.27	23.25	0.00	3	-	3	-	-	-	-	6	6
50-Sn-113m	1.25400E+03	58.58	14.48	0.00	1	-	1	-	-	-	-	9	12
50-Sn-117m	1.17504E+06	158.24	156.34	0.00	3	-	-	-	-	-	-	12	6
50-Sn-119m	2.53152E+07	78.26	11.36	0.00	2	-	-	-	-	-	-	8	6
50-Sn-121	9.71640E+04	115.89	0.00	0.00	-	1	-	-	-	-	-	-	-
50-Sn-121m	1.38535E+09	35.49	5.11	0.00	2	1	-	-	-	-	-	10	8
50-Sn-123	1.11629E+07	519.90	8.00	0.00	9	6	-	-	-	-	-	6	6
50-Sn-123m	2.40600E+03	475.46	141.20	0.00	5	3	-	-	-	-	-	6	6
50-Sn-125	8.32896E+05	805.01	316.10	0.00	49	15	-	-	-	-	-	60	6
50-Sn-125m	5.71800E+02	800.53	348.27	0.00	26	11	-	-	-	-	-	33	6
50-Sn-126	7.25809E+12	109.32	56.4	0.00	6	1	-	-	-	-	-	19	6
50-Sn-129	1.33800E+02	1097.58	1350.01	0.00	70	31	-	-	-	-	-	99	6
50-Sn-129m	4.32000E+02	705.53	1707.46	0.00	81	32	-	-	-	-	-	137	6
50-Sn-130	2.23800E+02	462.10	937.55	0.00	33	9	-	-	-	-	-	42	6
50-Sn-130m	1.02000E+02	1388.46	813.03	0.00	93	48	-	-	-	-	-	51	6
51-Sb-119	1.37880E+05	25.97	23.42	0.00	1	-	1	-	-	-	-	5	6
51-Sb-120	9.54000E+02	306.76	460.03	0.00	3	-	4	-	-	-	-	12	7
51-Sb-120m	4.97664E+05	45.05	2462.26	0.00	5	-	1	-	-	-	-	15	6
51-Sb-122	2.32920E+05	564.67	437.88	0.00	8	6	2	-	-	-	-	3	7
51-Sb-122m	2.51400E+02	93.06	70.53	0.00	3	-	-	-	-	-	-	11	6
51-Sb-124	5.20474E+06	381.74	1863.29	0.00	66	21	-	-	-	-	-	45	6
51-Sb-124m	9.30000E+01	114.07	437.54	0.00	5	3	-	-	-	-	-	16	8
51-Sb-124n	1.21200E+03	25.77	0.34	0.00	1	-	-	-	-	-	-	4	2
51-Sb-125	8.70653E+07	101.08	430.25	0.00	24	8	-	-	-	-	-	74	6

Nuclide	$T_{1/2}$ (s)	Mean Decay Energies (keV)			Number of Spectral Lines								
		Light Particle	Electro-magnetic	Heavy Particle	γ	β^-	EC/β^+	α	n	SF*	p	e^-	X-ray
51-Sb-126	1.07222E+06	332.68	2752.52	0.00	27	14	-	-	-	-	-	84	6
51-Sb-126m	1.14600E+03	624.77	1575.98	0.00	9	4	-	-	-	-	-	31	8
51-Sb-126n	1.10000E+01	22.44	0.38	0.00	1	-	-	-	-	-	-	4	2
51-Sb-127	3.31776E+05	314.67	658.38	0.00	36	15	-	-	-	-	-	96	6
51-Sb-129	1.56960E+04	354.83	1380.09	0.00	70	30	-	-	-	-	-	48	6
51-Sb-129m	1.06200E+03	998.86	1477.98	0.00	37	8	-	-	-	-	-	42	12
51-Sb-135	1.74000E+00	2966.53	688.10	177.09	41	26	-	-	8	-	-	51	6
51-Sb-141	3.00000E-01	3511.07	3275.00	85.00	-	-	-	-	-	-	-	-	-
52-Te-121	1.65542E+06	9.84	577.47	0.00	5	-	2	-	-	-	-	18	6
52-Te-121m	1.33056E+07	80.09	216.95	0.00	12	-	6	-	-	-	-	42	13
52-Te-125m	5.01120E+06	108.78	36.00	0.00	3	-	-	-	-	-	-	12	6
52-Te-127	3.36600E+04	224.40	4.85	0.00	9	5	-	-	-	-	-	30	6
52-Te-127m	9.41760E+06	82.14	11.58	0.00	6	4	-	-	-	-	-	24	12
52-Te-129	4.17600E+03	543.03	60.45	0.00	58	11	-	-	-	-	-	71	6
52-Te-129m	2.90304E+06	266.52	38.83	0.00	40	9	-	-	-	-	-	104	12
52-Te-132	2.79072E+05	103.13	233.69	0.00	4	1	-	-	-	-	-	15	6
53-I -125	5.13475E+06	19.22	42.44	0.00	1	-	1	-	-	-	-	6	6
53-I -126	1.12147E+06	143.82	435.63	0.00	10	3	6	-	-	-	-	21	13
53-I -132	8.21880E+03	489.82	2255.72	0.00	165	34	-	-	-	-	-	282	6
53-I -132m	4.98000E+03	162.74	344.82	0.00	9	4	-	-	-	-	-	29	12
53-I -136	8.35000E+01	1870.21	2489.8	0.00	116	51	-	-	-	-	-	141	6
53-I -136m	4.70000E+01	2242.00	2524.00	0.00	39	19	-	-	-	-	-	66	6
53-I -137	2.45100E+01	1861.83	1219.64	39.38	272	178	-	-	38	-	-	102	6
53-I -138	6.46000E+00	2720.49	1324.93	5.29	100	54	-	-	9	-	-	39	6
53-I -139	2.30000E+00	2532.93	672.34	11.12	111	44	-	-	6	-	-	115	6
54-Xe-125	6.08400E+04	34.51	270.53	0.00	35	-	11	-	-	-	-	36	7

Nuclide	$T_{1/2}$ (s)	Mean Decay Energies (keV)			Number of Spectral Lines								
		Light Particle	Electro-magnetic	Heavy Particle	γ	$β^-$	EC/$β^+$	α	n	SF*	p	e^-	X-ray
54-Xe-125m	5.60000E+01	136.39	116.06	0.00	2	-	-	-	-	-	-	9	6
54-Xe-127	3.14842E+06	32.50	280.66	0.00	6	-	3	-	-	-	-	21	6
54-Xe-127m	6.96000E+01	128.74	168.48	0.00	2	-	-	-	-	-	-	9	6
54-Xe-129m	7.67232E+05	183.89	51.92	0.00	2	-	-	-	-	-	-	9	6
54-Xe-131m	1.02557E+06	142.62	21.20	0.00	1	-	-	-	-	-	-	6	6
54-Xe-133	4.52995E+05	135.67	46.19	0.00	6	3	-	-	-	-	-	21	6
54-Xe-133m	1.89216E+05	192.38	40.79	0.00	1	-	-	-	-	-	-	6	6
54-Xe-134m	2.90000E-01	69.26	1896.07	0.00	3	-	-	-	-	-	-	12	6
54-Xe-139	3.96900E+01	1719.84	1017.25	0.00	271	64	-	-	-	-	-	156	6
55-Cs-123	3.54600E+02	942.45	1067.53	0.00	64	-	25	-	-	-	-	111	7
55-Cs-123m	1.70000E+00	112.15	44.13	0.00	4	-	-	-	-	-	-	14	6
55-Cs-129	1.15920E+05	17.42	283.21	0.00	30	-	8	-	-	-	-	87	6
55-Cs-131	8.37216E+05	6.37	23.12	0.00	-	-	1	-	-	-	-	3	6
55-Cs-132	5.64192E+05	14.11	715.25	0.00	13	2	4	-	-	-	-	45	13
55-Cs-134	6.51698E+07	163.39	1554.09	0.00	12	3	1	-	-	-	-	42	12
55-Cs-134m	1.04688E+04	111.78	27.08	0.00	3	-	-	-	-	-	-	11	6
55-Cs-135	7.57382E+13	66.86	0.00	0.00	-	1	-	-	-	-	-	-	-
55-Cs-135m	3.18000E+03	36.92	1596.54	0.00	2	-	-	-	-	-	-	9	6
55-Cs-136	1.12579E+06	141.89	2145.59	0.00	23	7	-	-	-	-	-	60	6
55-Cs-136m	1.90000E+01	616.67	616.67	0.00	-	-	-	-	-	-	-	-	-
55-Cs-137	9.52128E+08	186.54	0.04	0.00	-	2	-	-	-	-	-	-	-
55-Cs-140	6.40000E+01	1892.73	1827.41	0.00	269	62	-	-	-	-	-	456	6
56-Ba-126	6.00000E+03	18.13	565.11	0.00	90	-	26	-	-	-	-	114	7
56-Ba-129	8.56800E+03	127.27	466.47	0.00	94	-	8	-	-	-	-	209	7
56-Ba-129m	7.70400E+03	69.10	1207.46	0.00	95	-	12	-	-	-	-	206	7

UNCLASSIFIED

Nuclide	$T_{1/2}$ (s)	Mean Decay Energies (keV)			Number of Spectral Lines								
		Light Particle	Electro-magnetic	Heavy Particle	γ	β^-	EC/β^+	α	n	SF*	p	e^-	X-ray
56-Ba-131	9.97920E+05	46.25	459.52	0.00	62	-	12	-	-	-	-	177	7
56-Ba-131m	8.76000E+02	110.09	77.15	0.00	2	-	-	-	-	-	-	9	6
56-Ba-133	3.33677E+08	53.64	402.64	0.00	9	-	2	-	-	-	-	30	6
56-Ba-133m	1.37520E+05	221.61	66.91	0.00	4	-	1	-	-	-	-	17	12
56-Ba-137m	1.53180E+02	62.93	598.61	0.00	1	-	-	-	-	-	-	6	6
57-La-137	1.89346E+12	6.55	25.59	0.00	-	-	1	-	-	-	-	3	6
57-La-140	1.45026E+05	535.11	2312.59	0.00	39	18	-	-	-	-	-	74	6
57-La-152	2.80000E-01	2355.00	2885.00	23.97	0c	0c	-	-	0c	-	-	-	-
58-Ce-139	1.18930E+07	34.16	161.39	0.00	1	-	1	-	-	-	-	6	6
58-Ce-139m	5.61000E+01	55.09	699.12	0.00	1	-	-	-	-	-	-	6	6
58-Ce-145	1.77000E+02	762.59	601.03	0.00	88	22	-	-	-	-	-	153	6
58-Ce-147	5.70000E+01	1282.00	174.16	0.00	50	20	-	-	-	-	-	147	6
58-Ce-149	5.30000E+00	1818.17	84.56	0.00	21	12	-	-	-	-	-	57	6
58-Ce-153	1.50000E+00	1680.00	1125.00	1.57	0c	0c	-	-	0c	-	-	-	-
58-Ce-154	2.00000E+00	1694.00	958.70	1.62	0c	0c	-	-	0c	-	-	-	-
58-Ce-158	1.00000E+00	2441.75	2277.00	1.70	-	-	-	-	-	-	-	-	-
59-Pr-143	1.17158E+06	314.60	0.00	0.00	1	2	-	-	-	-	-	3	-
59-Pr-144	1.03680E+03	1200.64	33.76	0.00	21	10	-	-	-	-	-	27	6
59-Pr-144m	4.14000E+02	47.17	13.66	0.00	8	3	-	-	-	-	-	21	12
59-Pr-150	6.10000E+00	2230.23	554.20	0.00	41	23	-	-	-	-	-	75	6
59-Pr-156	5.00000E-01	2149.00	2688.00	8.93	0c	0c	-	-	0c	-	-	-	-
59-Pr-157	3.00000E-01	2387.00	1881.00	23.72	0c	0c	-	-	0c	-	-	-	-
60-Nd-140	2.91168E+05	6.73	27.73	0.00	-	-	1	-	-	-	-	3	6
60-Nd-141	8.95200E+03	16.29	77.79	0.00	14	-	9	-	-	-	-	15	7
60-Nd-141m	6.20000E+01	61.01	695.87	0.00	10	-	3	-	-	-	-	21	13

Nuclide	T1/2 (s)	Mean Decay Energies (keV)			Number of Spectral Lines								
		Light Particle	Electro-magnetic	Heavy Particle	γ	β^-	EC/β^+	α	n	SF*	p	e^-	X-ray
60-Nd-147	9.52128E+05	270.60	138.13	0.00	14	6	-	-	-	-	-	39	6
60-Nd-157	2.50000E+00	1668.00	1140.00	0.00	0c	0c	-	-	-	-	-	-	-
60-Nd-158	7.00000E-01	1589.00	923.90	0.01	0c	0c	-	-	0c	-	-	-	-
60-Nd-159	5.00000E-01	2063.00	1666.00	0.51	0c	0c	-	-	0c	-	-	-	-
60-Nd-160	3.00000E-01	2100.00	1206.00	2.49	0c	0c	-	-	0c	-	-	-	-
61-Pm-143	2.29824E+07	8.11	315.82	0.00	1	-	2	-	-	-	-	6	6
61-Pm-144	3.13632E+07	16.77	1555.59	0.00	12	-	4	-	-	-	-	30	6
61-Pm-145	5.58570E+08	12.20	31.53	0.00	2	-	3	1	-	-	-	9	6
61-Pm-146	1.74528E+08	94.41	754.29	0.00	6	2	3	-	-	-	-	24	12
61-Pm-147	8.27440E+07	61.76	0.00	0.00	3	3	-	-	-	-	-	12	6
61-Pm-148	4.63795E+05	726.30	576.49	0.00	20	10	-	-	-	-	-	30	6
61-Pm-148m	3.54672E+06	171.05	1983.64	0.00	23	4	-	-	-	-	-	72	12
61-Pm-149	1.91088E+05	366.77	12.70	0.00	44	15	-	-	-	-	-	119	6
61-Pm-151	1.01160E+05	303.20	324.16	0.00	262	33	-	-	-	-	-	727	6
61-Pm-152	2.47200E+02	1391.25	147.10	0.00	92	24	-	-	-	-	-	162	6
61-Pm-152m	4.50000E+02	900.26	1501.81	0.00	83	19	-	-	-	-	-	144	6
61-Pm-152n	8.64000E+02	728.41	2160.79	0.00	56	1	-	-	-	-	-	153	6
61-Pm-155	4.15000E+01	1061.08	561.66	0.00	5	37	-	-	-	-	-	18	6
61-Pm-159	3.00000E+00	1782.00	1160.00	0.02	0c	0c	-	-	0c	-	-	-	-
61-Pm-160	2.00000E+00	1969.00	2500.00	0.55	0c	0c	-	-	0c	-	-	-	-
62-Sm-145	2.93760E+07	29.50	62.99	0.00	3	-	3	-	-	-	-	6	6
62-Sm-146	3.15576E+15	0.00	0.00	2570.51	-	-	-	1	-	-	-	-	-
62-Sm-147	3.34511E+18	0.00	0.00	2310.65	-	-	-	1	-	-	-	-	-
62-Sm-151	2.84018E+09	19.87	0.01	0.00	1	2	-	-	-	-	-	4	2
62-Sm-153	1.66680E+05	268.30	62.82	0.00	58	15	-	-	-	-	-	76	6

Nuclide	$T_{1/2}$ (s)	Mean Decay Energies (keV)			Number of Spectral Lines								
		Light Particle	Electro-magnetic	Heavy Particle	γ	β^-	EC/β^+	α	n	SF*	p	e^-	X-ray
63-Eu-149	8.04384E+06	24.14	66.02	0.00	27	-	10	-	-	-	-	77	6
63-Eu-150	1.14739E+09	27.21	1528.02	0.00	122	-	23	-	-	-	-	354	7
63-Eu-150m	4.60800E+04	307.29	50.22	0.00	20	1	9	-	-	-	-	57	7
63-Eu-152	4.26730E+08	129.10	1164.20	0.00	130	14	17	-	-	-	-	252	13
63-Eu-152m	3.33900E+04	501.95	311.09	0.00	59	7	8	-	-	-	-	96	13
63-Eu-152n	5.76000E+03	72.26	75.51	0.00	5	-	-	-	-	-	-	15	6
63-Eu-154	2.71166E+08	274.46	1245.26	0.00	139	25	2	-	-	-	-	201	12
63-Eu-154m	2.78400E+03	82.50	74.36	0.00	16	-	-	-	-	-	-	36	6
63-Eu-155	1.52928E+08	66.56	64.16	0.00	12	6	-	-	-	-	-	33	6
63-Eu-156	1.31328E+06	447.83	1283.21	0.00	96	21	-	-	-	-	-	189	6
64-Gd-148	2.36677E+09	0.00	0.00	3271.32	-	-	-	1	-	-	-	-	-
64-Gd-150	5.74348E+13	0.00	0.00	2796.67	-	-	-	1	-	-	-	-	-
64-Gd-151	1.07136E+07	38.83	70.40	0.00	27	-	12	1	-	-	-	83	6
64-Gd-153	2.07792E+07	43.73	106.65	0.00	16	-	6	-	-	-	-	49	6
64-Gd-163	6.80000E+01	1064.29	490.40	0.00	19	7	-	-	-	-	-	41	6
65-Tb-146	8.00000E+00	2994.34	1365.81	0.00	3	-	3	-	-	-	-	9	7
65-Tb-146m	2.40000E+01	1454.43	4097.18	0.00	16	-	10	-	-	-	-	21	7
65-Tb-156	4.46688E+05	84.60	1935.37	0.00	111	-	20	-	-	-	-	201	6
65-Tb-156m	8.78400E+04	22.06	37.59	0.00	2	-	-	-	-	-	-	6	2
65-Tb-156n	1.83600E+04	84.06	4.74	0.00	1	-	1	-	-	-	-	9	13
65-Tb-157	3.12420E+09	5.70	10.39	0.00	1	-	2	-	-	-	-	6	6
65-Tb-158	5.68025E+09	111.73	813.70	0.00	14	2	7	-	-	-	-	48	13
65-Tb-158m	1.08000E+01	85.93	24.20	0.00	1	-	-	-	-	-	-	6	6
65-Tb-160	6.24672E+06	257.28	1129.73	0.00	41	13	-	-	-	-	-	108	6
65-Tb-161	5.95296E+05	200.74	33.76	0.00	37	9	-	-	-	-	-	109	6

UNCLASSIFIED

Nuclide	$T_{1/2}$ (s)	Mean Decay Energies (keV)			Number of Spectral Lines								
		Light Particle	Electro-magnetic	Heavy Particle	γ	β^-	EC/β^+	α	n	SF*	p	e^-	X-ray
66-Dy-157	2.93040E+04	13.29	350.36	0.00	26	-	11	-	-	-	-	66	6
66-Dy-159	1.24762E+07	12.82	45.51	0.00	9	-	5	-	-	-	-	30	6
66-Dy-166	2.93760E+05	157.86	41.87	0.00	7	4	-	-	-	-	-	22	6
67-Ho-160	1.51800E+03	70.34	1713.47	0.00	82	-	23	-	-	-	-	144	7
67-Ho-160m	1.80000E+04	81.67	649.78	0.00	166	-	46	-	-	-	-	90	13
67-Ho-160n	2.90000E+00	93.88	105.68	0.00	5	-	-	-	-	-	-	15	6
67-Ho-161	8.92800E+03	33.44	58.17	0.00	51	-	12	-	-	-	-	151	6
67-Ho-161m	6.77000E+00	107.19	103.68	0.00	1	-	-	-	-	-	-	6	6
67-Ho-162	8.40000E+02	59.85	165.54	0.00	27	-	7	-	-	-	-	66	7
67-Ho-162m	4.02000E+03	82.22	650.91	0.00	48	-	4	-	-	-	-	148	13
67-Ho-163	1.44218E+11	2.65	0.00	0.00	-	-	1	-	-	-	-	-	-
67-Ho-163m	1.10000E+00	61.24	236.53	0.00	1	-	-	-	-	-	-	6	6
67-Ho-164	1.71600E+03	184.26	28.16	0.00	4	2	3	-	-	-	-	18	12
67-Ho-164m	2.25600E+03	91.90	48.03	0.00	4	-	-	-	-	-	-	13	6
67-Ho-170	1.66800E+02	836.08	1834.58	0.00	43	11	-	-	-	-	-	89	6
67-Ho-170m	4.30000E+01	1365.31	679.36	0.00	31	22	-	-	-	-	-	24	6
68-Er-167m	2.27000E+00	110.06	97.59	0.00	1	-	-	-	-	-	-	6	6
68-Er-172	1.77480E+05	128.72	515.68	0.00	44	8	-	-	-	-	-	131	6
69-Tm-167	7.99200E+05	21.21	51.56	0.00	9	-	4	-	-	-	-	28	6
69-Tm-168	7.77600E+06	83.08	1210.45	0.00	72	1	17	-	-	-	-	174	13
69-Tm-170	1.11110E+07	327.54	4.15	0.00	2	2	2	-	-	-	-	12	12
69-Tm-171	6.04800E+07	25.56	0.68	0.00	1	2	-	-	-	-	-	6	6
69-Tm-172	2.28960E+05	527.71	480.50	0.00	50	16	-	-	-	-	-	69	6
70-Yb-175	3.61584E+05	121.64	79.94	0.00	6	3	-	-	-	-	-	21	6
70-Yb-176m	1.14000E+01	144.56	905.32	0.00	5	-	-	-	-	-	-	18	6
71-Lu-171	7.12800E+05	88.33	641.30	0.00	90	-	23	-	-	-	-	207	7

Nuclide	$T_{1/2}$ (s)	Mean Decay Energies (keV)			Number of Spectral Lines								
		Light Particle	Electro-magnetic	Heavy Particle	γ	β^-	EC/β^+	α	n	SF*	p	e^-	X-ray
71-Lu-171m	7.80000E+01	69.44	1.79	0.00	1	-	-	-	-	-	-	6	6
71-Lu-172	5.78880E+05	111.38	1955.21	0.00	197	-	29	-	-	-	-	534	7
71-Lu-172m	2.22000E+02	40.20	1.67	0.00	1	-	-	-	-	-	-	4	2
71-Lu-173	4.21632E+07	46.18	170.16	0.00	19	-	6	-	-	-	-	59	6
71-Lu-174	1.12320E+08	44.82	116.67	0.00	5	-	3	-	-	-	-	18	7
71-Lu-174m	1.22688E+07	116.85	61.67	0.00	12	-	1	-	-	-	-	40	12
71-Lu-177	5.78880E+05	147.42	36.86	0.00	6	4	-	-	-	-	-	21	6
71-Lu-177m	1.38499E+07	82.08	167.77	0.00	10	1	-	-	-	-	-	33	6
72-Hf-173	8.60400E+04	52.05	396.61	0.00	79	-	20	-	-	-	-	167	7
72-Hf-174	6.31152E+22	0.00	0.00	2503.61	-	-	-	1	-	-	-	-	-
72-Hf-175	6.04800E+06	45.51	362.99	0.00	8	-	4	-	-	-	-	27	6
72-Hf-177m	1.08000E+00	240.71	1068.02	0.00	39	-	-	-	-	-	-	118	6
72-Hf-177n	3.08400E+03	251.54	1177.27	0.00	10	-	-	-	-	-	-	27	6
72-Hf-178m	4.00000E+00	141.51	1005.89	0.00	5	-	-	-	-	-	-	18	6
72-Hf-178n	9.78286E+08	73.62	1223.12	0.00	11	-	-	-	-	-	-	35	6
72-Hf-179m	1.86700E+01	134.08	240.74	0.00	3	-	-	-	-	-	-	12	6
72-Hf-179n	2.16864E+06	186.34	919.03	0.00	13	-	-	-	-	-	-	41	6
72-Hf-180m	1.98000E+04	148.58	992.43	0.00	7	2	-	-	-	-	-	26	12
72-Hf-181	3.66163E+06	204.39	530.53	0.00	10	2	-	-	-	-	-	29	6
73-Ta-177	2.03040E+05	22.72	67.75	0.00	47	-	12	-	-	-	-	138	7
73-Ta-179	5.08032E+07	7.40	29.25	0.00	-	-	1	-	-	-	-	3	6
73-Ta-180	2.90880E+04	64.06	45.93	0.00	2	2	2	-	-	-	-	12	12
73-Ta-180m	5.68037E+22	125.85	562.52	0.00	6	1	1	-	-	-	-	24	12
73-Ta-182	9.91008E+06	216.34	1283.32	0.00	43	10	-	-	-	-	-	128	6
73-Ta-182m	2.83000E-01	14.32	1.92	0.00	1	-	-	-	-	-	-	4	2

Nuclide	$T_{1/2}$ (s)	Mean Decay Energies (keV)			Number of Spectral Lines								
		Light Particle	Electro-magnetic	Heavy Particle	γ	β^-	EC/β^+	α	n	SF*	p	e^-	X-ray
73-Ta-182n	9.50400E+02	244.38	254.64	0.00	5	-	-	-	-	-	-	18	6
73-Ta-183	4.39776E+05	349.36	286.64	0.00	31	4	-	-	-	-	-	93	6
74-W -176	9.00000E+03	57.30	171.53	0.00	6	-	3	-	-	-	-	18	6
74-W -178	1.86624E+06	6.99	19.16	0.00	-	-	1	-	-	-	-	3	6
74-W -181	1.04527E+07	12.68	41.21	0.00	3	-	4	-	-	-	-	10	6
74-W -183m	5.25000E+00	183.99	125.39	0.00	6	-	-	-	-	-	-	19	6
74-W -185	6.48864E+06	126.80	0.05	0.00	1	2	-	-	-	-	-	6	6
74-W -185m	1.00000E+02	171.99	25.74	0.00	14	-	-	-	-	-	-	38	6
74-W -187	8.58600E+04	301.26	442.10	0.00	48	17	-	-	-	-	-	118	6
74-W -188	6.02899E+06	99.59	1.91	0.00	6	4	-	-	-	-	-	20	6
75-Re-183	6.04800E+06	108.91	161.37	0.00	28	-	9	-	-	-	-	84	6
75-Re-183m	1.03000E-03	316.99	1588.64	0.00	16	-	-	-	-	-	-	51	6
75-Re-184	3.05856E+06	54.72	905.64	0.00	30	-	9	-	-	-	-	90	7
75-Re-184m	1.45152E+07	140.48	390.15	0.00	36	-	1	-	-	-	-	112	12
75-Re-186	3.24000E+05	337.33	20.89	0.00	9	4	2	-	-	-	-	30	12
75-Re-186m	5.99582E+12	129.8	19.81	0.00	4	-	-	-	-	-	-	12	6
75-Re-191	5.82000E+02	726.98	2.23	0.00	-	1	-	-	-	-	-	-	-
75-Re-192	6.20000E+00	1637.85	159.06	0.00	5	4	-	-	-	-	-	18	6
76-Os-180	1.29000E+03	23.82	136.78	0.00	21	-	10	-	-	-	-	60	7
76-Os-185	8.10432E+06	18.33	719.03	0.00	16	-	6	-	-	-	-	50	6
76-Os-189m	2.09160E+04	28.71	2.18	0.00	1	-	-	-	-	-	-	4	2
76-Os-190m	5.94000E+02	116.85	1588.53	0.00	5	-	-	-	-	-	-	17	6
76-Os-191	1.32192E+06	37.52	0.00	0.00	-	1	-	-	-	-	-	-	-
76-Os-191m	4.71600E+04	66.58	7.81	0.00	1	-	-	-	-	-	-	6	6
76-Os-194	1.89342E+08	44.29	4.09	0.00	2	3	-	-	-	-	-	8	6
76-Os-195	3.90000E+02	715.26	142.23	0.00	17	6	-	-	-	-	-	44	6

Nuclide	$T_{1/2}$ (s)	Mean Decay Energies (keV)			Number of Spectral Lines								
		Light Particle	Electro-magnetic	Heavy Particle	γ	β^-	EC/β^+	α	n	SF*	p	e^-	X-ray
76-Os-196	2.09400E+03	372.56	77.03	0.00	10	8	-	-	-	-	-	30	6
77-Ir-187	3.78000E+04	63.79	301.51	0.00	96	-	24	-	-	-	-	273	7
77-Ir-189	1.14048E+06	44.77	79.47	0.00	25	-	7	-	-	-	-	71	6
77-Ir-190	1.03680E+06	72.11	1478.08	0.00	63	-	10	-	-	-	-	132	7
77-Ir-190m	4.03200E+03	23.84	2.28	0.00	1	-	-	-	-	-	-	4	2
77-Ir-190n	1.11132E+04	28.88	58.87	0.00	6	-	1	-	-	-	-	21	12
77-Ir-191m	4.90000E+00	95.72	75.39	0.00	4	-	-	-	-	-	-	13	6
77-Ir-191n	5.50000E+00	45.76	1868.05	0.00	4	-	-	-	-	-	-	15	6
77-Ir-192	6.37822E+06	217.29	816.48	0.00	27	6	3	-	-	-	-	87	12
77-Ir-192m	8.64000E+01	54.43	2.44	0.00	4	3	-	-	-	-	-	16	8
77-Ir-192n	7.60522E+09	165.04	3.09	0.00	2	-	-	-	-	-	-	7	6
77-Ir-193m	9.09792E+05	77.70	2.59	0.00	1	-	-	-	-	-	-	6	6
77-Ir-194m	3.18300E-02	96.54	49.97	0.00	10	-	-	-	-	-	-	26	6
77-Ir-194n	1.47744E+07	103.37	2352.62	0.00	11	2	-	-	-	-	-	36	6
77-Ir-197	3.48000E+02	733.37	223.79	0.00	40	23	-	-	-	-	-	91	6
77-Ir-197m	5.34000E+02	680.01	2.04	0.00	1	1	-	-	-	-	-	6	6
78-Pt-190	2.05120E+19	0.00	0.00	3251.51	-	-	-	1	-	-	-	-	-
78-Pt-193	1.57788E+09	7.86	33.78	0.00	-	-	1	-	-	-	-	3	6
78-Pt-193m	3.74976E+05	137.96	12.33	0.00	3	-	-	-	-	-	-	7	6
78-Pt-195m	3.54240E+05	182.26	76.47	0.00	9	-	-	-	-	-	-	27	6
78-Pt-197	7.16094E+04	254.43	24.38	0.00	3	3	-	-	-	-	-	11	6
78-Pt-197m	5.71800E+03	316.94	76.08	0.00	2	1	-	-	-	-	-	8	6
78-Pt-202	1.58400E+05	658.92	1.93	0.00	-	1	-	-	-	-	-	-	-
79-Au-192m	2.90000E-02	126.10	8.85	0.00	4	-	-	-	-	-	-	12	6
79-Au-192n	1.60000E-01	161.47	134.69	0.00	6	-	-	-	-	-	-	19	6

Nuclide	$T_{1/2}$ (s)	Mean Decay Energies (keV)			Number of Spectral Lines								
		Light Particle	Electro-magnetic	Heavy Particle	γ	β^-	EC/β^+	α	n	SF*	p	e^-	X-ray
79-Au-195	1.60785E+07	48.79	86.33	0.00	5	-	5	-	-	-	-	17	6
79-Au-195m	3.05000E+01	115.53	203.01	0.00	5	-	-	-	-	-	-	16	6
79-Au-197m	7.74000E+00	183.82	225.44	0.00	5	-	-	-	-	-	-	17	6
79-Au-198	2.32788E+05	327.34	402.89	0.00	3	3	-	-	-	-	-	12	6
79-Au-198m	1.98720E+05	262.08	527.82	0.00	6	-	-	-	-	-	-	18	6
79-Au-199	2.71210E+05	145.08	96.07	0.00	3	3	-	-	-	-	-	11	6
80-Hg-190	1.20000E+03	68.07	204.38	0.00	25	-	14	-	-	-	-	76	7
80-Hg-194	1.40113E+10	7.34	14.68	0.00	-	-	1	-	-	-	-	3	6
80-Hg-197	2.32560E+05	69.15	73.51	0.00	3	-	3	-	-	-	-	11	6
80-Hg-197m	8.60400E+04	200.56	77.98	0.00	2	-	1	-	-	-	-	12	12
80-Hg-199m	2.52600E+03	347.70	184.57	0.00	4	-	-	-	-	-	-	15	6
80-Hg-203	4.02581E+06	99.11	237.74	0.00	1	1	-	-	-	-	-	6	6
80-Hg-205	3.12000E+02	536.24	6.89	0.00	13	7	-	-	-	-	-	24	6
81-Tl-193	1.30800E+03	94.34	555.90	0.00	50	-	26	-	-	-	-	87	7
81-Tl-193m	1.26600E+02	109.18	363.45	0.00	3	-	1	-	-	-	-	13	13
81-Tl-201	2.62742E+05	44.08	95.41	0.00	9	-	3	-	-	-	-	22	6
81-Tl-202	1.05754E+06	22.51	466.54	0.00	3	-	3	-	-	-	-	12	7
81-Tl-204	1.19603E+08	236.21	1.06	0.00	-	1	1	-	-	-	-	3	6
82-Pb-201	3.38400E+04	58.28	768.05	0.00	74	-	25	-	-	-	-	143	7
82-Pb-201m	6.10000E+01	262.19	366.14	0.00	1	-	-	-	-	-	-	6	7
82-Pb-202	1.67255E+12	9.28	69.97	0.00	-	-	1	-	-	-	-	3	6
82-Pb-202m	1.28520E+04	138.45	1975.52	0.00	22	-	3	-	-	-	-	72	13
82-Pb-203	1.86804E+05	52.33	315.18	0.00	3	-	2	-	-	-	-	12	6
82-Pb-203m	6.29000E+00	171.21	654.09	0.00	3	-	-	-	-	-	-	10	7
82-Pb-203n	4.80000E-01	216.40	1906.57	0.00	14	-	-	-	-	-	-	44	7

Nuclide	$T_{1/2}$ (s)	Mean Decay Energies (keV)			Number of Spectral Lines								
		Light Particle	Electro-magnetic	Heavy Particle	γ	β^-	EC/β^+	α	n	SF*	p	e^-	X-ray
82-Pb-204	4.41806E+24	0.00	0.00	1971.69	-	-	-	1	-	-	-	-	-
82-Pb-204m	4.05000E+03	103.27	2080.67	0.00	6	-	-	-	-	-	-	21	7
82-Pb-205	4.82831E+14	8.95	59.29	0.00	-	-	1	-	-	-	-	3	6
82-Pb-205m	5.10000E-03	39.92	974.47	0.00	13	-	-	-	-	-	-	39	7
82-Pb-207m	8.06000E-01	122.92	1510.36	0.00	2	-	-	-	-	-	-	9	7
83-Bi-201m	3.34800E+03	284.31	265.44	0.16	1	-	1	1	-	-	-	9	15
83-Bi-205	1.32278E+06	26.29	1554.68	0.00	147	-	26	-	-	-	-	409	8
83-Bi-207	1.00224E+09	118.46	1539.51	0.00	6	-	4	-	-	-	-	21	8
83-Bi-208	1.16132E+13	8.52	2657.34	0.00	1	-	1	-	-	-	-	3	7
84-Po-208	9.24638E+07	0.00	0.02	5215.29	8	-	1	2	-	-	-	28	14
86-Rn-223	1.45200E+03	624.91	330.14	0.00	294	60	-	-	-	-	-	270	7
90-Th-228	6.03590E+07	20.48	3.08	5497.53	14	-	-	9	-	-	-	43	7
90-Th-231	9.18720E+04	164.94	25.82	0.00	47	13	-	-	-	-	-	122	7
93-Np-239	2.03472E+05	262.84	182.19	0.00	33	8	-	-	-	-	-	89	7
95-Am-241	1.36581E+10	39.08	27.51	5557.44	185c	-	-	53	0c	0	-	372	7
95-Am-243	2.32416E+11	23.93	56.97	5358.99	18c	-	-	12	0c	0	-	46	7

* A zero in this column indicates the presence of spontaneous fission fragment data - no spectral data are specified (only mean energies) for the SF fragments in ENDF-6 format.

Appendices

Contents

This page is intentionally left blank to allow double-sided pagination.

Appendix 1
Derivation of Evaluated Data

This page is intentionally left blank to allow double-sided pagination.

Appendix 1: Derivation of Evaluated Data

Reference is made to the *Pandemonium effect* in this appendix - this name is given to the phenomenon whereby complex decay schemes that involve β^- population of high-energy nuclear levels of the daughter nuclide are highly susceptible to serious difficulties in the detection and definition of any resulting high-energy γ transitions by means of HPGe detectors. Under such circumstances, incorrect values will be derived for the total average $<E_\beta>$ and $<E_\gamma>$ parameters of particular importance in decay-heat calculations.

Acquisition of References

Journal references for all radionuclides were accrued via requests placed through:

electronic library facilities of the University of Surrey, Guildford, UK,

JoAnn Totans (NSR), National Nuclear Data Center, Brookhaven National Laboratory, USA, and

support staff of the Nuclear Data Section, International Atomic Energy Agency, Vienna, Austria.

The individual evaluations are discussed below, and a significant number of specific references are cited by first-named author and/or NSR keynumber (e.g. 1997Gr09). Nuclear Science References can be accessed through http://www.nndc.bnl.gov/nsr/ or http://www-nds.iaea.org/nsr/, and an appropriate search implemented by clicking on the Keynumber Search label and inputting the relevant keynumber(s) in the list column provided. For further details of these references, the reader is also referred to the Comments Section of the relevant ENDF-6 decay data file of the radionuclide, as reproduced in Appendix 2.

^{139}Xe

Although a recommended half-life of (39.69 ± 0.05) s was calculated from the measurements of 1966Ar08, 1968Al06, 1969Ca03 and 1974Gr29 by means of the Rajeval technique, this value is heavily dependent on the high accuracy of the value determined by Carlson *et al*. (1969Ca03) of (39.68 ± 0.05) s. Further confirmatory studies are merited under such circumstances.

A complex and comprehensive decay scheme has been derived from measurements of the relative gamma-ray emission probabilities by Lee and Talbert (1980Le03), and Faller *et al*. (1988Fa06). Various mixing ratios and multipolarities were adopted from the studies of Achterberg *et al*. (1972Ac02), while a significant number of (M1 + E2) gamma transitions were arbitrarily assigned to be (50%M1 + 50%E2) with a relatively high uncertainty of 20%, and a small number of other transitions were defined as 100%M1 (56.0, 175.15 and 218.64 keV). Previously unplaced gamma transitions were introduced into the proposed decay scheme – twenty five of these observed gamma rays were successfully allocated (466.4, 482.64, 523.67, 867.84, 909.46, 1129.2, 1184.6, 1218.48, 1267.44, 1458.63, 1543.2, 1635.5, 1665.9, 1768.6, 1818.38, 1828.99, 1853.68, 2099.62, 2249.5, 2673.6, 2791.01, 2887.47, 2941.90, 3028.76 and 3424.6 keV), some of which involved the introduction of new nuclear levels at 1186.4(3), 1780.03(24), 2058.4(3), 3948.63(16), 4066.03(19), 4134.9(4), 4186.26(13) and 4615.93(14) keV. A number of previously unresolved and partially resolved gamma emissions observed separately by Lee and Talbert Jr. and Faller *et al*. were judged to be identical transitions to be treated as single entities in the proposed decay scheme, rather than quantified erroneously as differing and frequently unplaced.

The proposed decay scheme of Xe-139 consists of 64 β^- emissions and 271 γ transitions. There are a significant number of uncertainties associated with the proposed decay scheme, and specific assumptions have been made concerning the relative merits of the main sources of gamma-ray data. Most importantly, the normalisation factor of (0.56 ± 0.04) adopted for the relative gamma-ray emission probabilities and calculation of the recommended β^- emission probabilities is based entirely on a direct β^- branch to the ^{139}Cs ground state of (15 ± 6)% reported by Faller *et al*.

(1998Fa06), as determined by Robertson (unpublished, albeit co-author of 1988Fa06). Further measurements of the absolute and relative gamma-ray emission probabilities are required to derive the decay scheme with much greater confidence, particularly for more accurate determinations of the β^- emission probabilities directly to the 1006.73-, 515.22-, 393.79-, 393.48-, 289.76-, 218.644-keV and ground states of Cs-139.

Rudstam *et al.* carried out studies of the continuous β^- and γ spectra of ^{139}Xe (1990Ru05), in which the β^- and γ data were expressed in terms of fifty-six energy increments of 100 keV each, ranging from 0 to 5600 keV. Total average $<E_\beta>$ of (1800 ± 50) keV and total average $<E_\gamma>$ of (920 ± 110) keV were derived from these data, along with total average $<E_\upsilon>$ of (2370 ± 180) keV, summing to a Q_β of (5090 ± 220) keV, and these values were recommended by Rudstam and adopted during the preparation of the JEF-2.2 decay-data library in December 1989. However, only a severely limited set of data was assembled from 2003NUBASE as part of the decay-data compilation for JEFF-3.1.1: total average $<E_\beta>$ = total average $<E_\gamma>$ = $(Q_\beta/3)$ = 5057/3 = 1685.67 keV. A Q_β of (5057 ± 4) keV has subsequently been recommended by Audi and Wang (2011), which differs slightly from the value tabulated by Rudstam *et al*. (difference of ~ 0.65%).

^{140}Cs

Although a recommended half-life of (64.0 ± 0.5) s has been calculated from the measurements of 1966Ar08, 1968Al06, 1969Ca03 and 1974Gr29 by means of the Rajeval technique, this value is heavily dependent on the high accuracy of the value determined by Carlson *et al*. (1969Ca03) of (63.8 ± 0.1) s. This unsatisfactory situation prevails despite increasing artificially the uncertainty of this particular value to ± 0.5 secs. Further confirmatory half-life measurements are merited under such circumstances.

A complex and comprehensive decay scheme has been derived from measurements of the relative gamma-ray emission probabilities by Schussler *et al*. (1973Sc18), Schick Jr. *et al*. (1974Sc14), and Robinson *et al*. (1986Ro16). Various mixing ratios and multipolarities were adopted primarily from the studies of Robinson *et al*., and a significant number of (M1 + E2) gamma transitions were arbitrarily assigned to be (50%M1 + 50%E2) with a relatively high uncertainty of 20%. Previously unplaced gamma transitions were introduced into the proposed decay scheme – thirty-eight of these observed gamma rays were successfully allocated (771.1, 1024.1, 1109.8, 1129.0, 1411.7, 1473.7, 1479.1, 1755.6, 1766.6, 1780.6, 1911.3, 1942.7, 2061.4, 2061.5, 2147.1, 2384.0, 2452.3, 2692.9, 3023.4, 3166.1, 3286.18, 3544.6, 3756.08, 3785.70, 3793.4, 3824.8, 3829.8, 3845.2, 4076.1, 4107.8, 4209.9, 4238.1, 4381.4, 4472.6, 4525.3, 4531.4, 4813.5 and 5227.6 keV), some of which involved the introduction of new nuclear levels at 2061.5(3), 3845.2(6), 4076.1(6), 4261.2(6), 4381.4(8), 4427.2(9), 4472.6(7), 4531.4(6), 4785.1(10), 4813.5(6), 5127.7(8), 5227.6(15), 5340.5(8), 5384.9(5), 5523.9 (3), 5748.8(4) and 5931.6(4) keV.

The proposed decay scheme of Cs-140 consists of 62 β^- emissions and 269 γ transitions. There are a significant number of uncertainties associated with the proposed decay scheme, and specific assumptions have been made concerning the relative merits of the main sources of gamma-ray data. Most importantly, the normalisation factor of (0.528 ± 0.014) adopted for the relative gamma-ray emission probabilities and calculation of the recommended β^- emission probabilities is based on a direct β^- branch to the ^{140}Ba ground state of (35.9 ± 1.7)% obtained by means of TAGS measurements by Greenwood *et al*. (1996Gr20, 1997Gr09). Further spectroscopic studies of the absolute and relative gamma-ray emission probabilities are required to derive the decay scheme with much greater confidence.

Rudstam *et al*. carried out studies of the continuous β^- and γ spectra of ^{140}Cs (1990Ru05), in which the β^- and γ data were expressed in terms of sixty energy increments of 100 keV each, ranging from 0 to 6000 keV. Total average $<E_\beta>$ of (1860 ± 40) keV and total average $<E_\gamma>$ of (1270 ± 8) keV were derived from these data, along with total average $<E_\upsilon>$ of (2440 ± 140) keV, summing to a Q_β of (5570 ± 150) keV. A Q_β of (6220 ± 10) keV has subsequently been recommended by Audi and Wang (2011), which differs significantly from the value tabulated by Rudstam *et al*. (difference of ~ 10.5% lends support to setting aside this particular set of continuous βγ data). Greenwood *et al*. undertook systematic studies of the distributions of β^- intensities by means of Total Absorption Gamma-ray Spectroscopy (TAGS), which included ^{140}Cs (1997Gr09). The resulting TAGS data listed in Table 14 of 1997Gr09, along with the equivalent set of E_β data derived from the recommended Q_β value and nuclear-level energies, were used to calculate a total average $<E_\beta>$ of (1890 ± 50) keV and total average $<E_\gamma>$ of (1819 ± 18) keV.

Corrections to ^{90}Rb decay-data file

Extensive β^- and γ data extracted from singles γ-ray spectroscopic measurements were adopted in the 2011/2012 evaluation and assembly of the ^{90}Rb decay-data file [16], along with a total average $<E_\gamma>$ of (2270 ± 240) keV and an incorrectly calculated total average $<E_\beta>$ of (1960 ± 190) keV derived from the TAGS studies of Greenwood *et al*. [24]. Both of these total average energies and the total average antineutrino energy have been re-calculated, and the following values and their uncertainties determined:

total average $<E_\beta>$ of (1904 ± 100) keV,

total average $<E_\gamma>$ of (2270 ± 80) keV,

total average $<E_{\bar{\nu}}>$ of (2410 ± 130) keV.

Consistency Checks

Rigorous consistency checks were undertaken for the two newly evaluated nuclides to confirm the validity and completeness of the data. The data files exhibit good to excellent consistency (see ΔQ (%) in Table A1), noting that these consistency checks apply to energy data derived primarily from the discrete gamma-ray studies and do not include consideration of any gross βγ or TAGS measurements.

Table A1: Evaluated Files of Discrete Decay Data - Consistency Check (ΔQ).

Radionuclide	Half-life	Decay properties [+ unplaced γ transitions]	ΔQ (%)
54-Xe-139	39.69 ±0.05 s	100% β^-: 64β^-/271γ	0.1475
55-Cs-140	64.0 ±0.5 s	100% β^-: 62β^-/269γ	0.0062

All energies identified with the various decay modes and components of such decays have been assembled together in Table A2, with somewhat overstated uncertainties. These energies have been exclusively derived from the evaluated discrete decay data, and are listed in terms of the following radioactive parameters:

(a). β^-, Auger electrons (Ae), and conversion electrons (ce),

(b). antineutrinos ($\bar{\nu}$),

(c). γ, X-rays and internal bremsstrahlung (IB),

(d). total average energies for light-particle and electromagnetic radiations (LP and EM), and

(e). total β^- decay energy (Q_β).

Although the above listing excludes quantification of the annihilation radiation arising from internal-pair formation ($\beta^+\beta^-$), Coster-Kronig transitions, and recoil energy following β^- and γ emissions, these specific contributions to the energy balance are judged to be very small in all cases.

Table A2: Component Decay Energies, Total Average Energies, and Calculated Q_β Values Derived from the Evaluated Discrete Decay Data.

	^{139}Xe	^{140}Cs
$E_{\beta-}$ (keV)	1700 ± 130	1902 ± 50
E_{Ae} (keV)[1]	0.84 ± 0.08	0.027 ± 0.003
E_{ce} (keV)[1]	22.3 ± 2.2	2.7 ± 0.3
E_{LP} (keV)	1720 ± 130	1905 ± 50
$E_{\bar{\nu}}$ (keV)	2320 ± 180	2552 ± 60
E_γ (keV)	1007 ± 70	1763 ± 50
E_X (keV)[1]	3.1 ± 0.3	0.105 ± 0.011
E_{IB} (keV)[1, 2]	7.0 ± 0.7	8.3 ± 0.8
E_{EM} (keV)	1017 ± 70	1771 ± 50
calculated Q_β (keV)	5050 ± 230	6220 ± 90

[1] Uncertainties for Ae, ce, X-ray and internal bremsstrahlung are set to a nominal value of 10% of the calculated number.
[2] Energy of internal bremsstrahlung radiation is not applied to calculation of Q_β.

Data Adopted for the UK ENDF Decay Data Files of ^{139}Xe and ^{140}Cs, and modifications to the ^{90}Rb file

Complex decay schemes that involve β^- population of high-energy nuclear levels of the daughter nuclide are highly susceptible to serious difficulties in detection and definition of any resulting high-energy γ transitions by means of HPGe detectors. The phenomenon has been referred to as the *Pandemonium effect*, and can result in the derivation of incorrect values for the total average $\langle E_\beta \rangle$ and $\langle E_\gamma \rangle$, which are extremely important components of the total average $\langle E_{LP} \rangle$ and $\langle E_{EM} \rangle$ parameters, respectively.

The recommended discrete decay data were used to calculate total average energies, and these values have been compared in Table A3 with (a) gross βγ spectral studies of Rudstam *et al.* (1990Ru05) and TAGS measurements of Greenwood *et al.* (1997Gr09); (b) equivalent data contained within the earlier JEF-2.2 and JEFF-3.1.1 decay-data libraries of the NEA Data Bank. Within both the JEF-2.2 and JEFF-3.1.1 files, changes were made to some of the total average $\langle E_\beta \rangle$ and $\langle E_\gamma \rangle$ data derived from the evaluated discrete β^- and γ emissions, and these modifications are also given in the table.

^{139}Xe

With a total average $\langle E_\gamma \rangle$ of (1007 ± 70) keV and total average $\langle E_\beta \rangle$ of (1700 ± 130) keV derived from the discrete decay-data evaluation, the measurements of Rudstam *et al*. that lead to a lower total average $\langle E_\gamma \rangle$ of (920 ± 110) keV and a higher total average $\langle E_\beta \rangle$ of (1800 ± 50) keV have been set aside (1990Ru05). The singles gamma studies of Lee and Talbert Jr. (1980Le03) and Faller *et al*., (1988Fa06) appear to have better addressed the problem of *Pandemonium* and are reasonably comprehensive, although their quantification of the high-energy γ rays should be viewed as potentially questionable. Thus, evaluated β^- and γ data derived from the discrete γ-ray measurements have been adopted, along with their resulting total average $\langle E_\beta \rangle$ and $\langle E_\gamma \rangle$ energies. Further studies are merited by Total Absorption Gamma-ray Spectroscopy (TAGS), and γ-γ and singles γ spectroscopy in order to develop a better understanding of the decay scheme.

^{140}Cs

The total average <E_γ> calculated from the various discrete γ-ray studies is (1763 ± 50) keV, compared with (1270 ± 50) keV from the gross βγ spectral data of Rudstam *et al.* and (1819 ± 18) keV from the TAGS measurements of Greenwood *et al.*, implying that the latter has somewhat better addressed the possibility of *Pandemonium*. While all three γ-singles and γ-γ spectroscopy studies are reasonably comprehensive and noteworthy, their assignment and quantification of the higher-energy γ rays should be viewed as potentially questionable. Therefore, the decay scheme and discrete decay data derived from an evaluation of the γ-ray measurements of Schussler *et al.* (1973Sc18), Schick Jr. and Talbert Jr. (1974Sc14), and Robinson *et al.* (1986Ro16) have been adopted, in conjunction with total average <E_β> and <E_γ> energies determined from Greenwood *et al.* (1997). Future emphasis should be placed on gross βγ and TAGS studies, along with comprehensive γ-γ and singles γ-ray spectroscopy, to achieve a higher degree of agreement and consistency between the various forms of measurement.

^{90}Rb

Corrections were made to the total average <E_β> and $<E_{\bar{\nu}}>$ derived from the TAGS studies of Greenwood *et al.* [24], following the initial establishment of the UKPADD6.11 library in March 2012. A corrected total average <E_β> of (1904 ± 100) keV has been inserted into the ^{90}Rb file, along with an adjusted total average $<E_{\bar{\nu}}>$ of (2410 ± 130) keV.

Recommended Decay Data

The decay data adopted in the resulting ^{90}Rb, ^{139}Xe and ^{140}Cs files are summarised in Table A4 from the point of view of their origins. Comprehensive results from the evaluation of known discrete decay data measurements were preferred for ^{139}Xe, while the total average β^- and γ energies for ^{90}Rb and ^{140}Cs from the TAGS data of Greenwood *et al.* (1997Gr09) were considered to be more appropriate in addressing known inadequacies in discrete decay data measurements of high-energy gamma-ray emissions by means of HPGe detectors (*Pandemonium effect*). However, under these circumstances and for completeness, relatively modest Auger-electron, conversion-electron, X-ray and internal bremsstrahlung energies for ^{90}Rb and ^{140}Cs were adopted from the discrete decay data evaluations.

An error in the estimated total average beta energy of Rb-90 has also been corrected from 1960(190) keV to a value of 1904(100) keV. This calculational issue arose when the file was being assembled for adoption in UKPADD6.11 at the beginning of 2012.

Table A3: Total Average $\langle E_\beta \rangle$ and $\langle E_\gamma \rangle$ Calculated from Discrete Data Compared with the Measurements of Rudstam *et al.* (25) and Greenwood *et al.* (24), and Equivalent Data Adopted for JEF-2.2 and JEFF-3.1.1.

	Calculated from Recommended Discrete Data (2013)	**Rudstam *et al.* (1990)**	**Greenwood *et al.* (TAGS) (1997)**	**JEF-2.2**	**JEFF-3.1.1**
^{90}Rb (adjustments)					
Q_β = (6584 ± 7) keV					
Total average $\langle E_\beta \rangle$	2036 ± 120	2200 ± 200	**1904 ± 100**	1865 ± 150	2049 ± 130 ↓ 1916 ± 19[‡]
Total average $\langle E_\nu \rangle$	2578 ± 150	2660 ± 230	–	2390 ± 150	2566 ± 160
Total average $\langle E_\gamma \rangle$	2014 ± 120	1710 ± 50	2270 ± **80**	2164 ± 24	1982 ± 42 ↓ 2271 ± 23[‡]
Calculated Q_β	6628 ± 230	Σ 6570 ± 310			
^{139}Xe					
Q_β = (5057 ± 4) keV					
Total average $\langle E_\beta \rangle$	**1700 ± 130**	1800 ± 50	–	1770 ± 220 ↓ 1800 ± 50[*]	1686 (Q/3)
Total average $\langle E_\nu \rangle$	**2320 ± 180**	2370 ± 180	–	2300 ± 140	1686 (Q/3)
Total average $\langle E_\gamma \rangle$	**1007 ± 70**	920 ± 110	–	1013 ± 20 ↓ 920 ± 110[*]	1686 (Q/3)
Calculated Q_β	**5050 ± 230**	Σ 5090 ± 220			
^{140}Cs					
Q_β = (6220 ± 10) keV					
Total average $\langle E_\beta \rangle$	**1902 ± 50**	1860 ± 40	1890 ± 50	1710 ± 70 ↓ 1860 ± 40[†]	1960 ± 70
Total average $\langle E_\nu \rangle$	**2552 ± 60**	2440 ± 140	–	2337 ± 150	2585 ± 90
Total average $\langle E_\gamma \rangle$	**1763 ± 50**	1270 ± 50	1819 ± 18	2100 ± 40 ↓ 1590 ± 40[†]	1675 ± 30
Calculated Q_β	**6220 ± 90**	Σ 5570 ± 150			

[*] Data modified as recommended by Rudstam, private communication, 1989.
[†] Data modified as recommended by Rudstam, private communication, December 1990.
[‡] Data modified according to Greenwood *et al.*, *Nucl. Instrum. Methods Phys. Res.* **A390** (1997) 95-154, with an uncertainty of only 1% assigned arbitrarily in JEFF-3.1.1 (subsequently corrected to a more appropriate value of ±10%).

Table A4: Component Decay Energies, Total Average Energies, and Calculated Q_β Values Adopted in the UKPADD6.12 Files.

	Origins of recommended decay data		
	Greenwood *et al.* (1997) [24]		Discrete decay data evaluation
	^{90}Rb	^{140}Cs	^{139}Xe
$E_{\beta-}$ (keV)[1]	1904 (100)	1890 (50)	1700 (130)
E_{Ae} (keV)[2]	0.0026 (3)[4]	0.027 (3)[4]	0.84 (8)
E_{ce} (keV)[2]	0.37 (4)[4]	2.7 (3)[4]	22.3 (22)
E_{LP} (keV)[1]	1904 (100)	1893 (50)	1720 (130)
$E_{\bar{\nu}}$ (keV)[1]	2410 (130)	2508 (50)	2320 (180)
E_{γ} (keV)[1]	2270 (80)	1819 (18)	1007 (70)
E_X (keV)[2]	0.0042 (4)[4]	0.105 (11)[4]	3.1 (3)
E_{IB} (keV)[2, 3]	8.7 (9)[4]	8.3 (8)[4]	7.0 (7)
E_{EM} (keV)[1]	2280 (80)	1827 (18)	1017 (70)
Calculated Q_β (keV)[1]	6584 (7)	6220 (10)	5050 (230)

[1] Energies and uncertainties for β^-, $\bar{\nu}$, γ, LP, EM and Q_β are expressed in the form 1234(*x*), where *x* is the uncertainty in the last digit or digits quoted in the calculated number – this uncertainty is generally expressed at the 1σ confidence level (examples: 1739(48) means 1739 ± 48; and 0.049(22) means 0.049 ± 0.022).
[2] Energies and uncertainties for Ae, ce, X-ray and internal bremsstrahlung are expressed in the form 1234(x), as defined in footnote 1, but with the uncertainties set to a nominal value of 10% of the calculated number.
[3] Energy of internal bremsstrahlung radiation is not applied to calculation of Q_β.
[4] Ae, ce, X-ray and internal bremsstrahlung energies for ^{90}Rb and ^{140}Cs are adopted from the discrete decay data evaluations.

This page is intentionally left blank to allow double-sided pagination.

Appendix 2
Comments from New Evaluations

This page is intentionally left blank to allow double-sided pagination.

Appendix 2: Comments from New Evaluations

Reproduced below are the descriptive comments from the evaluated ENDF-6 files for each of the nuclides evaluated in 2012/13. These comments include a list of references, the evaluator's comments, mean β- energies, mean decay energies, and a consistency check, and are formatted as they appear in the ENDF-6 evaluated file.

54-Xe-139


```
T W Burrows                Nucl Data Sheets 92(2001)623
N P Archer, G L Keech      Can J Phys 44(1966)1823 (T1/2)
T Alvager et al            Phys Rev 167(1968)1105
                           (T1/2, Egamma, Pgamma)
G C Carlson et al          Nucl Phys A125(1969)267 (T1/2)
K-L Kratz                  BMBW-FBK-71-12 (1971)7 (Egamma)
E Achterberg et al         Phys Rev C5(1972)1759
                           (Egamma, Pgamma, alpha(k),
                           multipolarity)
J P Adams et al            Phys Rev C8(1973)767 (Qbeta)
B Grapengiesser et al      J Inorg Nucl Chem 36(1974)2409
                           (T1/2)
K Aleklett et al           Nucl Phys A246(1975)425 (Qbeta)
F Wohn, W L Talbert Jr.    Phys Rev C18(1978)2328 (Qbeta)
M A Lee, W L Talbert Jr.   Phys Rev C21(1980)328
                           (Egamma, Pgamma, gamma-gamma)
R J Gehrke                 Int J Appl Radiat Isot 31(1980)37
                           (NF correction for Pgamma)
K Aleklett, G Rudstam      Nucl Sci Eng 80(1982)74
                           (average Ebeta)
S H Faller et al           Phys Rev C38(1988)905
                           (Egamma, Pgamma, gamma-gamma)
G Rudstam et al          At Data Nucl Data Tables 45(1990)239
                           (average Egamma, Ebeta, Enu)
J K Hwang et al            Phys Rev C57(1998)2250
                           (Egamma, nuclear levels)
A Nowak et al              Eur Phys J A6(1999)1
                           (Egamma, nuclear levels)
I M Band et al             At Data Nucl Data Tables
                           81(2002)1 (ICC)
S Raman et al              Phys Rev C66(2002)044312 (ICC)
G Audi et al               Nucl Phys A729(2003)337 (Q-value)
T Kibedi et al             Nucl Instrum Methods Phys Res
                           A589(2008)202 (ICC)
S H Liu et al              Phys Rev C80(2009)044314
                           (Egamma, nuclear levels)
B Roussiere et al          Eur Phys J A47(2011)106
                           (nuclear level half-lives)
G Audi, M Wang             Atomic mass evaluation,
                           private communication, CSNSM,
                           Orsay, France, April 2011 (Q-value)
```


An extremely complex and comprehensive decay scheme has been derived primarily from the gamma-ray measurements of Achterberg et al., Lee and Talbert Jr., Faller et al. and Roussiere et al., and the determination of the total average <Egamma>, <Ebeta> and <Enu> from continuous beta and gamma spectral studies by Rudstam et al.

HALF-LIFE

The recommended half-life has been determined from the measurements of Archer and Keech, Alvager et al., Carlson et al., and Grapengiesser et al. Limitation of relative statistical weight method (LWM), normalised residual method (NRM), Rajeval technique, bootstrap method, and Mandel-Paule approach were considered in the analysis of individual data sets. A value of (39.69 +/- 0.05) seconds was preferred, as quantified by both NRM and the Rajeval technique.

Q VALUES

A Q-value of 5057(4) keV for Xe-139 beta decay was adopted (Audi and Wang), which compares with a value of 5057(21) keV from an earlier published evaluation (Audi et al. (2003)).

GAMMA-RAY ENERGIES AND EMISSION PROBABILITIES

Energies

The energies of the gamma-ray emissions have been measured to various degrees of complexity by Alvager et al., Kratz, Achterberg et al., Lee and Talbert Jr., Faller et al., Hwang et al., Nowak et al., Liu et al. and Roussiere et al. Many of the data sources were subsequently assessed by Burrows to determine the nuclear-level energies of daughter Cs-139, and these values have been adopted.

Faller et al. identified the existence of two important, close-lying nuclear levels at 393.48 and 393.79 keV which create significant difficulties in the evaluation of the complex Xe-139 decay scheme:

1). significant uncertainties in the resolution and quantification of the relative emission probabilities of an extensive number of resulting doublets defined as 121.43-121.74, 174.84-175.15, 548.75-549.06, 612.94-613.25, 745.32-745.63, 1067.52-1067.83, 1114.45-1114.76, 1206.20-1206.51, 1344.90-1345.21, 1934.98-1935.29, 2736.5-2736.85 and 3110.88-3111.19 keV;

2). definition of the relative emission probabilities of the gamma rays populating or depopulating either the 393.48- or 393.79-keV nuclear levels only - 103.72, 338.90, 393.48, 498.10, 626.82, 1001.77, 1259.27, 1300.13, 1324.64, 1437.6, 1979.47, 2116.98, 2192.27, 2227.12, 2403.76, 2573.98 and 2815.04 keV.

The 393.48/393.79-keV doublet was established by Faller et al. from their observations of differences between the 175- and 393-keV gated gamma spectra. The 393.79-keV level is more weakly populated by direct beta decay, and depopulates only by means of a 175.15-keV gamma emission to the 218.644-keV nuclear level.

While a nuclear level at 1186.4 keV was proposed by Lee and Talbert Jr. that undergoes depopulation by means of the 896.6- and 967.8-keV gamma transitions, the re-allocation of the 896.6-keV gamma emission by Faller et al. to depopulate the 1411.7-keV nuclear level has brought the earlier assignments into significant doubt. Nevertheless, the 1186.4-keV nuclear level has been maintained in the evaluation, along with the postulated gamma-depopulation characteristics of the 1186.4- and 1411.7-keV nuclear levels (i.e. 896.6 and 967.8 keV, and 896.5 keV, respectively).

A number of previously unplaced gamma-ray transitions have been proposed as contributing to the depopulation of specific existing nuclear levels of Cs-139 (Burrows):

E(gamma) (keV)	E(nuclear level) (keV)
466.4 (3)	1652.75 (6)
482.64 (17)	1215.02 (16)
523.67 (17)	1738.69 (6)
867.84 (19)	2967.46 (11)
909.46 (12)	2304.71 (8)
1218.48 (9)	1508.24 (8)
1267.44 (12)	2304.71 (8)
1665.9 (4)	2852.31 (16)
1853.68 (4)	2586.06 (1)
2099.62 (16)	2099.62 (16)
2887.47 (23)	3924.74 (21)

Other unplaced gamma transitions have been assessed on the basis of their possible population of already existing nuclear levels - proposed nuclear levels of Cs-139 were identified as feasible for population by specific gamma transitions following Xe-139 beta decay:

E(nuclear level) (keV)	Depopulating E(gamma) (keV)
1780.03 (24)	1184.6 (2)
2058.4 (3)	1543.2 (5); 1768.6 (5)
3948.63 (16)	1828.99 (21); 2941.90 (17)
4066.03 (19)	1129.2 (3); 2249.5 (5); 3028.76 (21)
4134.9 (4)	2673.6 (4); 3424.6 (4)
4186.26 (13)	1458.63 (21); 2791.01 (16)
4615.93 (14)	1635.5 (3); 1818.38 (18)

A significant number of gamma-ray emissions observed and quantified by Lee and Talbert Jr. and Faller et al. have been judged to be equivalent and effectively identical transitions. They have been subsequently placed in the proposed decay scheme as single entities, rather than maintained as separate and frequently unplaced gamma-ray emissions: 980.53, 1612.8, 1652.75, 1665.9, 1765.4, 1804.2, 1851.92, 1911.42, 1939.54 and 2006.8 keV.

Emission Probabilities

Virtually all of the recommended relative emission probabilities were determined from the extensive gamma-ray measurements of Lee and Talbert Jr., and Faller et al. These data were either adopted as directly quantified by either measurement, or weighted-mean values were derived on the basis of either the LWM or NRM procedures. Although spectral resolution was problematic in a relatively significant number of instances, every effort was made to maintain a high degree of energy separation despite such overlap, bringing some of the resulting emission probabilities into question. Furthermore, the relative emission probabilities of the 745.32-, 745.63-, 786.5-, 818.63-, 896.5-, 909.46-, 924.9-, 1046.47-, 1219.39-, 1458.63- and 2791.01-keV gamma rays were subsequently adjusted from 0.84(9), 0.10(1), 0.04(1), 0.49(1), 0.13(1), 0.39(2), 0.20(11), 0.53(2), 0.28(4), 0.59(2) and 0.48(4) to 1.20(13), 0.14(2), 0.33(6), 0.46(4), 0.20(3), 0.24(3), 0.10(5), 0.48(6), 0.40(5), 0.40(10) and 0.32 (4), respectively, to achieve population-depopulation balances for the 1037.27-, 1139.11-, 1395.25-, 1411.7-, 1793.2- and 2727.63-keV nuclear levels. The existence of unresolved doublets was judged to be feasible with respect to the 1935-, 2737- and 3111-keV gamma transitions and their population of the 393.48- and 393.79-keV nuclear levels of Cs-139 - doublets were created at these gamma-ray energies, and in each case their relative emission probabilities were shared somewhat arbitrarily between the two proposed transitions.

Measurements reported by Nowak et al. provide evidence for the population of a 595.43-keV nuclear level of Cs-139 by 914.9-, 1126.5- and 1184.6-keV gamma transitions that originate from different lowly-populated levels with energies of 1510.33, 1721.94 and 1780.03 keV. These ill-defined 914.9-, 1126.5- and 1184.6-keV gamma rays have been included in the proposed decay scheme, each with highly questionable relative emission probabilities of 0.02(1)% (i.e. values below the perceived lower limit of detection of the measurements of Faller et al.), implying a summed value of 0.06(2)% for the relative emission probability of the 595.43-keV gamma ray - both the assignments and related decay data are doubtful.

Theoretical internal conversion coefficients were determined from the frozen orbital approximation of Kibedi et al., based on the theoretical model of Band et al. and Raman et al. Conversion-electron measurements by Achterberg et al. provided supportive evidence for a limited number of the gamma transitions. Almost all of the gamma rays with (M1 + E2) multipolarities and energies below 800 keV were arbitrarily assigned mixing ratios of 1.0(2) (50%M1 + 50%E2) in order to calculate reasonably realistic relative transition probabilities from their recommended relative emission probabilities. Exceptions are as follows: 100%M1 for 56.0-keV gamma ray; (92%M1 + 8%E2) for 103.72-keV gamma ray; (92.7%E1 + 7.3%M2) for 174.84-keV gamma ray; 100%M1 for 175.15-keV gamma ray; 100%M1 for 218.64-keV gamma ray; 100%E2 for 289.76-keV gamma ray; (80%E2 + 20%M3) for 356.76-keV gamma ray; 100%E2 for 393.48-keV gamma ray; and 100%E2 for 732.38-keV gamma ray.

Appropriate internal conversion coefficients (frozen orbital approximation) were obtained from the methodology of Kibedi et al. (2008). Although a significant number of gamma transitions undergo decay via internal pair formation, many of these gammas with energies above 1022 keV are not particularly well defined, and therefore this relatively low-impact behavior has not been quantified.

BETA-PARTICLE ENERGIES AND EMISSION PROBABILITIES

Energies

All beta-particle energies were calculated from the structural details of the proposed decay scheme. The nuclear level energies of Burrows and Q-value of 5057(4) keV (Audi and Wang) were used to determine the energies and uncertainties of the beta-particle emissions to the various levels.

Emission Probabilities

The beta-particle emission probabilities were calculated from consideration of the gamma-ray population-depopulation of the nuclear levels. As noted previously, recommended theoretical internal conversion coefficients were adopted in this process whenever possible, as determined from the frozen orbital approximation of Kibedi et al. based on the theoretical model of

Band et al. and Raman et al. Beta-particle emission probabilities of zero were assigned to the population of the 2727.63-, 1793.2-, 1411.7-, 1395.25-, 1139.11-, 1037.27- and 595.43-keV nuclear levels of Cs-139, arising from evidence for the balanced population-depopulation of these levels by the relevant gamma transitions.

The gamma-ray spectroscopic measurements of Lee and Talbert Jr. (1980) and Faller et al. (1988) provided guidance concerning the beta branch directly to the ground state of Cs-139. These particular studies furnished estimates of (21 +/- 9)% and (15 +/- 6)%, respectively, as derived from the intensities of the major gamma transitions of Xe-139(218.6 keV), Cs-139(1283.3 keV) and Ba-139(165.8 keV) determined in equilibrium and relative to an absolute emission probability of 23.76(25)% for the 165.8-keV gamma ray measured by Gehrke (1980). A direct beta branch to the Cs-139 ground state of (15 +/- 6)% has been adopted from Faller et al., and this value was used to determine the normalisation factor for the relative emission probabilities of the gamma rays:

(a) summation of the beta branch and absolute transition probabilities of gamma rays populating the Cs-139 ground state directly

Beta branch to Cs-139 ground state +
sum of TPgamma(abs) to Cs-139 ground state = 100%

where TPgamma(abs) are the individual absolute transition probabilities of the relevant gamma emissions (TPgamma(abs) = TPgamma(rel) x F, in which F is the normalisation factor for the relative gamma-ray emission and transition probabilities).

Therefore, 15(6)% + 151.4(10) x F = 100%
F = 85(6)/151.4(10) = 0.56 +/- 0.04

(b) summation of calculated relative emission probabilities of all known beta transitions populating nuclear levels of Cs-139, and the direct absolute beta emission probability to the ground state

Sum of beta population of Cs-139 nuclear levels = 100%

15(6)% + 151.5(24) x F = 100%
where F is the normalisation factor for the relative gamma-ray emission and transition probabilities,

F = 85(6)/151.5(24) = 0.56 +/- 0.04

Hence, a normalisation factor of (0.56 +/- 0.04) has been adopted in conjunction with the relative gamma-ray emission probabilities and theoretical internal conversion coefficients to determine the absolute gamma-ray and beta emission probabilities.

Aleklett and Rudstam (1982) undertook beta-spectrometry studies of a wide range of short-lived fission products in order to determine their total average beta energies. The OSIRIS on-line-isotope separator was used to study a significant number of short-lived fission-product radionuclides, including Xe-139 to derive a total average <Ebeta> value of 1720(60) keV, with total average experimental <Ebeta> to Q(beta) ratio of 0.352.

Rudstam et al. (1990) measured the continuous beta and gamma spectra of 114 short-lived fission products, including Xe-139. The resulting beta and gamma data for Xe-139 are expressed as follows:

gamma cut-off defined as 200 keV, below which gamma rays were not registered by NaI(Tl) spectrometer;
total average <Egamma> above cut-off = 884 +/- 39 keV;
contribution to total average <Egamma> of gamma rays below the cut-off energy was defined as 33 +/- 2 keV;
therefore, total average gamma-ray energy <Egamma> = 917 +/- 39 keV -> rounded-up to 920 +/- 40 keV;
average number of gamma rays per decay = 1.19 +/- 0.05;
total average beta energy <Ebeta> = 1800 +/- 50 keV;
total average nu energy <Enu> = 2370 +/- 180 keV;
sum of 5090 +/- 190 keV.

CONCLUDING REMARKS

Although a recommended half-life of (39.69 +/- 0.05) s was calculated from the measurements of Archer and Keech, Alvager et al., Carlson et al. and Grapengiesser et al. by means of the Rajeval technique, this value is heavily dependent on the high accuracy of the value determined by Carlson et al. of (39.68 +/- 0.05) s. Further confirmatory studies are merited under such circumstances.

A complex and comprehensive decay scheme has been derived from measurements of the relative gamma-ray emission probabilities by Lee and Talbert Jr., and Faller et al. Various mixing ratios and multipolarities were adopted from the studies of Achterberg et al., while a significant number of (M1 + E2) gamma transitions were arbitrarily assigned to be (50%M1 + 50%E2) with a relatively high uncertainty of 20%, and a small number of other transitions were defined as 100%M1 (56.0, 175.15 and 218.64 keV). Previously unplaced gamma transitions were introduced into the proposed decay scheme - twenty five of these observed gamma rays were successfully allocated (466.4, 482.64, 523.67, 867.84, 909.46, 1129.2, 1184.6, 1218.48, 1267.44, 1458.63, 1543.2, 1635.5, 1665.9, 1768.6, 1818.38, 1828.99, 1853.68, 2099.62, 2249.5, 2673.6, 2791.01, 2887.47, 2941.90, 3028.76 and 3424.6 keV), some of which involved the introduction of new nuclear levels at 1186.4(3), 1780.03(24), 2058.4(3), 3948.63(16), 4066.03(19), 4134.9(4), 4186.26(13) and 4615.93(14) keV. A number of previously unresolved and partially resolved gamma emissions observed separately by Lee and Talbert Jr. and Faller et al. were judged to be identical transitions to be treated as single entities in the proposed decay scheme, rather than quantified erroneously as differing and frequently unplaced.

The proposed decay scheme of Xe-139 consists of 64 beta emissions and 271 gamma transitions. There are a significant number of uncertainties associated with the proposed decay scheme, and specific assumptions have been made concerning the relative merits of the main sources of gamma-ray data. Most importantly, the normalisation factor of (0.56 +/- 0.04) adopted for the relative gamma-ray emission probabilities and calculation of the recommended beta emission probabilities is based entirely on a direct beta branch to the Cs-139 ground state of (15 +/- 6)% reported by Faller et al., as determined by Robertson (unpublished, albeit co-author of Faller et al.). Further measurements of the absolute and relative gamma-ray emission probabilities are required to derive the decay scheme with much greater confidence, particularly for more accurate determinations of the beta emission probabilities to the 1006.73-, 515.22-, 393.79-, 393.48-, 289.76-, 218.644-keV and ground states of Cs-139.

Rudstam et al. (1990) carried out studies of the continuous beta and gamma spectra of Xe-139, in which the beta and gamma data were expressed in terms of fifty-six energy increments of 100 keV each, ranging from 0 to 5600 keV. Total average <Ebeta> of (1800 +/- 50) keV and total average <Egamma> of (920 +/- 110) keV were derived from these data, along with total average <Enu > of (2370 +/- 180) keV, summing to a Qbeta of (5090 +/- 220) keV, and these values were recommended by Rudstam and adopted during the preparation of the JEF-2.2 decay-data library. However, only a severely limited set of data was assembled from the 2003NUBASE as part of the decay-data compilation for JEFF-3.1.1, and

```
average <Ebeta> = average <Egamma> = (Qbeta/3)
                = 5057/3 = 1685.67 keV
```

A Qbeta of (5057 +/- 4) keV has subsequently been recommended by Audi and Wang (2011), which differs slightly from the earlier value tabulated by Rudstam et al. (difference of ~ 0.65%).

With a total average <Egamma> of (1007 +/- 70) keV and total average <Ebeta> of (1700 +/- 130) keV calculated from the various discrete gamma-ray measurements compared with (920 +/- 110) and (1800 +/- 50) keV respectively from Rudstam et al., the discrete studies would also appear to have better addressed the problem of Pandemonium. There are a number of differences between the complex decay scheme derived by means of singles gamma-ray spectroscopy (Lee and Talbert Jr., 1980Le03; Faller et al., 1988Fa06) and the gross beta-gamma spectral measurements of Rudstam et al. (1990Ru05). Until these conflicting anomalies can be minimised and their impact on the decay scheme of Xe-139 quantified with confidence, the evaluator feels obliged to recommend a decay scheme based on the gamma-ray measurements of Lee and Talbert Jr. and Faller et al., and to set aside the gross beta-gamma studies of Rudstam et al. Both gamma-ray spectroscopy studies are reasonably comprehensive and noteworthy, although their assignment and quantification of the higher-energy gamma rays should be viewed as potentially questionable. Evaluated discrete beta- and gamma data derived from these gamma-ray measurements have been adopted, in conjunction with their resulting total average <Ebeta> and <Egamma> energies. Future emphasis should be placed on further gross beta-gamma and TAGS studies, along with comprehensive gamma-gamma and singles gamma-ray spectrosopic measurements, to achieve a higher degree of agreement and consistency.

```
   MEAN BETA- ENERGIES:-
END POINT(MEV)= 0.4410  SHAPE= 0  MEAN= 0.1323  INT= 0.0022
END POINT(MEV)= 0.8290  SHAPE= 0  MEAN= 0.2757  INT= 0.0017
END POINT(MEV)= 0.8710  SHAPE= 0  MEAN= 0.2922  INT= 0.0040
END POINT(MEV)= 0.9220  SHAPE= 0  MEAN= 0.3125  INT= 0.0013
END POINT(MEV)= 0.9910  SHAPE= 0  MEAN= 0.3403  INT= 0.0021
END POINT(MEV)= 1.1080  SHAPE= 0  MEAN= 0.3882  INT= 0.0011
```

```
END POINT(MEV)= 1.1320   SHAPE= 1   MEAN= 0.3981   INT= 0.0035
END POINT(MEV)= 1.2420   SHAPE= 1   MEAN= 0.4441   INT= 0.0019
END POINT(MEV)= 1.2810   SHAPE= 1   MEAN= 0.4606   INT= 0.0039
END POINT(MEV)= 1.3120   SHAPE= 1   MEAN= 0.4737   INT= 0.0045
END POINT(MEV)= 1.5520   SHAPE= 1   MEAN= 0.5770   INT= 0.0063
END POINT(MEV)= 1.6820   SHAPE= 1   MEAN= 0.6338   INT= 0.0050
END POINT(MEV)= 1.6840   SHAPE= 1   MEAN= 0.6347   INT= 0.0024
END POINT(MEV)= 1.8480   SHAPE= 1   MEAN= 0.7072   INT= 0.0040
END POINT(MEV)= 1.9010   SHAPE= 1   MEAN= 0.7308   INT= 0.0022
END POINT(MEV)= 1.9100   SHAPE= 1   MEAN= 0.7348   INT= 0.0015
END POINT(MEV)= 1.9270   SHAPE= 1   MEAN= 0.7424   INT= 0.0026
END POINT(MEV)= 2.0770   SHAPE= 1   MEAN= 0.8096   INT= 0.0018
END POINT(MEV)= 2.0900   SHAPE= 1   MEAN= 0.8155   INT= 0.0075
END POINT(MEV)= 2.1200   SHAPE= 1   MEAN= 0.8290   INT= 0.0016
END POINT(MEV)= 2.2050   SHAPE= 1   MEAN= 0.8674   INT= 0.0033
END POINT(MEV)= 2.2590   SHAPE= 1   MEAN= 0.8918   INT= 0.0100
END POINT(MEV)= 2.3030   SHAPE= 1   MEAN= 0.9118   INT= 0.0078
END POINT(MEV)= 2.4360   SHAPE= 1   MEAN= 0.9722   INT= 0.0077
END POINT(MEV)= 2.4710   SHAPE= 1   MEAN= 0.9882   INT= 0.0129
END POINT(MEV)= 2.5470   SHAPE= 1   MEAN= 1.0229   INT= 0.0185
END POINT(MEV)= 2.6250   SHAPE= 1   MEAN= 1.0586   INT= 0.0035
END POINT(MEV)= 2.6340   SHAPE= 1   MEAN= 1.0627   INT= 0.0004
END POINT(MEV)= 2.6840   SHAPE= 1   MEAN= 1.0857   INT= 0.0071
END POINT(MEV)= 2.7280   SHAPE= 1   MEAN= 1.1059   INT= 0.0267
END POINT(MEV)= 2.7520   SHAPE= 1   MEAN= 1.1169   INT= 0.0197
END POINT(MEV)= 2.8710   SHAPE= 1   MEAN= 1.1716   INT= 0.0348
END POINT(MEV)= 2.9370   SHAPE= 1   MEAN= 1.2020   INT= 0.0065
END POINT(MEV)= 2.9530   SHAPE= 1   MEAN= 1.2094   INT= 0.0018
END POINT(MEV)= 2.9570   SHAPE= 1   MEAN= 1.2113   INT= 0.0030
END POINT(MEV)= 2.9930   SHAPE= 1   MEAN= 1.2279   INT= 0.0031
END POINT(MEV)= 2.9990   SHAPE= 1   MEAN= 1.2306   INT= 0.0007
END POINT(MEV)= 3.2260   SHAPE= 1   MEAN= 1.3356   INT= 0.0034
END POINT(MEV)= 3.2410   SHAPE= 1   MEAN= 1.3425   INT= 0.0010
END POINT(MEV)= 3.2770   SHAPE= 1   MEAN= 1.3592   INT= 0.0001
END POINT(MEV)= 3.3180   SHAPE= 1   MEAN= 1.3782   INT= 0.0120
END POINT(MEV)= 3.3350   SHAPE= 1   MEAN= 1.3861   INT= 0.0001
END POINT(MEV)= 3.3390   SHAPE= 1   MEAN= 1.3880   INT= 0.0056
END POINT(MEV)= 3.3630   SHAPE= 1   MEAN= 1.3991   INT= 0.0045
END POINT(MEV)= 3.4040   SHAPE= 1   MEAN= 1.4181   INT= 0.0170
END POINT(MEV)= 3.4570   SHAPE= 1   MEAN= 1.4427   INT= 0.0038
END POINT(MEV)= 3.5470   SHAPE= 1   MEAN= 1.4845   INT= 0.0001
END POINT(MEV)= 3.5490   SHAPE= 1   MEAN= 1.4854   INT= 0.0020
END POINT(MEV)= 3.5960   SHAPE= 1   MEAN= 1.5073   INT= 0.0076
END POINT(MEV)= 3.8420   SHAPE= 1   MEAN= 1.6217   INT= 0.0025
END POINT(MEV)= 3.8710   SHAPE= 1   MEAN= 1.6353   INT= 0.0016
END POINT(MEV)= 4.0370   SHAPE= 1   MEAN= 1.7126   INT= 0.0109
END POINT(MEV)= 4.0500   SHAPE= 1   MEAN= 1.7187   INT= 0.0820
END POINT(MEV)= 4.1140   SHAPE= 1   MEAN= 1.7485   INT= 0.0110
END POINT(MEV)= 4.1650   SHAPE= 1   MEAN= 1.7723   INT= 0.0092
END POINT(MEV)= 4.3250   SHAPE= 1   MEAN= 1.8469   INT= 0.0184
END POINT(MEV)= 4.3470   SHAPE= 1   MEAN= 1.8572   INT= 0.0020
END POINT(MEV)= 4.4100   SHAPE= 1   MEAN= 1.8866   INT= 0.0026
END POINT(MEV)= 4.5420   SHAPE= 1   MEAN= 1.9482   INT= 0.2220
END POINT(MEV)= 4.6630   SHAPE= 1   MEAN= 2.0047   INT= 0.0482
END POINT(MEV)= 4.6640   SHAPE= 1   MEAN= 2.0052   INT= 0.1030
END POINT(MEV)= 4.7670   SHAPE= 1   MEAN= 2.0533   INT= 0.0140
END POINT(MEV)= 4.8380   SHAPE= 1   MEAN= 2.0864   INT= 0.0350
END POINT(MEV)= 5.0570   SHAPE= 2   MEAN= 2.1739   INT= 0.1500

   MEAN GAMMA ENERGY              =    1007.1285  KEV
   MEAN BETA- ENERGY              =    1696.6583  KEV
```

```
BETA- + NEUTRINO ENERGY         =   4016.0855  KEV
MEAN X-RAY ENERGY               =      3.1465  KEV
MEAN AUGER ELECTRON ENERGY      =      0.8390  KEV
MEAN CONVERSION ELECTRON ENERGY=      22.3405  KEV
INTERNAL BREMSSTRAHLUNG ENERGY =       6.9779  KEV
EFFECTIVE Q VALUE               =   5057.0000  KEV
UNCERTAINTY IN EFFECTIVE Q (%) =       0.1275
CALCULATED Q VALUE              =   5049.5400  KEV
% DEVIATION                     =      0.1475
```

55-Cs-140

N Nica	Nucl Data Sheets 108(2007)1287
N P Archer, G L Keech	Can J Phys 44(1966)1823 (T1/2)
E A Zherebin et al	Sov J Nucl Phys 3(1966)717 (Egamma, Pgamma)
T Alvager et al	Phys Rev 167(1968)1105 (T1/2, Egamma, Pgamma)
G C Carlson et al	Nucl Phys A125(1969)267 (T1/2)
K-L Kratz	BMBW-FBK-71-12(1971)7 (Egamma)
B Ehrenberg, S Amiel	Phys Rev C6(1972)618 (T1/2)
J P Adams et al	Phys Rev C8(1973)767 (Qbeta)
F Schussler et al	Nucl Phys A209(1973)589 (Egamma, Pgamma, gamma-gamma)
B Grapengiesser et al	J Inorg Nucl Chem 36(1974)2409 (T1/2)
W C Schick Jr., W L Talbert Jr.	Phys Rev C9(1974)2328 (Egamma, Pgamma, gamma-gamma)
K Aleklett et al	Nucl Phys A246(1975)425 (Qbeta)
L J Alquist et al	Phys Rev C13(1976)1277 (gamma-gamma, delta)
R Decker et al	Z Phys - Atoms and Nuclei A301(1981)165 (Qbeta)
K Aleklett, G Rudstam	Nucl Sci Eng 80(1982)74 (average Ebeta)
S J Robinson et al	J Phys G: Nucl Phys 12(1986)903 (Egamma, Pgamma, gamma-gamma, delta)
H Mach et al	Nucl Instrum Methods Phys Res A280(1989)49 (nuclear level T1/2)
G Rudstam et al	At Data Nucl Data Tables 45(1990)239 (average Egamma, Ebeta, Enu)
R C Greenwood et al	Nucl Instrum Methods Phys Res A378(1996)312 (Pbeta(g.s.))
R C Greenwood et al	Nucl Instrum Methods Phys Res A390(1997)95 (Pbeta)
W Urban et al	Nucl Phys A613(1997)107 (high-spin states)
I M Band et al	At Data Nucl Data Tables 81(2002)1 (ICC)
S Raman et al	Phys Rev C66(2002)044312 (ICC)
G Audi et al	Nucl Phys A729(2003)337 (Q-value)
Ts Venkova et al	Eur Phys J A34(2007)349 (high-spin states)
T Kibedi et al	Nucl Instrum Methods Phys Res A589(2008)202 (ICC)
G Audi, M Wang	Atomic mass evaluation, private communication, CSNSM, Orsay, France, April 2011 (Q-value)

An extremely complex and comprehensive decay scheme has been derived primarily from the gamma-ray measurements of Schussler et al. (1973), Schick Jr. and Talbert Jr. (1974), and Robinson et al. (1986), and the determination of the total average <Egamma>, <Ebeta> and <Enu> from continuous beta and gamma spectral studies by Rudstam et al. (1990) and Greenwood et al. (1997).

HALF-LIFE

The recommended half-life has been determined from the measurements of Archer and Keech, Alvager et al., Carlson et al., Ehrenberg and Amiel, and Grapengiesser et al. Limitation of relative statistical weight method (LWM), normalised residual method (NRM), Rajeval technique, bootstrap method, and Mandel-Paule approach were considered in the analysis of individual data sets.

A half-life value of (64.0 +/- 0.5) seconds was preferred and recommended, as quantified by the Rajeval analytical procedure.

Q VALUES
A Q- value for Cs-140 beta decay of 6220 (10) keV was adopted (Audi et al., and Audi and Wang).

GAMMA-RAY ENERGIES AND EMISSION PROBABILITIES
Energies
The energies of the gamma-ray emissions have been measured to various degrees of complexity by Zherebin et al., Alvager et al., Schussler et al., Schick Jr. and Talbert Jr., Robinson et al., Urban et al. and Venkova et al. Many of these data sources were subsequently assessed by Nica to determine the nuclear levels energies of daughter Ba-140 as adopted below.

The gamma-ray spectroscopic measurements of Schussler et al., Schick Jr. and Talbert Jr., and Robinson et al. are particularly detailed, and are highly relevant to the derivation of a reasonably comprehensive decay scheme. Gamma-ray emissions are reported up to a maximum energy of 4983 keV by Schussler et al., 5228 keV by Schick Jr. and Talbert Jr., and 3699 keV by Robinson et al., although uncertainties in the many gamma-ray energies and relative emission probabilities have only been quantified by Schick Jr. and Talbert Jr. and Robinson et al. A number of gamma emissions observed by Alvager et al. and Schussler et al. were judged to be of questionable origin, and were discarded: 901.9-, 1246.2-, 1499.9-, 1726.6-, 2193.0-, 3918.6-, 4003.7-, 4171.0- and 4405.0-keV gamma rays.

A limited number of unplaced gamma-ray transitions have been proposed as contributing to the depopulation of previously defined nuclear levels of Ba-140 (Nica):

E(gamma) (keV)	E(nuclear level) (keV)
2061.4 (3)	2663.8 (3)
3286.18 (20)	5109.97 (18)
3756.08 (17)	4358.44 (17)
3785.70 (21)	4388.06 (21)

All other remaining unplaced gamma transitions have been assessed on the basis of their possible population of already existing nuclear levels - thus, new gamma-depopulating nuclear levels of Ba-140 were proposed, and have been defined in terms of direct population by means of Cs-140 beta decay:

E(nuclear level) (keV)	Depopulating E(gamma) (keV)
2061.5 (3)	2061.5 (3)
3845.2 (6)	3845.2 (6)
4076.1 (6)	1755.6 (6); 1766.6 (6); 4076.1 (6)
4261.2 (6)	1473.7 (7); 1479.1 (7)
4381.4 (8)	4381.4 (8)

4427.2 (9)	771.1 (9); 3824.8 (9)
4472.6 (7)	1780.6 (8); 4472.6 (7)
4531.4 (6)	4531.4 (6)
4785.1 (10)	1129.0 (10); 1911.3 (10)
4813.5 (6)	1942.7 (6); 2384.0 (6); 4813.5 (6)
5127.7 (8)	4525.3 (8)
5227.6 (15)	3023.4 (15); 3166.1 (15); 5227.6 (15)
5340.5 (8)	3829.8 (8); 4209.9 (8)
5384.9 (5)	1109.8 (6); 1411.7 (5); 2452.3 (5); 2692.9 (7)
5523.9 (3)	1024.1 (3)
5748.8 (4)	2147.1 (7); 3544.6 (4); 4238.1 (4)
5931.6 (4)	3793.4 (4); 4107.8 (4)

The studies of Urban et al. and Venkova et al. involve the production of excited nuclear levels of Ba-140 by means of the spontaneous fission of Cm-248 and the fusion-fission reactions of C-12 + U-238 and O-18 + Pb-208, respectively. High-spin excited states were populated of no direct relevance to the beta decay of Cs-140, and these particular gamma-ray data have been set aside: 218.2-, 328.4-, 385.6-, 473.5-, 491.5-, 529.8-, 568.2-, 570.4-, 574.0-, 759.9-, 808.1-, 828.3-, 889.2-, 916.4-, 1021.6-, 1062.4- and 1140.2-keV gamma-ray emissions.

Emission Probabilities
Virtually all of the recommended relative emission probabilities were determined from the extensive gamma-ray measurements of Schussler et al., Schick Jr. and Talbert Jr., and Robinson et al. These data were either adopted as directly quantified, preferably by either Schick Jr. and Talbert Jr., and Robinson et al., or weighted-mean values were derived on the basis of the LWM procedure. Although energy resolution was problematic in a number of instances, every effort was made to maintain energy separation despite such overlap, bringing some of the resulting emission probabilities into question. This lack of adequate resolution created significant problems in the evaluation of the complex Cs-140 decay scheme, and some of the resulting assessments were deemed to be highly subjective and of questionable validity: uncertainties in the resolution and quantification of the relative emission probabilities for an extensive number of unresolved and partially resolved doublets defined as 794.40-795.1, 889.09-889.1, 938.78-938.98, 949.2-950.13, 980.26-981.49, 999.60-1000.83, 1063.50-1063.65, 1129.0-1129.74, 1136.44-1136.78, 1146.9-1147.01, 1172.2-1172.3, 1292.2-1292.40, 1375.91-1376.0, 1453.90-1455.43, 1517.61-1517.84, 1527.0-1527.06, 1650.43-1651.48, 1795.3-1795.76, 1798.8-1800.00, 2037.9-2037.93, 2061.4-2061.5, 2089.6-2090.5, 2234.35-2236.14, 2512.6-2515.06, 2662.95-2663.8, 3066.49-3068.38 and 3341.42-3341.6 keV, and a questionable triplet identified as 861.22-861.5-862.8 keV.

After consideration of their placement in the proposed decay scheme and impact upon nuclear-level population and depopulation balances, a large majority of the recommended relative emission probabilities of the unresolved and sometimes ill-defined doublets (and triplet) were arbitrarily shared between the two (and three) gamma transitions. However, this simple approach was not adopted with respect to the 1063.50-1063.65, 1129.0-1129.74, 1146.9-1147.01, 2037.9-2037.93, 2061.4-2061.5, 2234.35-2236.14 and 3066.49-3068.38 keV gamma rays, in which greater care was taken to define their individual relative emission probabilities owing to constraints arising from population and depopulation considerations. Furthermore, the relative emission probabilities of the 821.0-, 1281.2-, 1601.84-, 1718.5- and 3636.7-keV gamma rays were subsequently adjusted from 0.44(3), 0.14(5), 0.92(4), 0.46(4) and 0.22(3) to 0.47(3), 0.12(5), 1.26(6), 0.54(4) and 0.09(3), respectively, to achieve population-depopulation balances for the 1951.60-, 2204.20- and 2320.51-keV nuclear levels.

Theoretical internal conversion coefficients were determined from the frozen orbital approximation of Kibedi et al. based on the theoretical model of Band et al. and Raman et al. Almost all of the gamma rays with (M1 + E2) multipolarities and energies below 810 keV along with a few others of higher energy were arbitrarily assigned mixing ratios of 1.0(2) (50%M1 + 50%E2) in order to calculate reasonably realistic relative transition probabilities from their recommended relative emission probabilities: gamma rays with energies of 413.45, 627.56, 643.84, 693.53, 726.57, 736.35, 757.7, 795.1, 798.84, 809.84, 2009.9, 2170.30, 2277.06 and 2704.04 keV.

Directional correlation measurements on various gamma cascades by Robinson et al. provided specific mixing ratios and ranges of such data for a limited number of the gamma transitions. Similar gamma-gamma angular correlation studies by Alquist et al. do not exhibit good agreement, and the mixing ratios derived by Robinson et al. have been preferably adopted in these circumstances, as listed below.

(a) Definitive mixing ratios adopted primarily from Robinson et al.
(98.3%E1 + 1.7%M2) for 672.30-keV gamma ray;
(73.5%M1 + 26.5%E2) for 908.31-keV gamma ray;
(4.7%M1 + 95.3%E2) for 1007.64-keV gamma ray;
(25.7%M1 + 74.3%E2) for 1129.74-keV gamma ray;
(99.96%E1 + 0.04%M2) for 1200.53-keV gamma ray;
(96.9%M1 + 3.1%E2) for 1391.29-keV gamma ray;
(99.84%M1 + 0.16%E2) for 1535.87-keV gamma ray;
(50.0%M1 + 50.0%E2) for 1634.88-keV gamma ray;
(76.8%M1 + 23.2%E2) for 1827.16-keV gamma ray (as determined by Alquist et al.);
(94.6%M1 + 5.4%E2) for 1853.18-keV gamma ray;
(99.2%M1 + 0.8%E2) for 2101.68-keV gamma ray;
(96.5%M1 + 3.5%E2) for 2268.43-keV gamma ray;
(99.64%E1 + 0.36%M2) for 2330.27-keV gamma ray; and
(99.84%E1 + 0.16%M2) for 3053.71-keV gamma ray.

(b) Ranges for the mixing ratios of a number of (M1 + E2) gamma transitions with energies of 821.0 (assigned (13.8%M1 + 86.2%E2)), 918.85 (assigned (97.5%M1 + 2.5%E2)), 1601.84 (assigned (76.8%M1 + 23.2%E2)), 1707.15 (assigned (96.2%M1 + 3.8%E2)) and 1950.13 keV (assigned (89.6%M1 + 10.4%E2)) have been derived by Robinson et al., and specific values were selected in the determination of their multipolarities and relative transition probabilities. However, multipolarities have not been quantified for nearly 50 gamma transitions with energies above 820 keV that would appear to be (M1 + E2) .

(c) Ranges for the mixing ratios of a number of (E1 + M2) gamma transitions with energies of 1421.96 (assigned (>=91%M2 + E1)), 2340.38 (assigned (69%E1 + 31%M2)), 2462.52 (assigned

(91.2%E1 + 8.8%M2)), 2847.77 (assigned (8%E1 + 92%M2)), and 3370.83 keV (assigned (91.7%E1 + 8.3%M2)) have been derived by Robinson et al., and specific values were selected in the determination of their multipolarities and relative transition probabilities.

(d) E2 assignments were defined with reasonable confidence for the 401.31-, 528.23-, 602.36-, 1221.43-, 1993.65-, 2237.24- and 2309.51-keV gamma transitions, with some uncertainty for the 740.4-, 1073.61-, 1648.59-, 1798.8-, 2429.52-, 2521.81- and 2787.55-keV gamma transitions, and with significant uncertainty for the 2048.16-keV gamma transition.

(e) M2 assignments were defined with reasonable confidence for the 1281.2- and 2067.6-keV gamma transitions, but with some uncertainty for the 2361.57-, 3565.10- and 4052.54-keV gamma transitions.

(f) Ninety-three gamma transitions were identified with various degrees of confidence as E1 transitions.

(g) The multipolarities of seventy-one gamma transitions could not be quantified, and therefore values have not been proposed.

Appropriate internal conversion coefficients (frozen orbital approximation) were obtained from the methodology of Kibedi et al. A significant number of gamma transitions undergo decay via internal pair formation, and the coefficient for this process has also been quantified whenever possible from the tabulations of Kibedi et al.

BETA-PARTICLE ENERGIES AND EMISSION PROBABILITIES

Energies

All beta-particle energies were calculated from the structural details of the proposed decay scheme. The nuclear level energies recommended by Nica and Q-value of 6220(10) keV (Audi and Wang) were used to determine the energies and uncertainties of a significant number of the beta-particle transitions to the various levels. Other nuclear levels were derived from their proposed depopulation by previously unplaced gamma-ray emissions, and these data were subsequently used to calculate the energies and uncertainties of a much lesser number of beta-particle transitions.

Emission Probabilities

Beta-particle emission probabilities were calculated from gamma-ray energy balances. As noted previously, recommended theoretical internal conversion coefficients were adopted in this process whenever possible, as determined from the frozen orbital approximation of Kibedi et al. based on the theoretical model of Band et al. Beta-particle emission probabilities of zero were assigned to the population of the 2973.59-, 2692.0-, 2663.8-, 2320.51-, 2204.20-, 1951.60- and 1802.89-keV nuclear levels of Ba-140, arising from evidence for balanced population-depopulation of these levels by the relevant gamma transitions combined with consideration of spin and parity assignments.

The Total Absorption Gamma-ray Spectroscopy (TAGS) measurements of Greenwood et al. provided definitive guidance concerning the beta branch directly to the ground state of Ba-140 (Greenwood et al., 1996, 1997), furnishing an estimate of (35.9 +/- 1.7)%. This value was used to determine the normalisation factor for the relative emission probabilities of the gamma rays:

(a) summation of the beta branch and absolute transition probabilities of gamma rays populating the Cs-139 ground state directly

beta branch to Ba-140 ground state +
sum of TPgamma(abs) to Ba-140 ground state = 100%

where TPgamma(abs) are the individual absolute transition probabilities of the relevant gamma emissions (TPgamma(abs) = TPgamma(rel) x F, in which F is the normalisation factor for the relative gamma-ray emission and transition probabilities).

Therefore, 35.9(17)% + 121.29(54) x F = 100%
F = 64.1(17)/121.29(54) = 0.528 +/- 0.014

(b) summation of calculated relative emission probabilities of all known beta transitions populating nuclear levels of Ba-140, and the direct absolute beta emission probability to the ground state

Sum of beta population of Ba-140 nuclear levels = 100%

35.9(17)% + 121.43(158) x F = 100%
where F is the normalisation factor for the relative gamma-ray emission and transition probabilities,

F = 64.1(17)/121.43(158) = 0.528 +/- 0.016

Hence, a normalisation factor of (0.528 +/- 0.014) has been adopted in conjunction with the relative gamma-ray emission probabilities and theoretical internal conversion coefficients to determine the absolute gamma-ray and beta emission probabilities.

Beta-particle energies and emission probabilities derived from the gross beta-gamma and TAGS measurements of Rudstam et al. (1990) and Greenwood et al. (1997) have been compared with the equivalent data derived from the extensive gamma singles spectral studies of Schussler et al., Schick Jr. and Talbert Jr., and Robinson et al., as evaluated in this study.

Aleklett and Rudstam undertook beta-spectrometry measurements of a wide range of short-lived fission products in order to determine their total average beta energies (Aleklett et al.). The OSIRIS on-line-isotope separator was used to study a significant number of short-lived fission-product radionuclides, including Cs-140 - a total average <Ebeta> value of 1890(40) keV, with total average experimental <Ebeta> to Q(beta) ratio of 0.312.

Rudstam et al. (1990) measured the continuous beta and gamma spectra of 114 short-lived fission products, including Cs-140. The resulting beta and gamma data for Cs-140 are expressed as follows:

gamma cut-off defined as 400 keV, below which gamma rays were not registered by NaI(Tl) spectrometer;

total average <Egamma> above cut-off = 1270 +/- 8 keV;
contribution to total average <Egamma> of gamma rays below the cut-off energy was defined as 0 keV;
therefore, total average gamma-ray energy <Egamma> = 1270 +/- 8 keV;
average number of gamma rays per decay = 0.96 +/- 0.01;
total average beta energy <Ebeta> = 1860 +/- 40 keV;
total average neutrino energy <Enu> = 2440 +/- 140 keV;
sum of 5570 +/- 150 keV.

Greenwood et al. (1997) determined the spectral distributions of beta intensities for a wide range of fission-product radionuclides, including the beta decay characteristics of Cs-140. These studies for Cs-140 by means of Total Absorption Gamma-ray Spectroscopy (TAGS) result in the arbitrary introduction of five additional nuclear levels (defined as "pseudolevels" because of their uncertain energy quantification) and the rejection of others proposed originally from various gamma singles experiments. Nevertheless, there is reasonable overall agreement between the TAGS measurements for Cs-140 and the simulated spectra derived by Greenwood et al. from the ENSDF file of 1994. A total average beta energy <Ebeta> of (1890 +/- 50) keV and a total average gamma-ray energy <Egamma> of (1819 +/- 18) keV have been calculated from the TAGS measurements of Greenwood et al., based upon the reasonable assumption that the impact of the conversion-electron process upon the gamma component would be minimal in the Cs-140 decay scheme.

There is a significant difference of almost 550 keV between the total average gamma-ray energy <Egamma> of (1819 +/- 18) keV calculated from the TAGS data of Greenwood et al. (1997), and (1270 +/- 8) keV determined by Rudstam et al. However, the total average beta energies <Ebeta> of (1890 +/- 50) keV (Greenwood et al.(1997)) and (1860 +/- 40) keV (Rudstam et al. (1990)) are in reasonable agreement. A Q-value for Cs-140 beta decay of 6220 (10) keV has been adopted as evaluated by Audi et al., and is higher by 650 keV when compared with a summed energy of only 5570(150) keV derived by Rudstam et al. Under these circumstances, the total average energy data of Greenwood et al. have been adopted, with a calculated total antineutrino energy of (2511 +/- 50) keV:

total average beta energy <Ebeta> of 1890 +/- 50 keV,
total average gamma-ray energy <Egamma> of 1819 +/- 18 keV,
and total average neutrino energy <Enu> of 2511 +/- 50 keV,
based on and summing to a Q- value of (6220 +/- 70) keV.

CONCLUDING REMARKS

Although a recommended half-life of (64.0 +/- 0.5) s was calculated from the measurements of Archer and Keech, Alvager et al., Carlson et al. and Grapengiesser et al. by means of the Rajeval technique, this value is heavily dependent on the high accuracy of the value determined by Carlson et al. of (63.8 +/- 0.1) s. This unsatisfactory situation prevails despite increasing artificially the uncertainty of this particular measurement to +/- 0.5 secs. Further confirmatory half-life studies are merited under such circumstances.

A complex and comprehensive decay scheme has been derived from measurements of the relative gamma-ray emission probabilities by

Schussler et al., Schick Jr. and Talbert Jr., and Robinson et al. Various mixing ratios and multipolarities were adopted primarily from the studies of Robinson et al., and a significant number of (M1 + E2) gamma transitions were arbitrarily assigned to be (50%M1 + 50%E2) with a relatively high uncertainty of 20%. Previously unplaced gamma transitions were introduced into the proposed decay scheme - thirty-eight of these observed gamma rays were successfully allocated (771.1, 1024.1, 1109.8, 1129.0, 1411.7, 1473.7, 1479.1, 1755.6, 1766.6, 1780.6, 1911.3, 1942.7, 2061.4, 2061.5, 2147.1, 2384.0, 2452.3, 2692.9, 3023.4, 3166.1, 3286.18, 3544.6, 3756.08, 3785.70, 3793.4, 3824.8, 3829.8, 3845.2, 4076.1, 4107.8, 4209.9, 4238.1, 4381.4, 4472.6, 4525.3, 4531.4, 4813.5 and 5227.6 keV), some of which involved the introduction of new nuclear levels at 2061.5(3), 3845.2(6), 4076.1(6), 4261.2(6), 4381.4(8), 4427.2(9), 4472.6(7), 4531.4(6), 4785.1(10), 4813.5(6), 5127.7(8), 5227.6(15), 5340.5(8), 5384.9(5), 5523.9 (3), 5748.8(4) and 5931.6(4) keV.

The proposed decay scheme of Cs-140 consists of 62 beta emissions and 269 gamma transitions. There are a significant number of uncertainties associated with the proposed decay scheme, and specific assumptions have been made concerning the relative merits of the main sources of gamma-ray data. Most importantly, the normalisation factor of (0.528 +/- 0.014) adopted for the relative gamma-ray emission probabilities and calculation of the recommended beta emission probabilities is based on a direct beta branch to the Ba-140 ground state of (35.9 +/- 1.7)% obtained by means of TAGS measurements by Greenwood et al. (1996, 1997). Further spectroscopic studies of the absolute and relative gamma-ray emission probabilities are required to derive the decay scheme with even greater confidence.

Rudstam et al. carried out studies of the continuous beta and gamma spectra of Cs-140, in which the beta and gamma data were expressed in terms of sixty energy increments of 100 keV each, ranging from 0 to 6000 keV. Total average <Ebeta> of (1860 +/- 40) keV and total average <Egamma> of (1270 +/- 8) keV were derived from these data, along with total average <Enu> of (2440 +/- 140) keV, summing to a Qbeta of (5570 +/- 150) keV. However, as recommended by Rudstam in December 1990 during the preparation of the JEF-2.2 decay-data library, a total average <Ebeta> of (1860 +/- 40) keV and adjusted total average <Egamma> of (1590 +/- 40) keV were adopted. These data were further modified in June 2007 as part of the decay-data compilation for JEFF-3.1.1 to give a total average <Ebeta> of (1960 +/- 70) keV and total average <Egamma> of (1675 +/- 30) keV. A Qbeta of (6220 +/- 10) keV has subsequently been recommended by Audi and Wang (2011), which differs significantly from the value tabulated by Rudstam et al. (1990) - difference of approximately 10.5% lends support to setting aside this particular set of continuous beta-gamma data. Greenwood et al. undertook systematic studies of the distributions of beta intensities by means of Total Absorption Gamma-ray Spectroscopy (TAGS), which included Cs-140. The resulting TAGS data listed in Table 14 of Greenwood et al. (1997), along with the equivalent set of Ebeta data derived from the recommended Qbeta value and nuclear-level energies, were used to calculate a total average <Ebeta> of (1890 +/- 50) keV and total average <Egamma> of (1819 +/- 18) keV.

The total average <Egamma> calculated from the various discrete gamma-ray studies is (1763 +/- 50) keV, compared with

(1270 +/- 50) keV from the gross beta-gamma spectral data of Rudstam et al. and (1819 +/- 18) keV from the TAGS measurements of Greenwood et al., implying that the latter has somewhat better addressed the possibility of Pandemonium. While all three gamma-ray spectroscopy studies are reasonably comprehensive and noteworthy, their assignment and quantification of the higher-energy gamma rays should be viewed as potentially questionable. Therefore, the evaluator has adopted the decay scheme and discrete decay data derived from an evaluation of the gamma-ray measurements of Schussler et al. (1973Sc18), Schick Jr. and Talbert Jr. (1974Sc14), and Robinson et al. (1986Ro16), in conjunction with total average <Ebeta> and <Egamma> energies determined from Greenwood et al. (1997). Future emphasis should be placed on gross beta-gamma and TAGS studies, along with comprehensive gamma-gamma and singles gamma-ray spectroscopy, to achieve a higher degree of agreement and consistency between the various forms of measurement.

```
   MEAN BETA- ENERGIES:-
END POINT(MEV)= 0.2880  SHAPE= 0  MEAN= 0.0817  INT= 0.0025
END POINT(MEV)= 0.4550  SHAPE= 0  MEAN= 0.1370  INT= 0.0052
END POINT(MEV)= 0.4710  SHAPE= 0  MEAN= 0.1425  INT= 0.0048
END POINT(MEV)= 0.5690  SHAPE= 0  MEAN= 0.1772  INT= 0.0044
END POINT(MEV)= 0.6090  SHAPE= 0  MEAN= 0.1918  INT= 0.0037
END POINT(MEV)= 0.6320  SHAPE= 0  MEAN= 0.2003  INT= 0.0072
END POINT(MEV)= 0.6960  SHAPE= 0  MEAN= 0.2242  INT= 0.0012
END POINT(MEV)= 0.8310  SHAPE= 0  MEAN= 0.2760  INT= 0.0073
END POINT(MEV)= 0.8350  SHAPE= 0  MEAN= 0.2776  INT= 0.0027
END POINT(MEV)= 0.8800  SHAPE= 0  MEAN= 0.2953  INT= 0.0008
END POINT(MEV)= 0.9100  SHAPE= 0  MEAN= 0.3072  INT= 0.0044
END POINT(MEV)= 0.9920  SHAPE= 0  MEAN= 0.3401  INT= 0.0021
END POINT(MEV)= 1.0370  SHAPE= 0  MEAN= 0.3584  INT= 0.0084
END POINT(MEV)= 1.0460  SHAPE= 0  MEAN= 0.3620  INT= 0.0065
END POINT(MEV)= 1.0920  SHAPE= 0  MEAN= 0.3809  INT= 0.0006
END POINT(MEV)= 1.1100  SHAPE= 0  MEAN= 0.3883  INT= 0.0060
END POINT(MEV)= 1.2380  SHAPE= 0  MEAN= 0.4416  INT= 0.0020
END POINT(MEV)= 1.4070  SHAPE= 0  MEAN= 0.5133  INT= 0.0014
END POINT(MEV)= 1.4190  SHAPE= 0  MEAN= 0.5185  INT= 0.0050
END POINT(MEV)= 1.4350  SHAPE= 0  MEAN= 0.5254  INT= 0.0211
END POINT(MEV)= 1.6890  SHAPE= 0  MEAN= 0.6357  INT= 0.0005
END POINT(MEV)= 1.7200  SHAPE= 0  MEAN= 0.6494  INT= 0.0040
END POINT(MEV)= 1.7470  SHAPE= 0  MEAN= 0.6613  INT= 0.0011
END POINT(MEV)= 1.7930  SHAPE= 0  MEAN= 0.6816  INT= 0.0006
END POINT(MEV)= 1.8040  SHAPE= 0  MEAN= 0.6864  INT= 0.0025
END POINT(MEV)= 1.8320  SHAPE= 0  MEAN= 0.6988  INT= 0.0032
END POINT(MEV)= 1.8390  SHAPE= 0  MEAN= 0.7019  INT= 0.0003
END POINT(MEV)= 1.8620  SHAPE= 0  MEAN= 0.7121  INT= 0.0064
END POINT(MEV)= 1.9450  SHAPE= 0  MEAN= 0.7491  INT= 0.0043
END POINT(MEV)= 1.9590  SHAPE= 0  MEAN= 0.7553  INT= 0.0012
END POINT(MEV)= 2.1400  SHAPE= 0  MEAN= 0.8365  INT= 0.0124
END POINT(MEV)= 2.1440  SHAPE= 0  MEAN= 0.8383  INT= 0.0017
END POINT(MEV)= 2.1830  SHAPE= 0  MEAN= 0.8558  INT= 0.0087
END POINT(MEV)= 2.1870  SHAPE= 1  MEAN= 0.8576  INT= 0.0027
END POINT(MEV)= 2.2470  SHAPE= 0  MEAN= 0.8847  INT= 0.0271
END POINT(MEV)= 2.2760  SHAPE= 0  MEAN= 0.8979  INT= 0.0102
END POINT(MEV)= 2.3690  SHAPE= 0  MEAN= 0.9400  INT= 0.0220
END POINT(MEV)= 2.3750  SHAPE= 1  MEAN= 0.9427  INT= 0.0005
END POINT(MEV)= 2.5640  SHAPE= 0  MEAN= 1.0288  INT= 0.0260
END POINT(MEV)= 2.6180  SHAPE= 0  MEAN= 1.0535  INT= 0.0022
END POINT(MEV)= 2.6930  SHAPE= 1  MEAN= 1.0878  INT= 0.0036
```

```
END POINT(MEV)= 2.6990   SHAPE= 1   MEAN= 1.0906   INT= 0.0083
END POINT(MEV)= 2.7690   SHAPE= 0   MEAN= 1.1226   INT= 0.0076
END POINT(MEV)= 3.1220   SHAPE= 1   MEAN= 1.2851   INT= 0.0027
END POINT(MEV)= 3.2870   SHAPE= 0   MEAN= 1.3614   INT= 0.0425
END POINT(MEV)= 3.3460   SHAPE= 1   MEAN= 1.3887   INT= 0.0025
END POINT(MEV)= 3.3490   SHAPE= 1   MEAN= 1.3901   INT= 0.0096
END POINT(MEV)= 3.4320   SHAPE= 1   MEAN= 1.4285   INT= 0.0029
END POINT(MEV)= 3.4380   SHAPE= 2   MEAN= 1.4177   INT= 0.0005
END POINT(MEV)= 3.5160   SHAPE= 1   MEAN= 1.4675   INT= 0.0342
END POINT(MEV)= 3.6980   SHAPE= 1   MEAN= 1.5519   INT= 0.0285
END POINT(MEV)= 3.7900   SHAPE= 1   MEAN= 1.5947   INT= 0.0063
END POINT(MEV)= 3.9100   SHAPE= 1   MEAN= 1.6504   INT= 0.0097
END POINT(MEV)= 3.9830   SHAPE= 1   MEAN= 1.6844   INT= 0.0290
END POINT(MEV)= 4.0820   SHAPE= 2   MEAN= 1.7147   INT= 0.0051
END POINT(MEV)= 4.1590   SHAPE= 1   MEAN= 1.7663   INT= 0.0007
END POINT(MEV)= 4.2260   SHAPE= 1   MEAN= 1.7975   INT= 0.0045
END POINT(MEV)= 4.3960   SHAPE= 1   MEAN= 1.8767   INT= 0.0135
END POINT(MEV)= 4.7090   SHAPE= 1   MEAN= 2.0225   INT= 0.0380
END POINT(MEV)= 5.0890   SHAPE= 1   MEAN= 2.1997   INT= 0.0015
END POINT(MEV)= 5.6180   SHAPE= 1   MEAN= 2.4462   INT= 0.1550
END POINT(MEV)= 6.2200   SHAPE= 1   MEAN= 2.7265   INT= 0.3590

   MEAN GAMMA ENERGY              =   1763.0738  KEV
   MEAN BETA- ENERGY              =   1902.1406  KEV
   BETA- + NEUTRINO ENERGY        =   4453.7071  KEV
   MEAN X-RAY ENERGY              =      0.1055  KEV
   MEAN AUGER ELECTRON ENERGY     =      0.0269  KEV
   MEAN CONVERSION ELECTRON ENERGY=      2.7031  KEV
   INTERNAL BREMSSTRAHLUNG ENERGY =      8.2585  KEV
   EFFECTIVE Q VALUE              =   6220.0000  KEV
   UNCERTAINTY IN EFFECTIVE Q (%) =      0.1608
   CALCULATED Q VALUE             =   6219.6164  KEV
   % DEVIATION                    =      0.0062
```

Above consistency check applies to energy data derived primarily from the discrete gamma-ray studies.

The (5089 +/- 10)-keV beta- emission to the 1130.59-keV nuclear level of Ba-140 with spin and parity of 4+ constitutes a third forbidden non-unique transition, which has effectively been defined as first forbidden non-unique in the average energy calculations.

Average beta and gamma energies entered in the summary section of average energies are recommended for use in decay-heat calculations.
Above total mean gamma energy derived from discrete gamma-ray studies has been replaced in the summary section by Greenwood et al. (1997) estimate of (1819 +/- 18) keV.
Above total mean beta energy derived from discrete gamma-ray studies has been replaced in the summary section by Greenwood et al. (1997) value of (1890 +/- 50) keV.
Average antineutrino energy of (2508 +/- 50) keV has been calculated from the Q-value and above total mean energies.
However, the average beta and gamma energies in their respective radiation sections remain as derived from the discrete data, and therefore differ from the TAGS-based values adopted in the summary section.

Distribution

Dr A L Nichols	38 Mattock Way, Abingdon, Oxon OX14 2PQ, UK
Dr R A Forrest	Department of Nuclear Sciences and Applications, International Atomic Energy Agency, Wagramer Strasse 5, PO Box 100, A-1400 Vienna, AUSTRIA
Dr R Capote Noy	Department of Nuclear Sciences and Applications, International Atomic Energy Agency, Wagramer Strasse 5, PO Box 100, A-1400 Vienna, AUSTRIA
Dr P Dimitriou	Department of Nuclear Sciences and Applications, International Atomic Energy Agency, Wagramer Strasse 5, PO Box 100, A-1400 Vienna, AUSTRIA
Dr M Herman	National Nuclear Data Center, Bldg. 197D, Brookhaven National Laboratory, PO Box 5000, Upton, NY 11973-5000, UNITED STATES OF AMERICA
Dr A A Sonzogni	National Nuclear Data Center, Bldg. 197D, Brookhaven National Laboratory, PO Box 5000, Upton, NY 11973-5000, UNITED STATES OF AMERICA
Dr R W Mills	Desk 210/Level 3, B170, BNFL Sellafield, Seascale, Cumbria, CA201PG, UK
Dr J-Ch Sublet	Culham Centre for Fusion Energy, Neutronics and Nuclear Data Group, Theory and Modelling Department, D3 1.56, Abingdon, OX14 3DB, UK
Dr O Bersillon	CEA/DIF, BP no. 12, F-91680CEA Centre DAM Ile-de-France, Service de Physique Nucleaire, Bruyères-le-Châtel, 91297 ARPAJON Cedex, FRANCE
Dr N T Gulliford	NEA Data Bank, OECD Nuclear Energy Agency, Le Seine Saint-Germain, 12 boulevard des Iles, F-92130 Issy-les-Moulineaux, FRANCE
Dr E Dupont	NEA Data Bank, OECD Nuclear Energy Agency, Le Seine Saint-Germain, 12 boulevard des Iles, F-92130 Issy-les-Moulineaux, FRANCE
Dr F Michel-Sendis	NEA Data Bank, OECD Nuclear Energy Agency, Le Seine Saint-Germain, 12 boulevard des Iles, F-92130 Issy-les-Moulineaux, FRANCE
NST Database	AMEC, Winfrith (electronic copy)
Mr R P Hiles	AMEC, Winfrith
Mr R J Perry	AMEC, Winfrith
Dr G A Wright	AMEC, Winfrith

Also available via the UKNSF and NEA Databank web sites.