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Activation Product Decay Data: UKPADD6.11

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Executive Summary

This report describes the latest version of the UK Activation Product Decay Data Library (UKPADD6.11), as assembled for general use in March 2012.

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 also 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 UKPADD6.11 were carried out by Dr A L Nichols[1] whilst COGEND processing and verification were performed by SERCO. Data for five nuclides have been newly evaluated or re-evaluated for UKPADD6.11 during the course of 2011/12.

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).

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1 Introduction

The UK Activation Product Decay Data Library was first released in 1977 as UKPADD1 (1). Improvements in the available decay data through various spectroscopic measurements led to a comprehensive evaluation of the decay data for 236 radionuclides. 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 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 2010, a further 185 radionuclides were newly evaluated or re-evaluated, and details of these evaluations were published in a series of UK Nuclear Science Forum papers (6, 7, 8, 9, 10, 11, 12, 13, 14, 15). 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 (UKPADD6.11), released in April 2012, is described in this paper. This latest library contains evaluations for 593 radionuclides.

Data for five nuclides have been newly evaluated or re-evaluated by A L Nichols in preparation for the release of UKPADD6.11. The evaluation procedure and contents of UKPADD6.11 are summarized in the following sections.

2 Decay Data

UKPADD6.11 contains recommended data for the following parameters (see also Section 4):

(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 UKPADD6.11 (mean/average energies, discrete electrons, X-rays) were derived from the above data by using the processing code COGEND (16). 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 (17). 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 (18, 19).

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 UKPADD6.11 are listed as described in Reference 17, 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:

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

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 UKPADD6.11 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 emission-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) The 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 (20), CHECKR (20) and FIZCON (21) are applied to the file. Any diagnostic reports from these codes are reported to the evaluator who directs any further change necessary.

4 Activation Product Decay Data Library, UKPADD6.11

4.1 New Evaluations

Five nuclides were evaluated or re-evaluated during 2011/12 in response to the postulated accident study described in JEF/DOC-1291 (22). These were important fission products that either contained no spectral data in existing JEFF evaluations (Kr-90 and I-136m), or exhibited significant differences in the emitted gamma-ray dose between JEF2.2 and JEFF3.1.1 (Rb-90, Sr-94 and I-136). Decay data were prepared in ENDF-6 format.

Evaluated β^- and γ data derived from discrete γ-ray measurements have been adopted in all cases. Furthermore, the total average gamma and beta energies for Kr-90, Sr-94 and I-136 were also derived from the discrete gamma-ray measurements.

The mean gamma and beta energies for Rb-90 were determined from the TAGS studies of Greenwood *et al.* (23), while the mean energies for I-136m were obtained from the gross beta-gamma spectral studies of Rudstam *et al.* (24). Mean energies for both nuclides were derived from the experimental studies of Greenwood *et al.* and Rudstam *et al.*, and 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). Mean antineutrino energies have also been re-calculated to maintain the overall energy balance. This particular set of component data is recommended for decay-heat calculations, while 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 five evaluated decay-data files have been assembled with all others from previous versions of UKPADD to create the UKPADD6.11 library in ENDF-6 format, giving a grand total of 593 radionuclides.

4.2 Consistency Checks

All the files within UKPADD6.11 were checked using CHECKR7.02 (20) and FIZCON (21).

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 (17), 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 and I-136m, 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 Rb-90 and I-136m, as given in the average energy component data, were adopted from Greenwood *et al*. (23) and Rudstam *et al*. (24) 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. Further details of these evaluations are given in Section 4.3 below.

4.3 Contents of the Library

The UKPADD6.11 evaluated decay data library has been assembled in the internationally-accepted ENDF-6 format adopted for nuclear applications, as described in Reference 17. Comprehensive decay scheme data are presented for 593 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 (UKPADD6.11), 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 UKPADD6.11 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 (25), and they were considered as possible candidates for incorporation into UKPADD, with supportive data from Takahashi *et al.* (26) and Audi *et al.* (27). 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 discussed in more detail below - references associated with these particular comments are not defined in the reference list of this report, but can be found in the original database.

He-8
He-8 undergoes beta-particle and neutron decay. While a reasonably consistent decay scheme can be assembled, the neutron emissions are less well defined and constitute an incomplete decay scheme.

Li-9
Li-9 undergoes beta-particle and neutron decay. The latter emissions are relatively complex and poorly characterised, resulting in the formulation of an incomplete decay scheme.

V-54
There are major difficulties in defining the population-depopulation transitions of the 834.8- and 3159.3-keV nuclear levels. Furthermore, it is assumed that no beta transitions occur to the nuclear levels at 834.8, 3159.3, 3222.2 and 3436.8 keV, despite contrary evidence from gamma-ray measurements.

Sb-129m
A significant number of gamma-ray transitions can not be satisfactorily incorporated into the proposed decay scheme, and the calculated normalisation factor for the gamma rays is judged to be a poor estimate.

Cs-136m
Cs-136m has only been detected from an analysis of Cs X-rays following the proton irradiation of lanthanum. No decay data have been reported, although this metastable level at 600 keV has been postulated on the basis of the equivalent observed decay of I-136m. A decay scheme can not be proposed with such a lack of information.

Pm-155
A complete and consistent decay scheme can not be sensibly derived from the detailed TAGS (total absorption gamma-ray spectroscopy) studies of Greenwood *et al.* (1997) because of the significant lack of discrete gamma-ray and gamma-gamma coincidence measurements reported in the open literature. While the TAGS spectrum indicates the existence and population of at least 37 nuclear levels of Sm-155, only five gamma-ray emissions have been characterised (by Greenwood *et al*., 1982). Unpublished gamma-ray studies at the University of Idaho and INEL have been mentioned in relatively vague terms, and good agreement was claimed between these unreported measurements and the simulated spectra (through TAGS) up to a nuclear level energy of 1362.1 keV. Sixteen additional “pseudolevels” were also postulated by Greenwood *et al*. (1997) in order to explain the TAGS spectrum.

There are a very large number of uncertainties associated with the decay of Pm-155, and extensive gamma-ray studies are required to assist greatly in the evolution of a comprehensive and consistent decay scheme. Many features of the decay scheme need to be explored and clarified (particularly the emission probabilities of all the gamma rays, and the beta-particle energies and emission probabilities).

Ho-163
Ho-163 undergoes electron capture decay through the M and higher shells (N, O, etc.). The models in COGEND and the checking code FIZCON assume that this form of decay will involve capture from the innermost K and L shells. Hence, ENDF-6 data can not be generated using COGEND, nor checked by FIZCON. Fractional atomic shell electron capture probabilities calculated using the EC-CAPTURE code yield: P(K) = 0.0, P(L) = 0.0, P(M) = 0.1967, P(N) = 0.6688 and P(O) = 0.1346 for the 2.650-keV decay to the ground state of Dy-163. Auger and X-ray data need to be determined separately.

Au-198m
The significant 333-keV gamma ray observed in the decay of Au-198m can not be satisfactorily placed in the proposed decay scheme. There is also a lack of gamma-ray data to produce a satisfactory decay scheme.

Tl-201
There are difficulties in defining the emission probabilities and (M1+E2) mixing ratios of the low-energy 1.56- and 5.87-keV gamma rays, and there are significant uncertainties in these data. The emission probabilities of these low-energy transitions were derived from the various assumptions based on population/de-population of the relevant nuclear levels, an estimated emission probability for the 26.28-keV gamma ray, and zero EC decay to the 26.28-keV nuclear level and ground state of Hg-201. The nature of the low-energy gamma-ray emissions and their high internal conversion prevented confident recommendations for a number of the transitions in the Tl-201 decay scheme.

There are 593 full evaluations in UKPADD6.11, of which 35 files are assembled from theoretical data and 9 are defined as being incomplete data sets. The remaining 549 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.

Data for five nuclides have been newly evaluated or re-evaluated in 2011/12, and exhibit good to excellent consistency in terms of their discrete gamma-ray spectra. 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 the Rb-90 and I-136m data files by data from Greenwood et al. (23) and Rudstam et al. (24), respectively. These particular data are recommended for decay-heat calculations. However, 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.

All of the evaluated decay data have been assembled with other files from previous versions of UKPADD to create the UKPADD6.11 library in ENDF-6 format (593 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. UKPADD6.11 is available via the NEA Data Bank, and all the decay data comprising UKPADD6.11 have been submitted for possible inclusion in the JEFF-3 Decay Data Library.

6 Acknowledgements

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(Serco Ltd., 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 the evaluations and assembly of the final set of agreed files from July 2011 to March 2012.

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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
14-Si- 32	NOV82	330.0y	β–	0.0000

Nuclide	Evaluation Date	$T_{1/2}$	Decay Modes	Q % Deviation
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
23-V - 49	FEB83	330.0d	EC	0.0029

Nuclide	Evaluation Date	$T_{1/2}$	Decay Modes	Q % Deviation
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

Nuclide	Evaluation Date	$T_{1/2}$	Decay Modes	Q % Deviation
39-Y -104	MAR98	0.130s	β– (0.912230), β–n (0.087769)	#
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

Nuclide	Evaluation Date	$T_{1/2}$	Decay Modes	Q % Deviation
43-Tc-113	MAR98	0.130s	β– (0.928140), β–n (0.071864)	#
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

Nuclide	Evaluation Date	$T_{1/2}$	Decay Modes	Q % Deviation
47-Ag-106	JAN94	24.0m	β– (0.005), EC (0.995)	-0.0051
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

Nuclide	Evaluation Date	$T_{1/2}$	Decay Modes	Q % Deviation
50-Sn-113m	FEB91	20.9m	EC (0.089), IT (0.911)	-0.2109
50-Sn-117m	JAN90	13.6d	IT	-0.0006
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

Nuclide	Evaluation Date	$T_{1/2}$	Decay Modes	Q % Deviation
52-Te-132	OCT96	3.230d	β–	0.1077
53-I -125	JAN92	59.430d	EC	0.0709
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
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
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

Nuclide	Evaluation Date	$T_{1/2}$	Decay Modes	Q % Deviation
57-La-137	JUN01	6.000E+04y	EC	0.0353
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

Nuclide	Evaluation Date	$T_{1/2}$	Decay Modes	Q % Deviation
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)	#
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

Nuclide	Evaluation Date	$T_{1/2}$	Decay Modes	Q % Deviation
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
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

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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
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

Nuclide	Evaluation Date	$T_{1/2}$	Decay Modes	Q % Deviation
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
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

Nuclide	Evaluation Date	$T_{1/2}$	Decay Modes	Q % Deviation
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
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	β−	-0.3329
90-Th-228	SEP02	1.913y	α	-0.0175
90-Th-231	MAR95	1.063d	β−	-0.7156
93-Np-239	MAY91	2.355d	β−	-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 (25), Takahashi *et al.* (26) and Audi *et al.* (27).

\#\# 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
10-Ne- 23	3.72000E+01	1890.05	172.79	0.00	5	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
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
17-Cl- 39	3.33600E+03	822.65	1454.37	0.00	19	7	-	-	-	-	-	12	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
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
22-Ti- 45	1.10880E+04	373.34	871.84	0.00	15	-	6	-	-	-	-	6	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
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
27-Co- 58m	3.21840E+04	23.15	1.82	0.00	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
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
33-As- 73	6.93792E+06	5.23	4.76	0.00	-	-	1	-	-	-	-	3	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- 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
36-Kr- 79	1.26144E+05	24.63	257.77	0.00	41	-	11	-	-	-	-	57	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- 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	1960.00	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	-	-	-	-

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
42-Mo-112	1.00000E+00	2552.00	1354.00	7.96	0c	0c	-	-	0c	-	-	-	-
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

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-106	3.01000E+01	1401.28	218.09	0.00	87	36	-	-	-	-	-	48	6
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

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-110	2.47000E+01	1174.85	34.77	0.00	15	11	2	-	-	-	-	24	12
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

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-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
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

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-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
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

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
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
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
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	-	-	-	-	-	-	-
56-Ba-126	6.00000E+03	18.13	565.11	0.00	90	-	26	-	-	-	-	114	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
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
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

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
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
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	-	-	-	-	-

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
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
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

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
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
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

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
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
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

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-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
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

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-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
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

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
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
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

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-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
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.

Appendix I
Derivation of Evaluated Data

bringing service to life

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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 $\langle E_\beta \rangle$ and $\langle E_\gamma \rangle$ parameters of particular importance in decay-heat calculations.

Acquisition of References

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

> JoAnn Totans (NSR), National Nuclear Data Center, Brookhaven National Laboratory, USA,
>
> electronic library facilities of the University of Surrey, Guildford, UK, 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-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.

^{90}Kr

The accurately-quoted half-life measurement of Carlson *et al*. dominates the analysis of such data (1969Ca03). Other known half-life determinations are both unsatisfactory and inaccurate (1962Wa34, 1974Gr29). Under these circumstances, further measurements are recommended, if only to confirm the recommended value and uncertainty of (32.32 ± 0.09) s.

The extremely comprehensive γ-ray measurements of Duke *et al*. have been primarily adopted to derive the complex decay scheme of ^{90}Kr (1979Du04), fortified by earlier equivalent studies of Mason and James (1970Ma11). However, the γ-ray and ^{90}Rb nuclear-level energies were adopted from the evaluation of Browne (1997Br34, and available in ENSDF). Weighted-mean relative emission probabilities were calculated when deemed to be possible and appropriate, on the basis of the measurements of Wahlgren and Meinke (1962Wa34), Mason and Johns (1970Ma11), and Duke *et al*. (1970Du04). Unweighted data were recommended for the relative emission probabilities of the 242.19- and 539.49-keV γ rays. A normalisation factor of (0.370 ± 0.023) was determined from the relative emission probabilities of the γ transitions directly populating the ground and metastable states of ^{90}Rb, and the absolute emission probability of the β^- particle populating the ground state as determined by Wohn *et al*. (1976Wo05) – direct β^- decay to ^{90}Rb^m was assumed to be zero on the basis of spin-parity considerations ($0^+ \rightarrow 3^-$). Seven γ rays remained unplaced in the decay scheme out of a total of 102 γ transitions attributed to the β^- decay of Kr-90.

Rudstam *et al.* carried out studies of the continuous γ spectrum of ^{90}Kr (1990Ru05), in which the γ data for ^{90}Kr were expressed in terms of twenty-two 100-keV γ-energy increments from 0 to 2200 keV. No equivalent β^- spectrum was determined. However, the resulting total average $\langle E_\gamma \rangle$ of (770 ± 80) keV was judged by 1990Ru05 to be probably too low owing to insufficient statistics.

^{90}Rb

Some of the half-life studies highlighted problems in ensuring that only ^{90}Rb^g activity was being measured without contamination from other isomers (1964Jo02, 1974Gr29). However, half-lives determined by 1967Am01, 1969Ca03 and 1977Hu03 appear to be sound, and were used to obtain a LWM-based value of (157 ± 3) s.

The comprehensive γ-ray measurements of Talbert Jr. *et al*. have been primarily adopted to derive the complex decay scheme of $^{90}Rb^{g}$ (1981Ta05), fortified by the earlier equivalent studies of Mason and James (1970Ma11) and Huang *et al*. (1977Hu03). However, the γ-ray and ^{90}Sr nuclear-level energies were adopted from the evaluation of Browne (1997Br34, and available in ENSDF). Weighted-mean relative emission probabilities were calculated when deemed appropriate, on the basis of the measurements of Mason and Johns (1970Ma11), Huang *et al*. (1977Hu03) and Talbert Jr. *et al*. (1981Ta05); however, the majority of these data were directly adopted from the more detailed studies of Talbert Jr. *et al*. A normalisation factor of (0.399 ± 0.024) was determined from the relative emission probabilities of the γ transitions directly populating the ground state of ^{90}Sr, and the absolute emission probability of the β^- particle populating the ground state as determined by Greenwood *et al*. (1996Gr20) and supported by the studies of Wohn *et al*. (1976Wo05). Seven γ rays remained unplaced in the decay scheme out of a total of 95 γ transitions observed by Talbert Jr. *et al*.

Greenwood *et al*. undertook systematic studies of the distributions of β^- intensities by means of Total Absorption Gamma-ray Spectroscopy (TAGS), which included $^{90}Rb^{g}$ (1997Gr09). The resulting TAGS data listed in Table 2 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 (1960 ± 190) keV and total average $<E_\gamma>$ of (2270 ± 240) keV. Rudstam *et al*. carried out studies of the continuous β^- and γ spectra of $^{90}Rb^{g}$ (1990Ru05), in which the β^- and γ data for $^{90}Rb^{g}$ were expressed in terms of sixty-four energy increments of 100 keV each ranging from 0 to 6400 keV. A total average $<E_\beta>$ of (2200 ± 200) keV and total average $<E_\gamma>$ of (1710 ± 50) keV were derived from these data, along with a total average $<E_\nu>$ of (2660 ± 230) keV, summing to a quoted Q_β of (6570 ± 310) keV. A Q_β value of (6584 ± 7) keV has been recommended by Audi and Wang (2011), which differs by only 0.2% from the value derived by Rudstam *et al*. The total average $<E_\gamma>$ calculated from the various discrete γ-ray studies is (2014 ± 120) keV, compared with a lower value of (1710 ± 50) keV by Rudstam *et al*. and a higher value of (2270 ± 240) keV from Greenwood *et al*.

^{94}Sr

Some half-life studies originated from the same laboratory (1973Ta09, 1983Ok08, 1986Ok03), and therefore their most recently published half-life was adopted to avoid duplication within the weighted-mean analysis procedures. Thus, the half-life measurements of 1967Am01, 1973Gr14, 1974Gr29, 1979En02 and 1986Ok03 were used to obtain a weighted-mean value of (75.3 ± 0.2) s.

The γ-ray measurements of Funakoshi *et al*. were adopted to derive the proposed decay scheme of ^{94}Sr (1984Fu12), fortified by earlier studies of Grimm and Herzog (1973Gr14) and Tamai *et al*. (1973Ta09). However, γ-ray and ^{94}Y nuclear-level energies were adopted from the evaluation of Abriola and Sonzogni (2006Ab37, and available in ENSDF). Weighted-mean relative emission probabilities were calculated when deemed appropriate, based on the measurements of Grimm and Herzog, Tamai *et al*. and Funakoshi *et al*. A normalisation factor of (0.9442 ± 0.0021) was determined from the relative emission probabilities of the γ transitions directly populating the ground state of ^{94}Y, assuming no direct β^- decay to this ground state on the basis of spin-parity considerations ($0^+ \rightarrow 2^-$).

Greenwood *et al*. undertook studies of the distributions of β^- intensities by means of Total Absorption Gamma-ray Spectroscopy (TAGS) (1997Gr09). The resulting TAGS data listed in Table 7 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 (841 ± 62) keV and total average $<E_\gamma>$ of (1420 ± 80) keV. Rudstam *et al.* carried out studies of the continuous β^- and γ spectra of ^{94}Sr (1990Ru05), in which the β^- and γ data for ^{94}Sr were expressed in terms of thirty-six energy increments of 100 keV each, ranging from 0 to 3600 keV. A total average $<E_\beta>$ of (880 ± 30) keV and total average $<E_\gamma>$ of (1450 ± 10) keV were derived from these data, along with a total average $<E_\nu>$ of (1250 ± 80) keV, to sum to a quoted Q_β of (3580 ± 80) keV. However, a Q_β value of (3510 ± 8) keV has been recommended by Audi and Wang (2011), which differs by 2% from the value derived by Rudstam *et al*. The average $<E_\gamma>$ calculated from the various discrete γ-ray studies is (831 ± 4) keV, comparing well with (880 ± 30) keV of Rudstam *et al*. and (841 ± 62) keV of Greenwood *et al*., and implying that the discrete γ measurements have adequately addressed and avoided the possibility of *Pandemonium*.

^{136}I

The comprehensive γ-ray measurements of Western *et al*. (1977We04) have been primarily adopted to derive the complex decay scheme of ^{136}I, fortified by the earlier equivalent studies of Carraz *et al*. (1970Ca25), Erten *et al*. (1971Er06), and Lundán (1971Lu02). However, the ^{136}Xe nuclear-level energies were adopted from the evaluation of Sonzogni ((2002So05) and available in ENSDF), and used to calculate the recommended γ-ray energies. While weighted-mean relative emission probabilities were calculated when deemed appropriate on the basis of the measurements of Carraz *et al*. (1970Ca25), Erten *et al*. (1971Er06) and Western *et al*. (1977We04), the majority of these data were adopted directly from the detailed studies of Western *et al*. A normalisation factor of (0.678 ± 0.006) was determined from the relative emission probabilities of those γ transitions populating the ground state of ^{136}Xe, and an assumed absolute emission probability of zero for direct $β^-$ population of the ground state. The recommended decay scheme consists of 51 $β^-$ emissions and 116 γ transitions (of which two are identified as fully converted E0 transitions with $P_γ$ values of zero).

Rudstam *et al*. (1990Ru05) carried out studies of the continuous $β^-$ and γ spectra of ^{136}I, in which the $β^-$ and γ data for ^{136}I were expressed in terms of sixty energy increments of 100 keV each, ranging from 0 to 6000 keV. A total average $<E_β>$ of (1960 ± 30) keV and total average $<E_γ>$ of (1520 ± 160) keV were derived from these data, along with a total average $<E_ν>$ of (2550 ± 90) keV, and summing to a quoted $Q_β$ of (6030 ± 180) keV. Rudstam recommended that the total average $<E_γ>$ value be significantly modified to (2394 ± 50) keV in December 1990 during the preparation of the JEF-2.2 decay-data library, and this value became (2349 ± 35) keV with the adoption of a discrete decay-data evaluation for JEFF-3.1.1. A $Q_β$ value of (6857 ± 19) keV has been recommended by Audi and Wang (2011AuZZ), which conflicts with the initial value derived by Rudstam *et al*. Also, the total average $<E_γ>$ calculated from the various discrete γ studies is (2482 ± 40) keV compared with the earlier value of (1520 ± 160) keV from Rudstam *et al*., implying that the former has better addressed any possibility of *Pandemonium*.

$^{136}I^m$

The comprehensive γ-ray measurements of Western *et al*. (1977We04) have been primarily adopted to derive the complex decay scheme of $^{136}I^m$. However, the γ-ray and ^{136}Xe nuclear-level energies were adopted from the evaluation of Sonzogni ((2002So05) and available in ENSDF). A normalisation factor of (0.9991 ± 0.0001) was determined from the relative emission probability of the only γ transition directly populating the ground state of ^{136}Xe, with the emission probability of the $β^-$ particle populating the ground state defined as zero from spin-parity considerations. Significant adjustments were made to the relative emission probabilities of the 197.32- and 381.36-keV gamma rays to avoid the derivation of large population-depopulation imbalances for the 1694.39- and 1313.027-keV nuclear levels of ^{136}Xe – these difficulties encompass the main gamma transitions identified with the nuclear levels below an energy of 2130 keV, which need to be investigated further and characterised with greater confidence by means of gamma-ray spectroscopy. The possibility of direct beta decay to the 1694.39-, 1313.027- and 0.0-keV nuclear levels of ^{136}Xe also needs to be unambiguously ruled out. Well-defined spectral data of relevance to this important area of the proposed decay scheme would require a full re-assessment of the more significant $β^-$ and γ emission probabilities.

Rudstam *et al*. (1990Ru05) carried out studies of the gross $β^-$ and γ spectra of $^{136}I^m$, in which the $β^-$ and γ data for $^{136}I^m$ were expressed in terms of fifty-two energy increments of 100 keV each, ranging from 0 to 5200 keV. A total average $<E_β>$ of (2210 ± 40) keV and total average $<E_γ>$ of (2590 ± 180) keV were derived from these data, along with a total average $<E_ν>$ of (2820 ± 80) keV, and summing to a quoted $Q_β$ of (7620 ± 200) keV. However, the total average $<E_γ>$ value was modified to (2510 ± 180) keV by Rudstam in December 1990, during the preparation of the JEF-2.2 decay-data library, summing to a $Q_β$ of (7540 ± 200) keV. A $Q_β$ value of (7500 ± 110) keV has been derived from Audi and Wang (2011AuZZ), which differs by ~ 0.5% from the value determined by Rudstam *et al*. Furthermore, the total average $<E_γ>$ was calculated from the various discrete γ studies to be (2137 ± 30) keV compared with a higher value of (2510 ± 180) keV from Rudstam *et al*. (private communication, December 1990), implying that the singles γ-ray measurements exhibited a modest degree of *Pandemonium.*

Consistency Checks

Rigorous consistency checks were undertaken for the five newly evaluated nuclides to confirm the validity and completeness of the data. All five 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 (%)
36-Kr-90	32.32 (9) s	87.2% β^-(^{90}Rb) + 12.8% β^-(^{90}Rb^m): 25β^-/95γ [+ 7 unplaced γ transitions]	– 0.3831
37-Rb-90	157 (3) s	100% β^-: 26β^-/88γ [+ 7 unplaced γ transitions]	– 0.6699
38-Sr-94	75.3 (2) s	100% β^-: 7β^-/16γ	0.0312
53-I-136	83.5 (15) s	100% β^-: 51β^-/116γ	– 0.0091
53-I-136m	47 (1) s	100% β^-: 19β^-/39γ	– 0.0482

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.

	^{90}Kr	^{90}Rb	^{94}Sr	^{136}I	^{136}I^m
$E_{\beta-}$ (keV)[1]	1325 (75)	*2036 (120)*	831 (4)	1868 (60)	*2310 (200)*
E_{Ae} (keV)[2]	0.34 (4)	*0.0026 (3)*	0.0013 (1)	0.025 (3)	*0.93 (9)*
E_{ce} (keV)[2]	6.7 (7)	*0.37 (4)*	0.25 (3)	2.26 (23)	*31 (3)*
E_{LP} (keV)[1]	1332 (75)	*2036 (120)*	831 (4)	1870 (60)	*2342 (200)*
$E_{\bar{\nu}}$ (keV)[1]	1800 (100)	*2578 (150)*	1247 (6)	2505 (75)	*3022 (260)*
E_γ (keV)[1]	1277 (80)	*2014 (120)*	1431 (4)	2482 (40)	*2137 (30)*
E_X (keV)[2]	0.49 (5)	*0.0042 (4)*	0.0022 (2)	0.090 (9)	*3.3 (3)*
E_{IB} (keV)[2, 3]	4.8 (5)	*8.7 (9)*	2.45 (25)	7.9 (8)	*10.3 (10)*
E_{EM} (keV)[1]	1282 (80)	*2023 (120)*	1433 (4)	2490 (40)	*2151 (30)*
calculated Q_β (keV)[1]	4409 (150)	*6628 (230)*	3509 (8)	6857 (100)	*7505 (330)*

[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 1*σ* 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 arbitrarily at 10% of the calculated number.

[3] Energy of internal bremsstrahlung radiation is not applied to calculation of $Q_β$.

Data Adopted for the UK ENDF-B Decay Data Files of ^{90}Kr, ^{90}Rb, ^{94}Sr, ^{136}I and ^{136}I^m

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 $<E_β>$ and $<E_γ>$, which are extremely important components of the total average $<E_{LP}>$ and $<E_{EM}>$ 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 with the earlier JEF-2.2 and JEF-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 $<E_β>$ and $<E_γ>$ data derived from the evaluated discrete $β^-$ and γ emissions, and these modifications are also given in the table.

^{90}Kr

With a total average $<E_γ>$ of (1277 ± 80) keV and total average $<E_β>$ of (1325 ± 75) keV derived from the discrete decay-data evaluation, the limited measurements of Rudstam *et al*. have been set aside (1990Ru05). The singles gamma studies of Duke *et al*. (1979Du04) appear to be 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 $<E_β>$ and $<E_γ>$ 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.

^{90}Rb

There are a number of significant differences between the complex decay schemes derived by means of singles γ-ray spectroscopy (Talbert Jr. *et al*. (1981Ta05)) and the continuous spectral and TAGS measurements of Rudstam *et al*. (1990Ru05) and Greenwood *et al*. (1997Gr09), respectively. There are major anomalies to address and resolve between the experimental techniques, particularly the disagreements in $P_β$ for the 1157-, 1396-, 1634- (P), 2218-, 2734- (P), 3384- (P), 4692- and 5752-keV $β^-$ emissions ("(P)" means $β^-$ population of a newly-proposed "pseudo-level" as specified by Greenwood *et al*.). Until these differences can be minimised and their impact on the decay scheme of ^{90}Rb quantified with confidence, the evaluator feels obliged to adopt and recommend a decay scheme based on the γ-ray measurements of Mason and Johns (1970Ma11), Huang *et al*. (1977Hu03) and Talbert Jr. *et al*. (1981Ta05). The studies of Talbert Jr. *et al*. are particularly comprehensive and noteworthy, although their quantification of the many high-energy gamma rays should be viewed as potentially problematic.

Evaluated $β^-$ and γ data derived from the singles γ-ray spectroscopic measurements have been adopted, along with a total average $<E_β>$ of (1960 ± 190) keV and total average $<E_γ>$ of (2270 ± 240) keV determined from the TAGS studies of Greenwood *et al*. (1996Gr09). Future emphasis should be placed on further gross βγ and TAGS studies along with comprehensive γ-γ and singles γ-ray spectroscopy, in order to achieve a greater degree of agreement and consistency.

^{94}Sr

There are a number of differences between the decay scheme derived by means of singles γ-ray spectroscopy (Funakoshi *et al*. (1984Fu12)) and the gross βγ spectral and TAGS measurements of Rudstam *et al*. (1990Ru05) and Greenwood *et al*. (1997Gr09), respectively. Anomalies arise between the experimental techniques, particularly the disagreement in $P_β$ for the 1427.71-keV $β^-$ emission and the possible existence of a significant number of low-intensity $β^-$ emissions above

1500 keV as proposed by Greenwood *et al*. However, until these differences can be resolved and their impact on the decay scheme of ^{94}Sr quantified with confidence, the evaluator feels obliged to adopt and recommend a decay scheme based on the γ-ray measurements of Grimm and Herzog (1973Gr14), Tamai *et al*. (1973Ta09) and Funakoshi *et al*. (1984Fu12).

Evaluated discrete β^- and γ data derived from the singles γ-ray spectroscopic measurements have been adopted, along with the resulting total average $<E_\beta>$ and $<E_\gamma>$ energies determined from these discrete decay data. Further studies are merited by Total Absorption Gamma-ray Spectroscopy (TAGS), and γ-γ and singles γ-ray spectroscopy to resolve the existing anomalies associated with proposed ^{94}Y nuclear levels at approximately 1600 keV and above. Emphasis should also be placed on comprehensive γ-γ and singles γ-ray spectroscopy to achieve a higher degree of consistency with the TAGS data.

^{136}I

There are a number of differences between the complex decay schemes derived by means of singles γ-ray spectroscopy and the gross βγ spectral measurements of Rudstam *et al*. (1990Ru05). Until these conflicting anomalies can be minimised and their impact on the decay scheme of ^{136}I quantified with confidence, the evaluator feels obliged to recommend a decay scheme based on the singles γ-ray measurements of Western *et al*. (1977We04). The studies of Western *et al*. are particularly comprehensive and noteworthy, 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 $<E_\beta>$ and $<E_\gamma>$ energies. Future emphasis should be placed on gross βγ and TAGS studies, in conjunction with comprehensive γ-γ and singles γ-ray spectroscopic measurements to achieve a greater degree of agreement and consistency.

$^{136}I^m$

There are a number of significant differences between the complex decay scheme derived by means of singles γ-ray spectroscopy of Western *et al*. (1977We04) and the gross βγ spectral measurements of Rudstam *et al*. (1990Ru05). Although the studies of Western *et al*. are particularly comprehensive and noteworthy, their quantification of the many high-energy γ rays should be viewed as potentially problematic. Thus, the evaluated discrete beta- and gamma data derived from the singles gamma-ray spectroscopic measurements have been adopted, in conjunction with a total average $<E_\beta>$ of (2210 ± 40) keV and total average $<E_\gamma>$ of (2510 ± 180) keV as determined from the gross beta-gamma spectral studies of Rudstam *et al*. (private communication, December 1990). Further emphasis should be placed on gross beta-gamma and TAGS studies, along with comprehensive gamma-gamma and singles gamma-ray spectroscopy, in order to achieve a greater degree of agreement and consistency.

Recommended decay data

The decay data adopted in the resulting ^{90}Kr, ^{90}Rb, ^{94}Sr, ^{136}I and $^{136}I^m$ files are summarised in Table A4 from the point of view of their origins. Results from the evaluations of known discrete decay data measurements were preferred for ^{90}Kr, ^{94}Sr and ^{136}I. Derivation of total average β^- and γ energies for ^{90}Rb from the TAGS data of Greenwood *et al*. (1997Gr09) and the gross βγ studies of $^{136}I^m$ by Rudstam *et al*. (1990Ru05, and private communication, December 1990) 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 $^{136}I^m$ were adopted from the discrete decay data evaluations.

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.* (24) and Greenwood *et al.* (23), and Equivalent Data Adopted for JEF-2.2 and JEFF-3.1.1.

	Calculated from Recommended Discrete Data (2012)	Rudstam *et al.* (1990)	Greenwood *et al.* (TAGS) (1997)	JEF-2.2	JEFF-3.1.1
^{90}Kr					
Q_β = (4392 ± 40) keV					
Total average $\langle E_\beta \rangle$	**1325 ± 75**	–	–	1282 ± 130 ↓ 1295 ± 130†	1459 (Q/3)
Total average $\langle E_\nu \rangle$	**1800 ± 100**	–	–	1748 ± 130	1459 (Q/3)
Total average $\langle E_\gamma \rangle$	**1277 ± 80**	770 ± 80*	–	1289 ± 33 ↓ 1237 ± 100†	1459 (Q/3)
Calculated Q_β	**4409 ± 150**				
^{90}Rb					
Q_β = (6584 ± 7) keV					
Total average $\langle E_\beta \rangle$	**2036 ± 120**	2200 ± 200	1960 ± 190	1865 ± 150	2049 ± 130 ↓ 1916 ± 190‡
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 ± 240	2164 ± 24	1982 ± 42 ↓ 2271 ± 230‡
Calculated Q_β	**6628 ± 230**	Σ 6570 ± 310			
^{94}Sr					
Q_β = (3510 ± 8) keV					
Total average $\langle E_\beta \rangle$	**831 ± 4**	880 ± 30	841 ± 62	903 ± 210 ↓ 880 ± 30#	833 ± 6
Total average $\langle E_\nu \rangle$	**1247 ± 6**	1250 ± 80	–	1308 (± 300)	1249 ± 10
Total average $\langle E_\gamma \rangle$	**1431 ± 4**	1450 ± 10	1420 ± 80	1210 ↓ 1450 ± 10#	1425 ± 11
Calculated Q_β	**3509 ± 8**	Σ 3580 ± 90Δ			
^{136}I					
Q_β = (6857 ± 19) keV					
Total average $\langle E_\beta \rangle$	**1868 ± 60**	1960 ± 30	–	1954 ± 100 ↓ 1960 ± 30†	1985 ± 60
Total average $\langle E_\nu \rangle$	**2505 ± 75**	2550 ± 90	–	2605 ± 130	2610 ± 80
Total average $\langle E_\gamma \rangle$	**2482 ± 40**	1520 ± 160	–	2386 ± 50 ↓ 2394 ± 50†	2349 ± 35
Calculated Q_β	**6857 ± 100**	Σ 6030 ± 190Δ			
^{136}I^{m}					
Q_β = (7500 ± 110) keV					
Total average $\langle E_\beta \rangle$	**2310 ± 200**	2210 ± 40	–	2111 ± 190 ↓ 2210 ± 40†	2525 (Q/3)
Total average $\langle E_\nu \rangle$	**3022 ± 260**	2820 ± 80	–	2890 ± 240	2525 (Q/3)
Total average $\langle E_\gamma \rangle$	**2137 ± 30**	2590 ± 180	–	2132 ± 150 ↓ 2510 ± 180†	2525 (Q/3)
Calculated Q_β	**7505 ± 330**	Σ 7620 ± 200			

* Insufficient statistics, and therefore judged to be too low by Rudstam *et al.* *ADNDT* **45** (1990) 239-320.
† 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 10% assigned arbitrarily.
# Data modified as recommended by Rudstam *et al.*, private communication, 1989.
Δ Uncertainty adjusted upwards slightly on the basis of a summation of the listed set of total average energy data.

Table A4: Component Decay Energies, Total Average Energies, and Calculated Q_β Values Adopted in the UKPADD6.11 Files.

	Origins of recommended decay data				
	Discrete decay data evaluations			Greenwood *et al.* (1997) [23]	Rudstam *et al.* (1990) [24] + Dec 1990
	^{90}Kr	^{94}Sr	^{136}I	^{90}Rb	^{136}I^{m}
$E_{\beta-}$ (keV)[1]	1325 (75)	831 (4)	1868 (60)	1960 (190)	2210 (40)
E_{Ae} (keV)[2]	0.34 (4)	0.0013 (1)	0.025 (3)	0.0026 (3)[4]	0.93 (9)[4]
E_{ce} (keV)[2]	6.7 (7)	0.25 (3)	2.26 (23)	0.37 (4)[4]	31 (3)[4]
E_{LP} (keV)[1]	1332 (75)	831 (4)	1870 (60)	1960 (190)	2242 (40)
$E_{\bar{\nu}}$ (keV)[1]	1800 (100)	1247 (6)	2505 (75)	2353 (310)	2744 (210)
E_γ (keV)[1]	1277 (80)	1431 (4)	2482 (40)	2270 (240)	2510 (180)
E_X (keV)[2]	0.49 (5)	0.0022 (2)	0.090 (9)	0.0042 (4)[4]	3.3 (3)[4]
E_{IB} (keV)[2, 3]	4.8 (5)	2.45 (25)	7.9 (8)	8.7 (9)[4]	10.3 (10)[4]
E_{EM} (keV)[1]	1282 (80)	1433 (4)	2490 (40)	2280 (240)	2524 (180)
calculated Q_β (keV)[1]	4409 (150)	3509 (8)	6857 (100)	6584 (7)	7500 (110)

[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 1*σ* 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 arbitrarily at 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 ^{136}I^{m} are adopted from the discrete decay data evaluations.

Appendix 2
Comments from New Evaluations

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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 2011/12. 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.

36-Kr- 90

E Browne	Nucl Data Sheets 82(1997)379
G C Carlson et al	Nucl Phys A125(1969)267 (T1/2)
M A Wahlgren, W W Meinke	J Inorg Nucl Chem 24(1962)1527 (T1/2, Egamma, Pgamma)
J F Mason, M W Johns	Can J Phys 48(1970)2056 (Egamma, Pgamma, beta-gamma, gamma-gamma)
B Grapengiesser et al	J Inorg Nucl Chem 36(1974)2409 (T1/2)
F K Wohn et al	Phys Rev C13(1976)2492 (Pbeta(g.s.))
H G Borner et al	Nucl Instrum Methods 164(1979)579 (Egamma)
C L Duke et al	Phys Rev C19(1979)2322 (Egamma, Pgamma, gamma-gamma, ICC, delta)
G Rudstam et al	At Data Nucl Data Tables 45(1990)239 (av. Egamma)
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)
G Audi, M Wang	Atomic mass evaluation, private communication,CSNSM, Orsay, France, April 2011 (Q-value)

A complex and comprehensive decay scheme has been derived from the gamma-ray measurements of Wahlgren and Meinke, Mason and Johns, and Duke et al., beta(gs) studies of Wohn et al., and determination of the total average <Egamma> from continuous gamma spectral measurements by Rudstam et al.

HALF-LIFE
Determined from the measurements of Wahlgren and Meinke, Carlson et al., and Grapengiesser et al., of which the Carlson et al. value of (32.32 +/- 0.09) secs possesses much the lowest uncertainty. A value of (32.32 +/- 0.09) secs has been adopted on the basis of these measurements.

Q-VALUES
Q(beta-)-value of 4406(7) keV to the ground state of Rb-90 was adopted from Audi and Wang, which compares with a less accurate value of 4392(17) keV from an earlier published evaluation (Audi et al.). Whereas a Q(beta-)-value of 4299(7) keV to the metastable state of Rb-90 was calculated from the ground state Q-value and nuclear level energy of 106.90 (3) keV for Rb-90m (Browne).

BRANCHING FRACTIONS
Calculated from the appropriate relative beta and gamma emission probabilities, and the normalisation factor derived from the measured data and proposed decay scheme (see below).

(1). beta- decay to metastable state (Rb-90m, half-life of 258 s)
no direct beta- decay to the metastable state;
sum of populating gamma transition probabilities x NF =
34.7(15) x 0.370 = 12.8(6)%

(2). beta- decay to ground state (Rb-90, half-life of 158 s)
29(4)% direct beta- decay to the ground state (Wohn et al.);
sum of populating gamma transition probabilities x NF =
157.3(43) x 0.370 = 58.2(16)%

therefore, (beta- + gamma) to ground state is
58.2(16)% + 29(4)% = 87.2(43)% -> 87.2(6)%, with the lower uncertainty adopted from the calculated BF to the metastable state of 12.8(6)%.

36-Kr-90(beta-)37-Rb-90 branching fraction,
BF = 0.872 +/- 0.006;
36-Kr-90(beta-)37-Rb-90m branching fraction,
BF = 0.128 +/- 0.006.

GAMMA-RAY ENERGIES AND EMISSION PROBABILITIES
Energies
While the energies of many of the gamma-ray emissions placed within the proposed decay scheme have been directly measured by Mason and Johns, and Duke et al., all of their recommended gamma-ray energies were calculated from the nuclear level energies of daughter Rb-90 as adopted from Browne.

Emission Probabilities
The emission probabilities were determined from the measurements of Wahlgren and Meinke, Mason and Johns, and Duke et al. Weighted mean values were calculated for the relative emission probabilities of the 492.63-, 554.38-, 619.08-, 677.82-, 690.89-, 731.30-, 941.81-, 1039.14-, 1165.59-, 1386.71-, 1423.78-, 1466.30-, 1537.82-, 1552.18-, 1620.10-, 1658.22-, 1780.01-, 1885.39-, 1980.88-, 2127.58-, 2149.55-, 2468.65-, 2726.84- and 2865.91-keV gamma rays, while unweighted mean values were determined for the relative emission probabilities of the 242.19- and 539.49-keV gamma rays. All other gamma-ray emission probabilities were adopted from the more comprehensive set of data measured by Duke et al.

Seven gamma rays observed primarily by Duke et al. with energies of 476.10, 658.1, 1309.68, 3256.2, 3465.1, 3855.3 and 4166.5 keV could not be placed in the proposed decay scheme.

Duke et al. determined internal conversion coefficients from the relative intensities of the gamma peaks coupled with the combined intensities of the K-conversion electrons from the 106- and 121-keV doublets (although the 106.90-keV M3 gamma ray is identified with the IT decay of Rb-90m daughter). Alpha(K), alpha(L) and their uncertainties have been recalculated from the measured P(rel) data, and these values adopted to derive the mixing ratios (delta) of the M1+E2 gamma transitions.

A reasonable segment of the gamma decay occurs via internal-pair formation for gamma-transition energies above 1022 keV (judged as significant above 1552 keV). This behaviour is not accommodated satisfactorily within the ENDF-B format by COGEND, and therefore the relevant gamma-ray energies and their internal-pair formation coefficients are listed below:

Gamma energy (keV)	Internal-pair formation coefficient
1552.18(4)	0.000288(4)
1658.22(4)	0.000373(6)
1780.01(3)	0.000465(7)
1899.75(6)	0.000553(8)
2005.79(6)	0.000630(9)
2127.58(5)	0.000715(10)
2855.24(8)	0.001151(17)
2865.91(12)	0.001156(17)
3010.85(14)	0.001228(18)

Rudstam et al. carried out studies of the continuous beta- and gamma spectra of 114 short-lived fission products, although no beta- spectrum was measured for Kr-90. The resulting gamma data for Kr-90 were expressed in terms of twenty-two 100-keV gamma-energy increments from 0 to 2200 keV, which were analysed as follows:

gamma cut-off defined as 125 keV, below which gamma rays were not registered by NaI(Tl) spectrometer;
total average <Egamma> above cut-off = 769 +/- 77 keV;
contribution to total average <Egamma> of gamma rays below the cut-off energy was defined as zero;
therefore, total average gamma-ray energy
<Egamma> = 769 +/- 77 keV -> rounded-up to 770 +/- 80 keV;
average number of gamma rays per decay = 1.03 +/- 0.08.

Total average <Egamma> judged by Rudstam et al. to be probably too low owing to insufficient statistics.

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 Browne and Q-value of 4406(7) keV (Audi and Wang) to the ground state of Rb-90 were used to determine the energies and uncertainties of the beta-particle transitions to the various levels.

Emission Probabilities

The beta-particle emission probabilities were calculated from gamma-ray energy balances. Although severely limited, recommended internal conversion coefficients were also 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 also Raman et al. Beta-particle emission probabilities of zero were assigned to the population of the 227.83-, 242.19-, 536.91-, 661.28-, 1102.19- and 1153.41-keV nuclear levels of Rb-90, arising from the balanced population-population of these levels by the gamma-ray transitions. Furthermore, direct beta- population of both the 227.83- and 106.90-keV nuclear levels of Rb-90 was judged to be zero on the basis of spin-parity considerations.

Wohn et al. have undertaken measurements designed to determine the beta- branch to the ground state of Rb-90. Contamination was limited to 158-sec ground state of Rb-90 (amount of 258-sec Rb-90m isomer was judged to be negligible):

beta- transition direct to Rb-90 ground state =
(29 +/- 4)%, with log ft = 5.91 +/- 0.06 (Wohn et al.)

This value was adopted in the evaluation, and provided the means of calculating the normalisation factor (NF) for the relative emission probabilities of the gamma transitions, along with the derivation of the absolute emission probabilities of the other beta-particle emissions populating the excited nuclear levels of Rb-90:

Sum of direct gamma population of Rb-90 ground state
+ Pbeta(0,0) = 100%

(191.9(46))NF + 29(4)% = 100%

NF = 71(4)%/(191.9(46)) = 0.370 +/- 0.023

CONCLUDING REMARKS

The accurately-quoted half-life measurement of Carlson et al. dominates the analysis of such data by the Limitation of Relative Statistical Weight Method (LWM). Other known half-life determinations are both unsatisfactory and inaccurate. Under these circumstances, further measurements are recommended, if only to confirm the recommended value of (32.32 +/- 0.09) s.

The extremely comprehensive gamma-ray measurements of Duke et al. have been primarily adopted to derive the complex decay scheme of Kr-90, fortified by earlier equivalent studies of Mason and Johns. However, the gamma-ray and Rb-90 nuclear-level energies were adopted from the evaluation of Browne (available in ENSDF). Weighted-mean relative emission probabilities were calculated when deemed to be possible and appropriate, on the basis of the measurements of Wahlgren and Meinke, Mason and Johns, and Duke et al. Unweighted data were recommended for the relative emission probabilities of the 242.19- and 539.49-keV gamma rays. A normalisation factor of (0.370 +/- 0.023) was determined from the relative emission probabilities of the gamma transitions directly populating the ground and metastable states of Rb-90, and the absolute emission probability of the beta- particle populating the ground state as determined by Wohn et al. - direct beta- decay to Rb-90m was assumed to be zero on the basis of spin-parity considerations (0+ -> 3-). Seven gamma rays remained unplaced in the decay scheme out of a total of 102 gamma transitions attributed to the beta- decay of Kr-90.

Rudstam et al. carried out studies of the continuous gamma spectrum of Kr-90, in which the gamma data for Kr-90 were expressed in terms of twenty-two 100-keV gamma-energy increments from 0 to 2200 keV. No equivalent beta- spectrum was determined. However, the resulting total average <Egamma> of (770 +/- 80) keV was judged by Rudstam et al. to be probably too low owing to insufficient statistics. With a total average

<Egamma> of (1277 +/- 80) keV and total average <Ebeta> of (1325 +/- 75) keV derived from the discrete decay-data evaluation, the limited measurements of Rudstam et al. have been set aside. The singles gamma studies of Duke et al. appear to be reasonably comprehensive, although their quantification of the high-energy gamma rays should be viewed as potentially questionable. Thus, evaluated beta- and gamma data derived from the discrete gamma-ray measurements have been adopted, along with their resulting total average <Ebeta> and <Egamma> energies. Further studies are merited by Total Absorption Gamma-ray Spectroscopy (TAGS), and gamma-gamma and singles gamma spectroscopy in order to develop a better understanding of the decay scheme.

```
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END POINT(MEV)= 0.5270  SHAPE= 0  MEAN= 0.1676  INT= 0.0007
END POINT(MEV)= 0.7020  SHAPE= 0  MEAN= 0.2345  INT= 0.0016
END POINT(MEV)= 0.7810  SHAPE= 0  MEAN= 0.2659  INT= 0.0010
END POINT(MEV)= 0.9300  SHAPE= 0  MEAN= 0.3268  INT= 0.0003
END POINT(MEV)= 1.1670  SHAPE= 0  MEAN= 0.4271  INT= 0.0018
END POINT(MEV)= 1.3120  SHAPE= 0  MEAN= 0.4901  INT= 0.0066
END POINT(MEV)= 1.3230  SHAPE= 0  MEAN= 0.4949  INT= 0.0194
END POINT(MEV)= 1.9720  SHAPE= 0  MEAN= 0.7873  INT= 0.0029
END POINT(MEV)= 2.1350  SHAPE= 0  MEAN= 0.8625  INT= 0.0009
END POINT(MEV)= 2.2780  SHAPE= 0  MEAN= 0.9289  INT= 0.0216
END POINT(MEV)= 2.5040  SHAPE= 0  MEAN= 1.0344  INT= 0.0033
END POINT(MEV)= 2.6260  SHAPE= 0  MEAN= 1.0917  INT= 0.6200
END POINT(MEV)= 2.7180  SHAPE= 0  MEAN= 1.1350  INT= 0.0017
END POINT(MEV)= 2.9430  SHAPE= 0  MEAN= 1.2412  INT= 0.0002
END POINT(MEV)= 3.0050  SHAPE= 0  MEAN= 1.2705  INT= 0.0008
END POINT(MEV)= 3.4730  SHAPE= 0  MEAN= 1.4929  INT= 0.0055
END POINT(MEV)= 3.5680  SHAPE= 0  MEAN= 1.5382  INT= 0.0014
END POINT(MEV)= 3.6650  SHAPE= 0  MEAN= 1.5845  INT= 0.0033
END POINT(MEV)= 3.6940  SHAPE= 0  MEAN= 1.5983  INT= 0.0019
END POINT(MEV)= 3.7300  SHAPE= 0  MEAN= 1.6155  INT= 0.0009
END POINT(MEV)= 3.7920  SHAPE= 0  MEAN= 1.6451  INT= 0.0020
END POINT(MEV)= 4.0500  SHAPE= 0  MEAN= 1.7685  INT= 0.0053
END POINT(MEV)= 4.2840  SHAPE= 1  MEAN= 1.8806  INT= 0.0072
END POINT(MEV)= 4.4060  SHAPE= 1  MEAN= 1.9391  INT= 0.2900

   MEAN GAMMA ENERGY               =   1277.1791  KEV
   MEAN BETA- ENERGY               =   1324.9571  KEV
   BETA- + NEUTRINO ENERGY         =   3124.4599  KEV
   MEAN X-RAY ENERGY               =      0.4880  KEV
   MEAN AUGER ELECTRON ENERGY      =      0.3382  KEV
   MEAN CONVERSION ELECTRON ENERGY=       6.6653  KEV
   INTERNAL BREMSSTRAHLUNG ENERGY =       4.8207  KEV
   EFFECTIVE Q VALUE               =   4392.3040  KEV
   UNCERTAINTY IN EFFECTIVE Q (%) =       0.8526
   CALCULATED Q VALUE              =   4409.1305  KEV
   % DEVIATION                     =     -0.3831
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37-Rb- 90

E Browne	Nucl Data Sheets 82(1997)379
N R Johnson et al	Phys Rev 135(1964)B36 (T1/2, Egamma, Pgamma, Pbeta)
I Amarel et al	Phys Lett 24B(1967)402 (T1/2)
E A Zherebin et al	Sov J Nucl Phys 5(1967)1 (Egamma, Pgamma, Ebeta, Pbeta)
G C Carlson et al	Nucl Phys A125(1969)267 (T1/2)
J F Mason, M W Johns	Can J Phys 48(1970)2056 (Egamma, Pgamma, beta-gamma, gamma-gamma)
B Ehrenberg, S Amiel	Phys Rev C6(1972)618 (T1/2)
J R Clifford et al	Phys Rev C7(1973)2535 (Qbeta)
B Singh, M W Johns	Can J Phys 51(1973)865 (spin)
B Grapengiesser et al	J Inorg Nucl Chem 36(1974)2409 (T1/2)
F K Wohn et al	Phys Rev C13(1976)2492 (Pbeta(g.s.))
H Huang et al	Z Phys A282(1977)285 (Egamma, Pgamma, Ebeta, Pbeta)
R Stippler et al	Z Phys A284(1978)95 (Qbeta)
F K Wohn, W L Talbert Jr.	Phys Rev C18(1978)2328 (Qbeta)
K D Wunsch et al	Z Phys A288(1978)105 (Qbeta)
C Ekstrom et al	Phys Scripta 19(1979)516 (g.s. spin)
R Decker et al	Z Phys A294(1980)35 (Qbeta)
W L Talbert Jr. et al	Phys Rev C23(1981)1726 (Egamma, Pgamma)
G Rudstam et al	At Data Nucl Data Tables 45(1990)239 (av. Egamma)
H Mach et al	Nucl Phys A523(1991)197 (J(Pi))
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)
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)
G Audi, M Wang	Atomic mass evaluation, private communication, CSNSM, Orsay, France, April 2011 (Q-value)

A complex and comprehensive decay scheme has been derived from the gamma-ray measurements of Mason and Johns (1970), Huang et al. (1977) and Talbert Jr. et al. (1981), beta(gs) studies of Wohn et al. (1976) and Greenwood et al. (1996), and determination of the total average <Ebeta> and <Egamma> from gross beta-gamma and TAGS measurements by Rudstam et al. (1990) and Greenwood et al. (1997).

HALF-LIFE

LWM adopted to determine a recommended half-life value from the measurements of Amarel et al. (1967), Carlson et al. (1969) and Huang et al. (1977) of (157 +/- 3) secs.

Q-VALUE
Q(beta-)-value of 6584(7) keV was adopted from Audi and Wang (2011), which compares with a similar value of 6580(7) keV from an earlier published evaluation (Audi et al. (2003)).

GAMMA-RAY ENERGIES AND EMISSION PROBABILITIES
Energies
While the energies of the gamma-ray emissions have been directly measured by Johnson et al. (1964), Zherebin et al. (1967), Mason and Johns (1970), Huang et al. (1977) and Talbert Jr. et al. (1981), all recommended gamma-ray energies were calculated from the nuclear level energies of daughter Rb-90 as adopted from Browne (1997).

Emission Probabilities
The emission probabilities were determined from the measurements of Mason and Johns (1970), Huang et al. (1977), and Talbert Jr. et al. (1981). Weighted mean values were calculated for the relative emission probabilities of the 997.9-, 1060.7-, 1326.8-, 1892.4-, 2148.3-, 2207.6-, 2216.4-, 2239.9-, 2473.7-, 2688.4-, 3039.3-, 3148.7-, 3362.0-, 3383.4-, 3534.3-, 3814.7-, 4087.4-, 4135.6-, 4366.1-, 4646.4-, 4919.1-, 4974.0-, 5070.2-, 5187.5-, 5254.3- and 5333.2-keV gamma rays. All other gamma-ray emission probabilities were adopted from the more comprehensive set of data measured by Talbert Jr. et al. (1981). However, the emission probabilities of the 824.24- and 2980.5-keV gamma rays were subsequently adjusted from 0.52(4) and 0.24(5) to 0.72(6) and 0.21(5) respectively, to achieve population-depopulation balances for the 1655.92- and 2207.04-keV nuclear levels of Sr-90.

Seven gamma rays observed primarily by Talbert Jr. et al. (1981) with energies of 4061.7-, 4278.4-, 4332.14-, 4934.8-, 5007.7-, 5070.2- and 5299.5-keV could not be placed in the proposed decay scheme.

A reasonable segment of the gamma decay occurs via internal-pair formation for gamma-transition energies above 1022 keV (judged as significant above 1375 keV). This behaviour is not accommodated satisfactorily within the ENDF-B format by COGEND, and therefore the relevant gamma-ray energies and their internal-pair formation coefficients are listed below (Kibedi et al. (2008)):

Gamma energy (keV)	Internal-pair formation coefficient
1375.4(1)	0.0001578(23)
1665.6(1)	0.000128(2)
1892.4(1)	0.000256(4)
2139.5(2)	0.000376(6)
2497.3(1)	0.000548(8)
3304.0(1)	0.00084(2)
4135.6(1)	0.001213(17)

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 Browne (1997) and Q-value of 6584(7) keV (Audi and Wang (2011)) were used to determine the energies and uncertainties of the beta-particle transitions to the various levels.

Emission Probabilities
The beta-particle emission probabilities were calculated from gamma-ray energy balances. Although severely limited, recommended internal conversion coefficients were also adopted in this process whenever possible, as determined from the frozen orbital approximation of Kibedi et al. (2008) based on the theoretical model of Band et al. (2002) (also Raman et al. (2002)). Beta-particle emission probabilities of zero were assigned to the population of the 3954.33-, 3627.0-, 3555.84-, 3144.9-, 3032.87-, 2971.14-, 2927.71-, 2570.62-, 2497.31-, 2207.04- and 1655.92-keV nuclear levels of Sr-90, arising from the balanced population-population of these levels by the gamma-ray transitions. Furthermore, direct beta- population of the 2207.04- and 1655.92-keV nuclear levels of Sr-90 was judged to be zero on the basis of spin-parity considerations.

Greenwood et al. determined the spectral distributions of beta-intensities for a wide range of fission-product radionuclides, including the beta- decay characteristics of Rb-90g,m (Greenwood et al. (1997)). These studies for Rb-90g by means of Total Absorption Gamma-ray Spectroscopy (TAGS) result in the arbitrary introduction of nine 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 Rb-90g and the simulated spectra derived by Greenwood et al. (1997) from the ENSDF file of 1989.

Beta-particle energies and emission probabilities derived from the TAGS measurements of Greenwood et al. (1997) have been compared with the equivalent data derived from the extensive gamma singles spectral studies of Talbert Jr. et al. (1981). While this comparison shows reasonable overall agreement, there is a clear excess of beta energy below 1.3 MeV and above 5.7 MeV in the beta- data derived from Talbert Jr. et al. Thus, Pbeta(5752 keV) to the 831.68-keV nuclear level of Sr-90 as determined from the studies of Talbert Jr. et al. (1981) is a factor of two larger than the value derived by Greenwood et al. (1997).

Rudstam et al. carried out studies of the continuous beta- and gamma spectra of 114 short-lived fission products, including Rb-90g (Rudstam et al. (1990)). The resulting beta and gamma data for Rb-90g were expressed separately in terms of sixty-four 100-keV energy increments from 0 to 6400 keV, which were analysed as follows

gamma cut-off defined as 700 keV, below which gamma rays were not registered by NaI(Tl) spectrometer;
total average <Egamma> above cut-off = 1713 +/- 28 keV;
contribution to total average <Egamma> of gamma rays below

the cut-off energy was defined as zero;
therefore, total average gamma-ray energy <Egamma> = 1713 +/- 28 keV -> rounded-down to 1710 +/- 50 keV;
average number of gamma rays per decay = 0.80 +/- 0.02;
total average beta energy <Ebeta> = 2200 +/- 200 keV;
total average neutrino energy <Enu> = 2660 +/- 230 keV;
sum of 6570 +/- 310 keV.

Wohn et al. (1976) have undertaken measurements designed to determine the beta- branch to the ground state of Sr-90:

beta- transition direct to Sr-90 ground state = (37 +/- 5)%, with log ft = 7.21 +/- 0.06 (Wohn et al. (1976)).

This compares with a value of (32.8 +/- 3.4)% determined by means of total absorption gamma-ray spectroscopy (Greenwood et al (1996)). A value of (33 +/- 4)% was adopted in the evaluation, and provided the means of calculating the normalisation factor (NF) for the relative emission probabilities of the gamma transitions, along with the derivation of the absolute emission probabilities of the other beta-particle emissions populating the excited nuclear levels of Sr-90:

Sum of direct gamma population of Sr-90 ground state + Pbeta(0,0) = 100%
(167.928(1292))NF + 33(4)% = 100%
NF = 67(4)%/(167.928(1292)) = 0.399 +/- 0.024

CONCLUDING REMARKS
Some of the half-life studies highlighted problems in ensuring that only Rb-90g activity was being measured without the danger of contamination from other isomers (Johnson et al. (1964), Grapengiesser et al. (1974)). However, half-life determinations by Amarel et al. (1967), Carlson et al. (1969) and Huang et al. (1977) appear to be sound, and were used to obtain LWM-based value of (157 +/- 3) s.

The comprehensive gamma-ray measurements of Talbert Jr. et al. (1981) have been primarily adopted to derive the complex decay scheme of Rb-90g, fortified by the earlier equivalent studies of Mason and Johns (1970) and Huang et al. (1977). However, the gamma-ray and Sr-90 nuclear-level energies were adopted from the evaluation of Browne ((1997) available in ENSDF). Weighted-mean relative emission probabilities were calculated when deemed appropriate, on the basis of the measurements of Mason and Johns (1970), Huang et al. (1977) and Talbert Jr. et al. (1981); nevertheless, the majority of these data were adopted directly from the more detailed studies of Talbert Jr. et al. A normalisation factor of (0.399 +/- 0.024) was determined from the relative emission probabilities of the gamma transitions directly populating the ground state of Sr-90, and the absolute emission probability of the beta- particle populating the ground state as determined by Greenwood et al. (1996) and supported by the studies of Wohn et al. (1976). Seven gamma rays remained unplaced in the decay scheme out of a total of 95 gamma transitions observed by Talbert Jr. et al. (1981).

Greenwood et al. undertook systematic studies of the distributions of beta- intensities by means of Total Absorption

Gamma-ray Spectroscopy (TAGS), which included Rb-90g (Greenwood et al. (1997)). The resulting TAGS data listed in Table 2 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 (1960 +/- 190) keV and total average <Egamma> of (2270 +/- 240) keV. Rudstam et al. (1990) carried out studies of the continuous beta- and gamma spectra of Rb-90g, in which the beta- and gamma data for Rb-90g were expressed in terms of sixty-four energy increments of 100 keV each, ranging from 0 to 6400 keV. A total average <Ebeta> of (2200 +/- 200) keV and total average <Egamma> of (1710 +/- 50) keV were derived from these data, along with a total average <Enu> of (2660 +/- 230) keV, summing to a quoted Qbeta of (6570 +/- 310) keV. A Qbeta value of (6584 ± 7) keV has been recommended by Audi and Wang (2011), which differs by only 0.2% from the value derived by Rudstam et al. The total average <Egamma> calculated from the various discrete gamma-ray studies is (2014 +/- 120) keV, compared with a lower value of (1710 +/- 50) keV by Rudstam et al. and a higher value of (2270 +/- 240) keV from Greenwood et al. Under these mildly discrepant circumstances with respect to total average <Egamma>, further studies are merited by Total Absorption Gamma-ray Spectroscopy (TAGS), and gamma-gamma and singles gamma-ray spectroscopy to resolve such issues.

There are a number of significant differences between the complex decay schemes derived by means of singles gamma-ray spectroscopy (Talbert Jr. et al. (1981)) and the gross beta-gamma/TAGS measurements of Rudstam et al. (1990) and Greenwood et al. (1997). Various anomalies need to be addressed and resolved between the experimental techniques, particularly the disagreements in Pbeta for the 1157-, 1396-, 1634- (P), 2218-, 2734- (P), 3384- (P), 4692- and 5752-keV beta- emissions (in which "(P)" stands for the beta- population of a newly-proposed "pseudo-level" as specified by Greenwood et al.). Until these differences can be minimised and their impact on the decay scheme of Rb-90g quantified with confidence, the evaluator feels obliged to adopt and recommend a decay scheme based on the gamma-ray measurements of Mason and Johns (1970), Huang et al. (1977) and Talbert Jr. et al. (1981). The studies of Talbert Jr. et al. are particularly comprehensive and noteworthy, although their quantification of the many high-energy gamma rays should be viewed as potentially problematic.

The evaluated beta- and gamma data derived from the singles gamma-ray spectroscopic measurements have been adopted, along with a total average <Ebeta> of (1960 +/- 190) keV and total average <Egamma> of (2270 +/- 240) keV determined from the TAGS studies of Greenwood et al. Future emphasis should be placed on further gross beta-gamma and TAGS studies, along with comprehensive gamma-gamma and singles gamma-ray spectroscopy, in order to achieve a greater degree of agreement and consistency.

```
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 END POINT(MEV)= 1.1570  SHAPE= 1  MEAN= 0.4219  INT= 0.0381
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END POINT(MEV)= 1.5430  SHAPE= 2  MEAN= 0.6076  INT= 0.0075
END POINT(MEV)= 1.6100  SHAPE= 2  MEAN= 0.6370  INT= 0.0060
END POINT(MEV)= 1.6650  SHAPE= 2  MEAN= 0.6613  INT= 0.0034
END POINT(MEV)= 1.7940  SHAPE= 2  MEAN= 0.7185  INT= 0.0014
END POINT(MEV)= 1.9380  SHAPE= 1  MEAN= 0.7704  INT= 0.0260
END POINT(MEV)= 2.0030  SHAPE= 2  MEAN= 0.8123  INT= 0.0036
END POINT(MEV)= 2.2180  SHAPE= 1  MEAN= 0.8995  INT= 0.0880
END POINT(MEV)= 2.4350  SHAPE= 2  MEAN= 1.0094  INT= 0.0001
END POINT(MEV)= 2.4460  SHAPE= 2  MEAN= 1.0144  INT= 0.0006
END POINT(MEV)= 2.4480  SHAPE= 1  MEAN= 1.0067  INT= 0.0770
END POINT(MEV)= 2.5470  SHAPE= 2  MEAN= 1.0610  INT= 0.0035
END POINT(MEV)= 2.5650  SHAPE= 2  MEAN= 1.0693  INT= 0.0007
END POINT(MEV)= 3.2010  SHAPE= 1  MEAN= 1.3616  INT= 0.0565
END POINT(MEV)= 3.5450  SHAPE= 2  MEAN= 1.5281  INT= 0.0055
END POINT(MEV)= 3.9100  SHAPE= 2  MEAN= 1.7011  INT= 0.0002
END POINT(MEV)= 4.6920  SHAPE= 2  MEAN= 2.0740  INT= 0.0250
END POINT(MEV)= 5.7520  SHAPE= 2  MEAN= 2.5829  INT= 0.2620
END POINT(MEV)= 6.5840  SHAPE= 1  MEAN= 2.9819  INT= 0.3300

   MEAN GAMMA ENERGY                =   2014.0817  KEV
   MEAN BETA- ENERGY                =   2035.5740  KEV
   BETA- + NEUTRINO ENERGY          =   4613.6452  KEV
   MEAN X-RAY ENERGY                =      0.0042  KEV
   MEAN AUGER ELECTRON ENERGY       =      0.0026  KEV
   MEAN CONVERSION ELECTRON ENERGY=        0.3726  KEV
   INTERNAL BREMSSTRAHLUNG ENERGY =        8.7000  KEV
   EFFECTIVE Q VALUE                =   6584.0000  KEV
   UNCERTAINTY IN EFFECTIVE Q (%) =        0.1063
   CALCULATED Q VALUE               =   6628.1064  KEV
   % DEVIATION                      =     -0.6699
```

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

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 this summary section by Greenwood et al. (1997) estimate of (2270 +/- 240) keV.
Above total mean beta energy derived from discrete gamma-ray studies has been replaced in this summary section by Greenwood et al. (1997) value of (1960 +/- 190) keV.
Average antineutrino energy of (2353 +/- 310) 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.

38-Sr- 94

D Abriola, A A Sonzogni	Nucl Data Sheets 107(2006)2423
I Amarel et al	Phys Lett 24B(1967)402 (T1/2)
M I Macias-Marques	PhD thesis, Universite Paris-Sud , FRNC-TH-136(1971) (Qbeta, Pbeta (g.s.))
W Grimm, W Herzog	Z Phys 259(1973)67 (T1/2, Egamma, Pgamma, beta-gamma, gamma-gamma)
T Tamai et al	Inorg Nucl Chem Lett 9(1973)245 (T1/2, Egamma, Pgamma)
B Grapengiesser et al	J Inorg Nucl Chem 36(1974)2409 (T1/2)
G Engler et al	Phys Rev C19(1979)1948 (T1/2)
K Aleklett, G Rudstam	Nucl Sci Eng 80(1982)74 (average Ebeta)
Y Funakoshi et al	Ann Rep Res Reactor Inst, Kyoto Univ 15(1982)151 (Egamma, Pgamma, Pbeta, beta-, gamma-gamma)
K Okano et al	Ann Rep Res Reactor Inst, Kyoto Univ 16(1983)108 (T1/2)
Y Funakoshi et al	Nucl Phys A431(1984)461 (Egamma, Pgamma, Pbeta, beta-, gamma-gamma)
K Okano et al	Appl Radiat Isot 37(1986)521 (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)
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)
G Audi, M Wang	Atomic mass evaluation, private communication, CSNSM, Orsay, France, April 2011 (Q-value)

The decay scheme has been derived from the gamma-ray measurements of Grimm and Herzog, Tamai et al. and Funakoshi et al., and determination of the total average <Egamma> and <Ebeta> from continuous beta-gamma spectral measurements by Rudstam et al. and Total Absorption Gamma-ray Spectroscopy studies (TAGS) of Greenwood et al. (1997).

HALF-LIFE
Determined from the measurements of Amarel et al., Grimm and Herzog, Grapengiesser et al., Engler et al., and Okano et al. (1986). A value of (75.3 +/- 0.2) secs has been adopted from consideration of these measurements.

Q-VALUE
Q(beta-) value of 3510(8) keV was adopted from Audi and Wang, which compares with a value of 3508(8) keV from an earlier published evaluation (Audi et al.).

GAMMA-RAY ENERGIES AND EMISSION PROBABILITIES

Energies

While the energies of a limited number of the gamma-ray emissions have been measured by Grimm and Herzog, and Tamai et al., and somewhat more by Funakoshi et al. (1982 and 1984), all recommended gamma-ray energies were calculated from the nuclear level energies of daughter Y-94 as adopted from Abriola and Sonzogni.

Emission Probabilities

Relative emission probabilities were determined from the gamma singles studies of Grimm and Herzog, Tamai et al., and Funakoshi et al. However, the measurements of Tamai et al. deviate significantly from the equivalent data of Grimm and Herzog, and Funakoshi et al., and were set aside from weighted mean calculations for the 621.7-, 703.9-, 723.8- and 806.0-keV gamma rays. Efforts were also made to accommodate the existence of the high-energy, low-intensity beta- emissions populating the 723.80- and 621.70-keV nuclear levels of Y-94, as implied from the TAGS studies of Greenwood et al. (1997) - thus, modest and somewhat arbitrary adjustments were implemented with respect to the relative emission probabilities of the gamma rays with energies of 621.7- (adjusted from 2.13(13) to 2.25(15)), 703.9- (adjusted from 2.24(13) to 2.20(15)), 723.8- (adjusted from 2.57(14) to 2.61(14)), and 806.0-keV (adjusted from 1.87(10) to 1.81(15)). All other gamma-ray emission probabilities were adopted from the set of data measured by Funakoshi et al.

A reasonable segment of the gamma decay occurs via internal-pair formation for gamma-transition energies above 1022 keV (judged as significant above 1427 keV). This behaviour is not accommodated satisfactorily within the ENDF-B format by COGEND, and therefore the relevant gamma-ray energies and their internal-pair formation coefficients are listed below:

Gamma energy (keV)	Internal-pair formation coefficient
1427.7(1)	0.000191(3)
1751.3(2)	0.000441(7)
2063.0(3)	0.000667(10)
2182.4(2)	0.000749(11)
2246.1(3)	0.000791(11)

Rudstam et al. carried out studies of the continuous beta- and gamma spectra of 114 short-lived fission products, including Sr-94. The resulting beta- and gamma data for Sr-94 were expressed in terms of thirty-six 100-keV gamma-energy increments from 0 to 3600 keV, which were analysed as follows:

gamma cut-off defined as 100 keV, below which gamma rays were not registered by NaI(Tl) spectrometer;
total average <Egamma> above cut-off = 1451 +/- 4 keV;
contribution to total average <Egamma> of gamma rays below the cut-off energy was defined as zero;
therefore, total average gamma-ray energy <Egamma> = 1451 +/- 4 keV -> rounded-down to 1450 +/- 10 keV;
average number of gamma rays per decay = 1.11 +/- 0.01;

total average beta energy <Ebeta> = 880 +/- 30 keV;
total average neutrino energy <Enu> = 1250 +/- 80 keV;
sum of 3580 +/- 80 keV.

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 Abriola and Sonzogni and Q-value of 3510(8) keV (Audi and Wang) were used to determine the energies and uncertainties of the beta-particle transitions to the various levels.

Emission Probabilities
The beta-particle emission probabilities were calculated from gamma-ray energy balances. Whenever possible, recommended internal conversion coefficients were adopted in this process, as determined from the frozen orbital approximation of Kibedi et al. based on the theoretical model of Band et al. and Raman et al. A beta-particle emission probability of zero was assigned to the population of the 906.91-keV nuclear level of Y-94, arising from the balanced population-population of this level by the gamma-ray transitions. Furthermore, direct beta-population of ground state of Y-94 was judged to be zero on the basis of spin-parity considerations.

Greenwood et al. determined the spectral distributions of beta-intensities for a wide range of fission-product radionuclides, including the beta- decay characteristics of Sr-94 (Greenwood et al. (1997)). These studies for Sr-94 by means of Total Absorption Gamma-ray Spectroscopy (TAGS) result in the arbitrary introduction of twelve additional nuclear levels (defined as "pseudolevels" because of the inherent uncertainty in quantifying their energies). Nevertheless, there is reasonable overall agreement between the TAGS measurements for Sr-94 and the simulated spectra derived by Greenwood et al. from the ENSDF file of 1989.

Beta-particle energies and emission probabilities derived from the TAGS measurements of Greenwood et al. (1997) have been compared with the equivalent data derived from the gamma singles spectral studies. While this comparison confirms that the beta-decay of Sr-94 occurs primarily through the 1427.71-keV nuclear level of Y-94, there is a clear deficit of beta energy above this level in the beta- data determined from the gamma singles measurements.

Greenwood et al. used their TAGS measurements to determine a beta- branch of 1.8(36)% directly to the ground state of Y-94 (Greenwood et al. (1996)). However, this value with such a large uncertainty was deemed to be effectively zero on the basis of spin-parity considerations (0+ -> 2-). The normalisation factor (NF) for the relative emission probabilities of the gamma transitions and the derivation of the absolute emission probabilities of the beta-particle emissions populating the excited nuclear levels of Y-94 was calculated from the sum of all the gamma transitions that populated the ground state of Y-94:

Sum of direct gamma population of Y-94 ground state

+ Pbeta(0,0) = 100%
(105.91(24))NF + 0% = 100%
NF = 100%/(105.91(24)) = 0.9442 +/- 0.0021

CONCLUDING REMARKS

Some half-life studies originated from the same laboratory (Tamai et al., Okano et al. (1983 & 1986)), and therefore their most recently published half-life was adopted to avoid duplication within the weighted-mean analysis procedures. Thus, the half-life measurements of Amarel et al., Grimm and Herzog, Grapengiesser et al., and Okano et al. (1986) were judged to be sound, and were used to obtain a weighted-mean value of (75.3 +/- 0.2) s.

The gamma-ray measurements of Funakoshi et al. have been primarily adopted to derive the proposed decay scheme of Sr-94, fortified by the earlier studies of Grimm and Herzog and Tamai et al. However, the gamma-ray and Y-94 nuclear-level energies were adopted from the evaluation of Abriola and Sonzogni (available in ENSDF). Weighted-mean relative emission probabilities were calculated when deemed to be appropriate, based on the measurements of Grimm and Herzog, Tamai et al., and Funakoshi et al. A normalisation factor of (0.9442 +/- 0.0021) was determined from the relative emission probabilities of the gamma transitions directly populating the ground state of Sr-94, assuming no direct beta- decay to the ground state of Y-94 on the basis of spin-parity considerations (0+ -> 2-).

Greenwood et al. undertook systematic studies of the distributions of beta- intensities by means of Total Absorption Gamma-ray Spectroscopy (TAGS), including Sr-94 (Greenwood et al. (1997)). The resulting TAGS data listed in Table 7 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 (841 +/- 62) keV and total average <Egamma> of (1420 +/- 80) keV. Rudstam et al. carried out studies of the continuous beta- and gamma spectra of Sr-94, in which the beta- and gamma data for Sr-94 were expressed in terms of thirty-six energy increments of 100 keV each, ranging from 0 to 3600 keV. A total average <Ebeta> of (880 +/- 30) keV and total average <Egamma> of (1450 +/- 10) keV were derived from these data, along with a total average <Enu> of (1250 +/- 80) keV, to sum to a quoted Qbeta of (3580 +/- 80) keV. However, a Qbeta value of (3510 +/- 8) keV has been recommended by Audi and Wang (2011), which differs by 2% from the value derived by Rudstam et al. The average <Egamma> calculated from the various discrete gamma-ray studies is (831 +/- 4) keV, comparing well with (880 +/- 30) keV of Rudstam et al. and (841 +/- 62) keV of Greenwood et al., and implying that the discrete gamma measurements have adequately addressed and avoided the possibility of Pandemonium.

There are a number of differences between the decay scheme derived by means of singles gamma-ray spectroscopy (Funakoshi et al.) and the beta-gamma/TAGS measurements of Rudstam et al. and Greenwood et al. (1997). Anomalies arise between the experimental techniques, particularly the disagreement in Pbeta for the 1427.71-keV beta- emission and the possible existence of a significant number of low-intensity beta- emissions above

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1500 keV as proposed by Greenwood et al. (1997). Until these differences can be resolved and their impact on the decay scheme of Sr-94 quantified with confidence, the evaluator feels obliged to adopt and recommend a decay scheme based on the gamma-ray measurements of Grimm and Herzog, Tamai et al. and Funakoshi et al.

Evaluated beta- and gamma data derived from the singles gamma-ray spectroscopic measurements have been adopted, along with the resulting total average <Ebeta> and <Egamma> energies determined from these discrete decay data. Further studies are merited by Total Absorption Gamma-ray Spectroscopy (TAGS), and gamma-gamma and singles gamma-ray spectroscopy to resolve the existing anomalies associated with proposed Y-94 nuclear levels at approximately 1600 keV and above. Emphasis should also be placed on comprehensive gamma-gamma and singles gamma-ray spectroscopy to achieve a higher degree of consistency with the TAGS data.

```
   MEAN BETA- ENERGIES:-
END POINT(MEV)= 0.5400  SHAPE= 0  MEAN= 0.1717  INT= 0.0008
END POINT(MEV)= 1.1370  SHAPE= 1  MEAN= 0.4125  INT= 0.0011
END POINT(MEV)= 1.3280  SHAPE= 0  MEAN= 0.4951  INT= 0.0076
END POINT(MEV)= 2.0730  SHAPE= 1  MEAN= 0.8310  INT= 0.0019
END POINT(MEV)= 2.0820  SHAPE= 0  MEAN= 0.8352  INT= 0.9826
END POINT(MEV)= 2.7860  SHAPE= 1  MEAN= 1.1635  INT= 0.0029
END POINT(MEV)= 2.8880  SHAPE= 1  MEAN= 1.2116  INT= 0.0029

   MEAN GAMMA ENERGY              =   1430.6768  KEV
   MEAN BETA- ENERGY              =    831.0280  KEV
   BETA- + NEUTRINO ENERGY        =   2077.9761  KEV
   MEAN X-RAY ENERGY              =      0.0022  KEV
   MEAN AUGER ELECTRON ENERGY     =      0.0013  KEV
   MEAN CONVERSION ELECTRON ENERGY=      0.2493  KEV
   INTERNAL BREMSSTRAHLUNG ENERGY =      2.4526  KEV
   EFFECTIVE Q VALUE              =   3510.0000  KEV
   UNCERTAINTY IN EFFECTIVE Q (%) =      0.2279
   CALCULATED Q VALUE             =   3508.9057  KEV
   % DEVIATION                    =      0.0312
```

53-I -136

A A Sonzogni	Nucl Data Sheets 95(2002)837
N R Johnson, G D O'Kelley	Phys Rev 114(1959)279 (T1/2, Egamma, Pgamma, Pbeta)
L C Carraz et al	Nucl Phys A158(1970)403 (T1/2, Egamma, Pgamma)
H N Erten et al	J Inorg Nucl Chem 33(1971)4005 (Egamma, Pgamma)
A Lundan	Z Phys 242(1971)107 (T1/2, Egamma, Pgamma)
E Achterberg et al	Phys Rev C5(1972)1759 (alpha(K), multipolarity)
F P Larkins	At. Data Nucl. Data Tables 20(1977)311 (Eeb)
W R Western et al	Phys Rev C15(1977)1822 (T1/2, Egamma, Pgamma)
U Keyser et al	Proc 6th Int Conf Atomic Masses and Fundamental Constants, Plenum Press, New York (1980)485 (Qbeta)
K Aleklett, G Rudstam	Nucl Sci Eng 80(1982)74 (average Ebeta)
G Rudstam et al	At Data Nucl Data Tables 45(1990)239 (average Egamma, Ebeta, Enu)
P F Mantica et al	Phys Rev C43(1991)1696 (2582-, 4320-keV E0 transitions)
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)
H von Garrel et al	Phys Rev C73(2006)054315 (nuclear levels)
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)
D Savran et al	Phys Rev C84(2011)024326 (nuclear levels)

A complex and comprehensive decay scheme has been derived from the gamma-ray measurements of Johnson and O'Kelley, Carraz et al., Erten et al., Lundan, and Western 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

LWM adopted to determine a recommended half-life value from the measurements of Johnson and O'Kelley, Carraz et al., Lundan, and Western et al. A value of (83.5 +/- 1.5) s has been adopted.

Q-VALUE

Q(beta-)value of 6857(19) keV was adopted from Audi and Wang, which compares with 6930(50) keV from an earlier published evaluation (Audi et al.) and a previously measured value of 6925(70) keV by Keyser et al.

GAMMA-RAY ENERGIES AND EMISSION PROBABILITIES

Energies

While the energies of the gamma-ray emissions have been measured by Johnson and O'Kelley, Carraz et al., Erten et al., Lundan, and Western et al., all of the recommended gamma-ray energies were calculated from the nuclear level energies of daughter Xe-136 as adopted from Sonzogni. Additional nuclear levels were introduced from the gamma-ray placements proposed by Western et al. (particularly for the decay of the higher-energy gamma rays directly to the ground state), which were supported by the nuclear resonance fluorescence studies of von Garrel et al. and Savran et al.

Population of the 2608.43-keV nuclear level of Xe-136 necessitated the introduction of a series of depopulating gamma transitions that have been observed in the equivalent beta decay of I-136m to be 346.9-, 482.8-, 716.7- and 914.0-keV gamma rays, followed by the population of the 2261.53- and 1891.70-keV nuclear levels, and subsequent depopulation by means of the 396.83- and 197.32-keV gamma transitions. A similar problem arises as a consequence of the observed gamma population of the 1694.39-keV nuclear level, for which a 381.36-keV gamma transition was introduced into the proposed decay scheme to assure depopulation from this level. These unobserved gamma rays were incorporated into the decay scheme on the basis of known nuclear-level energies and the emission probabilities of the various proposed gamma transitions feeding these levels.

Emission Probabilities

The emission probabilities were determined from the gamma-ray measurements of Carraz et al., Erten et al. and Western et al. Equivalent gamma-ray emission probabilities determined by Johnson and O'Kelley (inadequate energy resolution) and Lundan (no assigned uncertainties) were not considered in these quantitative assessments. Weighted mean values were calculated for the relative emission probabilities of the 1246.8-, 1321.1-, 2289.5-, 2414.7-, 2634.2-, 2869.0-, 2956.3- and 3141.0-keV gamma rays, although a large majority of the gamma-ray emission probabilities were adopted from the significantly more comprehensive set of data measured by Western et al. However, the relative emission probabilities of the 431.29-, 812.65- and 1962.2-keV gamma rays were subsequently adjusted from 0.30(10), 1.3(4) and 3.42(19) to 0.32(10), 1.65(5) and 3.73(21), respectively, to achieve population-depopulation balances for the 2125.68- and 3275.22-keV nuclear levels of Xe-136.

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. and Mantica Jr. et al. provided supportive evidence for a limited number of the gamma transitions. Gamma rays with (M1 + E2) multipolarities and energies below 500 keV were arbitrarily assigned mixing ratios of 1.0 (50%M1 + 50%E2) in order to calculate more reasonably realistic relative transition probabilities from their recommended relative emission probabilities. A significant number of gamma transitions undergo decay via internal-pair formation for gamma rays with energies above 1022 keV. Appropriate internal-pair formation coefficients were determined as described by Kibedi et al., and are listed below.

Gamma Energy (keV)	IPF Coefficient	Gamma Energy (keV)	IPF Coefficient
1178.9(2)	0.00000428(7)	2828.7(3)	0.001118(16)
1246.8(1)	0.00001294(19)	2849.43(10)	0.000696(10)
1313.027(10)	0.0000247(4)	2869.00(11)	0.000705(10)
1321.13(7)	0.0000251(4)	2979.07(22)	0.000753(11)
1583.6(2)	0.0001103(16)	3141.0(2)	0.001276(18)
1709.5(1)	0.0001624(23)	3195.4(3)	0.000845(12)
1819.9(2)	0.000465(7)	3211.91(20)	0.000852(12)
1962.2(2)	0.000569(8)	3482.5(3)	0.000960(14)
2039.3(2)	0.000582(9)	3674.4(3)	0.001037(15)
2289.53(9)	0.000436(7)	4269.32(9)	0.001253(18)
2414.74(12)	0.000496(7)	4454.07(17)	0.00182(3)
2634.16(7)	0.000599(9)	5217.8(4)	0.001543(22)
2657.9(4)	0.000610(9)		

Conversion-electron spectral studies by Mantica et al. provide evidence for the existence of 0+ nuclear levels at 2582.4 and 4320 keV. Various K- and L-electron intensities were measured, and suggest that both levels decay directly and fully to the ground state of Xe-136 by means of E0 transitions. Conversion-electron energies for both of these E0 transitions were determined from the evaluated gamma-ray energies and electron binding energies tabulated by Larkins. Their total transition probabilities have been identified solely with conversion electrons, and there are no gamma-ray emissions.

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 Sonzogni and Q-value of 6857(19) keV (Audi and Wang) were used to determine the energies and uncertainties of the beta-particle transitions to the various levels.

Emission Probabilities

The 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. and Raman et al. Beta-particle emission probabilities of zero were assigned to the population of the 2608.43-, 2582.4-, 2125.68- and 1694.39-keV nuclear levels of Xe-136, arising from the balanced population-depopulation of these levels by the relevant gamma transitions. Direct beta- population of the 3275.22-, 2261.53-, 1891.70- and 0.0-keV nuclear levels of Xe-136 were also judged to be zero on the basis of either spin-parity considerations, or the extremely low-intensity and non-existent beta- emissions observed to populate the 0+ levels (as applied to the ground state in alignment with estimates for the 4320- and 2582.4-keV nuclear levels).

The gamma-ray spectroscopic measurements of Johnson and O'Kelley, Carraz et al., Erten et al., Lundan, and Western et al. provided guidance concerning the beta- branch directly to the ground state of Xe-136. All of these studies suggested estimates for the upper limit of this important decay parameter:

Johnson and O'Kelley	- defined as being <= 6%,
Carraz et al.	- defined as being <= 1%,
Erten et al.	- judged to be zero,
Lundan	- judged to be of low intensity, or doubtful existence (zero), and
Western et al.	- defined as being < 2.0%.

Their reasonable agreement constitutes support for the adoption of a recommended beta- branch to the ground state of zero (0.0%).

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 and Rudstam). The OSIRIS on-line-isotope separator was used to study both I-136 and I-136m - a total average <Ebeta> value of 1970(80) keV was derived for I-136 (half-life of 83 sec), with total average experimental <Ebeta> to Q(beta) ratio of 0.281. Rudstam et al. measured the continuous beta- and gamma spectra of 114 short-lived fission products, including I-136 (Rudstam et al.). The resulting beta and gamma data for I-136 were expressed as follows:

gamma cut-off defined as 800 keV, below which gamma rays were not registered by NaI(Tl) spectrometer;
total average <Egamma> above cut-off = 1489 +/- 85 keV;
contribution to total average <Egamma> of gamma rays below the cut-off energy was defined as 28 +/- 1 keV;
therefore, total average gamma-ray energy <Egamma> = 1517 +/- 85 keV -> rounded-up to 1520 +/- 160 keV;
average number of gamma rays per decay = 0.93 +/- 0.06;
total average beta energy <Ebeta> = 1960 +/- 30 keV;
total average nu energy <Enu> = 2550 +/- 90 keV;
sum of 6030 +/- 180 keV.

A value of zero was adopted for the Pbeta emission directly to the ground state of Xe-136, based on the observed beta- population of other 0+ nuclear levels (0.00010(3)% for the 4320-keV level, and 0.00% for the 2582.4-keV level) and the upper limits estimated by Johnson and O'Kelley, Carraz et al., Erten et al., Lundan, and Western et al. The normalisation factor (NF) for the relative emission probabilities of the gamma transitions was calculated by summing the gamma population directly to the Xe-136 ground state (defined as 100%), and this value was also used to derive the absolute emission probabilities of the other beta-particle emissions populating the excited nuclear levels of Xe-136:

Sum of direct gamma population of Xe-136 ground state = 100%
(147.6(12))NF = 100%
NF = 100%/(147.6(12)) = 0.678 +/- 0.006

CONCLUDING REMARKS

A recommended half-life of (83.5 +/- 1.5) s was calculated from the measurements of Johnson and O'Kelley, Carraz et al., Lundan, and Western et al.

The comprehensive gamma-ray measurements of Western et al. have been primarily adopted to derive the complex decay scheme of I-136, fortified by the earlier equivalent studies of Carraz et al., Erten et al., and Lundan. However, the Xe-136 nuclear-level energies were adopted from the evaluation of Sonzogni (available in ENSDF), and have been used to calculate the recommended gamma-ray energies. While weighted-mean relative emission probabilities were calculated when deemed appropriate on the basis of the measurements of Carraz et al., Erten et al., and Western et al., the majority of these data were adopted directly from the detailed studies of Western et al. A normalisation factor of 0.678 +/- 0.006 was determined from the relative emission probabilities of those gamma transitions populating the ground state of Xe-136, and an assumed absolute emission probability of zero for direct beta- population of the ground state. The recommended decay scheme consists of 51 beta-emissions and 116 gamma transitions (of which two are identified as fully converted E0 transitions with Pgamma values of zero).

Rudstam et al. carried out studies of the continuous beta- and gamma spectra of I-136, in which the beta- and gamma data for I-136 were expressed in terms of sixty energy increments of 100 keV each, ranging from 0 to 6000 keV. A total average <Ebeta> of 1960 +/- 30 keV and total average <Egamma> of 1520 +/- 160 keV were derived from these data, along with a total average <Enu> of 2550 +/- 90 keV, and summing to a quoted Qbeta of 6030 +/- 180 keV. Rudstam recommended that the total average <Egamma> value be significantly modified to (2394 +/- 50) keV in December 1990 during the preparation of the JEF-2.2 decay-data library, and this value was adjusted further to (2349 +/- 35) keV for JEFF-3.1.1. A Qbeta value of (6857 +/- 19) keV has been recommended by Audi and Wang (2011), which conflicts with the initial value derived by Rudstam et al. Also, the total average <Egamma> calculated from the discrete gamma studies is (2482 +/- 40) keV compared with the earlier value of (1520 +/- 160) keV from Rudstam et al., implying that the former has better addressed any possibility of Pandemonium.

There are a number of differences between the complex decay schemes derived by means of singles gamma-ray spectroscopy (Western et al.) and the total beta-gamma spectral measurements of Rudstam et al. Until these conflicting anomalies can be minimised and their impact on the decay scheme of I-136 quantified with confidence, the evaluator feels obliged to recommend a decay scheme based on the gamma-ray measurements of Western et al. The studies of Western et al. are particularly comprehensive and noteworthy, although their quantification of the high-energy gamma rays should be viewed as potentially questionable. Thus, evaluated beta- and gamma data derived from the discrete gamma-ray measurements have been adopted, in conjunction with their resulting total average <Ebeta> and <Egamma> energies. Further emphasis should be placed on gross beta-gamma and TAGS studies, along with comprehensive gamma-gamma and singles gamma-ray spectroscopic measurements, to achieve a greater degree of agreement and consistency.

```
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   END POINT(MEV)= 0.2330   SHAPE= 0   MEAN= 0.0648   INT= 0.0054
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END POINT(MEV)= 0.6570  SHAPE= 1  MEAN= 0.2102  INT= 0.0001
END POINT(MEV)= 0.6870  SHAPE= 1  MEAN= 0.2215  INT= 0.0001
END POINT(MEV)= 0.7310  SHAPE= 1  MEAN= 0.2382  INT= 0.0009
END POINT(MEV)= 0.7430  SHAPE= 1  MEAN= 0.2428  INT= 0.0007
END POINT(MEV)= 0.7530  SHAPE= 1  MEAN= 0.2466  INT= 0.0024
END POINT(MEV)= 0.8040  SHAPE= 1  MEAN= 0.2664  INT= 0.0016
END POINT(MEV)= 0.8440  SHAPE= 1  MEAN= 0.2821  INT= 0.0002
END POINT(MEV)= 0.8890  SHAPE= 1  MEAN= 0.2999  INT= 0.0001
END POINT(MEV)= 0.9860  SHAPE= 1  MEAN= 0.3388  INT= 0.0012
END POINT(MEV)= 1.0250  SHAPE= 1  MEAN= 0.3547  INT= 0.0010
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END POINT(MEV)= 1.2490  SHAPE= 1  MEAN= 0.4479  INT= 0.0024
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END POINT(MEV)= 1.6390  SHAPE= 1  MEAN= 0.6161  INT= 0.0008
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END POINT(MEV)= 1.9100  SHAPE= 1  MEAN= 0.7362  INT= 0.0022
END POINT(MEV)= 1.9680  SHAPE= 1  MEAN= 0.7622  INT= 0.0015
END POINT(MEV)= 1.9930  SHAPE= 1  MEAN= 0.7734  INT= 0.0002
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END POINT(MEV)= 2.1270  SHAPE= 1  MEAN= 0.8337  INT= 0.0003
END POINT(MEV)= 2.1340  SHAPE= 1  MEAN= 0.8369  INT= 0.0001
END POINT(MEV)= 2.1460  SHAPE= 1  MEAN= 0.8423  INT= 0.0005
END POINT(MEV)= 2.2150  SHAPE= 1  MEAN= 0.8735  INT= 0.0018
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END POINT(MEV)= 3.0630  SHAPE= 1  MEAN= 1.2625  INT= 0.0018
END POINT(MEV)= 3.6450  SHAPE= 1  MEAN= 1.5329  INT= 0.0023
END POINT(MEV)= 3.8780  SHAPE= 1  MEAN= 1.6415  INT= 0.0009
END POINT(MEV)= 3.9880  SHAPE= 1  MEAN= 1.6929  INT= 0.0480
END POINT(MEV)= 4.0080  SHAPE= 1  MEAN= 1.7022  INT= 0.0114
END POINT(MEV)= 4.2230  SHAPE= 1  MEAN= 1.8026  INT= 0.3530
END POINT(MEV)= 4.2970  SHAPE= 1  MEAN= 1.8372  INT= 0.0255
END POINT(MEV)= 4.4420  SHAPE= 1  MEAN= 1.9050  INT= 0.0610
END POINT(MEV)= 4.5670  SHAPE= 1  MEAN= 1.9635  INT= 0.1040
END POINT(MEV)= 5.5440  SHAPE= 1  MEAN= 2.4206  INT= 0.2780

   MEAN GAMMA ENERGY               =   2481.8347  KEV
   MEAN BETA- ENERGY               =   1867.9265  KEV
   BETA- + NEUTRINO ENERGY         =   4373.4176  KEV
   MEAN X-RAY ENERGY               =      0.0898  KEV
   MEAN AUGER ELECTRON ENERGY      =      0.0247  KEV
   MEAN CONVERSION ELECTRON ENERGY=       2.2576  KEV
   INTERNAL BREMSSTRAHLUNG ENERGY =       7.8715  KEV
   EFFECTIVE Q VALUE               =   6857.0000  KEV
   UNCERTAINTY IN EFFECTIVE Q (%) =       0.2771
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```
CALCULATED Q VALUE              =   6857.6245  KEV
% DEVIATION                     =     -0.0091
```

53-I -136m

A A Sonzogni	Nucl Data Sheets 95(2002)837
L C Carraz et al	Nucl Phys A158(1970)403 (T1/2, Egamma, Pgamma)
H N Erten et al	J Inorg Nucl Chem 33(1971)4005 (T1/2, Egamma, Pgamma)
A Lundan	Z Phys 242(1971)107 (T1/2, Egamma, Pgamma)
E Achterberg et al	Phys Rev C5(1972)1759 (alpha(K), multipolarity)
W R Western et al	Phys Rev C15(1977)1822 (T1/2, Egamma, Pgamma)
U Keyser et al	Proc 6th Int Conf Atomic Masses and Fundamental Constants, Plenum Press, New York (1980)485 (Qbeta)
K Aleklett, G Rudstam	Nucl Sci Eng 80(1982)74 (average Ebeta)
G Rudstam et al	At Data Nucl Data Tables 45(1990)239 (average Egamma, Ebeta, Enu)
P F Mantica et al	Phys Rev C43(1991)1696 (2582-, 4320-keV E0 transitions)
H Mach, B Fogelberg	Physica Scripta T56(1995)270 (level lifetimes)
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)
G Audi, M Wang	Atomic mass evaluation, private communication, CSNSM, Orsay, France, April 2011 (Q-value)

A complex and comprehensive decay scheme has been derived from the gamma-ray measurements of Carraz et al., Erten et al., Lundan, and Western 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
LWM adopted to determine a recommended half-life value from the measurements of Carraz et al., Erten et al., Lundan, and Western et al. of (47 +/- 1) s.

Q-VALUE
Q(beta-)-value of 7500(110) keV was adopted from Audi and Wang (Q(beta-)-value for I-136 ground state of 6857(19) keV, and nuclear-level energy of 640(110) keV for I-136m), which compares with 7580(130) keV from an earlier published evaluation (Audi et al.) and a previously measured value of 7565(120) keV by Keyser et al.

GAMMA-RAY ENERGIES AND EMISSION PROBABILITIES
Energies
While the energies of the gamma-ray emissions have been measured by Carraz et al., Erten et al., Lundan, and Western et al., all

of the recommended gamma-ray energies were calculated from the nuclear level energies of daughter Xe-136 as adopted from Sonzogni. Additional nuclear levels were introduced on the basis of the extensive gamma-ray measurements of Western et al. (identified with the introduction of the 682.7-, 1686.1-, 1689.0-, 1738.1-, 2427.8-, 3132.1-, 3489.4-, 3925.0-, 3967.8- and 4873.5-keV gamma rays into the proposed decay scheme).

Emission Probabilities

The emission probabilities were determined from the measurements of Carraz et al., Erten et al., Lundan, and Western et al. Weighted mean values were calculated for the relative emission probabilities of the 197.32-, 369.83- and 381.36-keV gamma rays. All other gamma-ray emission probabilities were adopted from the more comprehensive set of data measured by Western et al.
Some of the gamma rays observed by Western et al. could not be identified unambiguously with either I-136 or I-136m beta decay. The relative emission probabilities of such unplaced gamma emissions were quantified and normalised by Western et al. in terms of I-136 (defined by the authors as the 83.5-sec isomer). However, some of these unclassified gammas have now been incorporated into the proposed decay scheme of the 47-sec metastable state (I-136m). As recommended by Western et al., and in order to maintain internal consistency within this specific data set, these particular relative emission probabilities have been adjusted by a multiplication factor of 0.733 so as to define values relative to the 1313.027-keV gamma ray of the 47-sec isomer. Similar adjustments have been made in this evaluation to the relative gamma-ray emission probabilities identified with the beta decay of both I-136 and I-136m: 197.32-, 346.9-, 369.83-, 381.36-, 482.8-, 716.7- and 914.0-keV gamma rays. The 431.29-, 812.65- and 1313.027-keV gamma rays are also emitted by I-136 and I-136m, but their relative emission probabilities were separately quantified by Western et al. for both isomers, and require no further adjustment.

Adjustments to relative gamma-ray emission probabilities determined by Western et al. (relative to 1313.027-keV gamma transition which Western et al. defined as 1000):

1. Previously unclassified - now identified with I-136m:

Gamma Energy (keV)	Original P(rel) (Western et al.)	Adjusted P(rel)
682.7(3)	2.8(4)	2.1(3)
1686.1(3)	4.6(5)	3.4(4)
1689.0(3)	3.9(5)	2.9(4)
1738.1(2)	2.4(4)	1.8(3)
2427.8(3)	2.7(4)	2.0(3)
3132.1(5)	0.73(15)	0.54(11)
3489.4(5)	0.70(12)	0.51(9)
3626.3(4)	2.5(2)	1.8(2)
3925.0(5)	1.21(19)	0.89(14)
3967.8(5)	1.41(18)	1.03(13)
4873.5(5)	0.28(12)	0.21(9)

2. Previously classified as I-136m beta decay only, but now evaluated as within decay schemes of the beta decay of both

I-136 and I-136m:

Gamma Energy (keV)	Original P(rel) identified only with I-136m	Evaluated P(rel) identified with I-136	Adjusted P(rel) I-136	Adjusted P(rel) I-136m
197.32(2)	783.(45)	1.4(1)	1.0(1)	782.(45)
346.9(1)	30.1(18)	1.2(1)	0.9(1)	29.2(17)
369.83(9)	175.(10)	1.2(1)	0.9(1)	174.(10)
381.36(2)	998.(55)	17.2(13)	12.6(10)	985.(54)
482.8(1)	17.5(9)	0.7(1)	0.5(1)	17.0(9)
716.7(1)	9.8(7)	0.4(1)	0.3(1)	9.5(7)
914.0(1)	35.(2)	1.4(1)	1.0(1)	34.6(20)

Population-depopulation balance requirements for the 2125.68-, 1694.386- and 1313.027-keV nuclear levels of Xe-136 necessitated decreases in the recommended relative emission probabilities of the 197.32-, 381.36-, 431.29- and 812.65-keV gamma transitions. Therefore, the following modifications were made to these particular relative emission probabilities:

197.32-keV gamma ray adjusted from a weighted mean value of 77(5)% to 72.2(70)%;
381.36-keV gamma ray adjusted from a weighted mean value of 99(3)% to 95.7(70)%;
431.29-keV gamma ray adjusted from 0.63(19)% to 0.53(20)%; and
812.65-keV gamma ray adjusted from 2.6(9)% to 2.3(9)%.

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. and Mantica Jr. et al. and fast-timing beta-gamma coincidence studies by Mach and Fogelberg provided supportive evidence for a limited number of the gamma transitions and nuclear levels of Xe-136. Gamma rays with (M1 + E2) multipolarities and energies below 800 keV were arbitrarily assigned mixing ratios of 1.0 (50%M1 + 50%E2) in order to calculate more reasonably realistic relative transition probabilities from their recommended relative emission probabilities. Internal-pair formation coefficients were determined as described by Kibedi et al., and are listed below.

Gamma Energy (keV)	IPF coefficient
1313.027(10)	0.0000247(4)
1592.6(2)	0.0001138(16)
2135.7(2)	0.000362(5)
2178.4(2)	0.000382(6)
2363.2(2)	0.000471(7)

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 Sonzogni and Q-value of 7500(110) keV (Audi and Wang) were used to determine the energies and uncertainties of the beta-particle transitions to the various levels.

Emission Probabilities
The beta-particle emission probabilities were calculated from gamma-ray energy balances. As noted above, recommended internal conversion coefficients were adopted in this process whenever possible, as determined from the frozen orbital approximation of Kibedi et al. and 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 2125.68-, 1313.027- and 0.0-keV nuclear levels of Xe-136 from spin-parity considerations. Furthermore, direct beta- population of the 1694.39-keV nuclear level was also judged to be zero on the basis of an assumed population-depopulation balance for the relevant gamma transitions.

Aleklett and Rudstam measured the beta spectra of a wide range of short-lived fission products in order to determine their total average beta- energies (Aleklett and Rudstam). The OSIRIS on-line-isotope separator was used to study both I-136 and I-136m - a total average <Ebeta> value of 2110(120) keV was derived for I-136m (half-life of 48 sec), with a total average experimental <Ebeta> to Q(beta) ratio of 0.301. Rudstam et al. carried out studies of the continuous beta- and gamma spectra of 114 short-lived fission products, including I-136m (Rudstam et al.). The resulting beta and gamma data for I-136m were expressed separately in terms of fifty-two 100-keV energy increments from 0 to 5200 keV, which were analysed as follows:

gamma cut-off defined as 300 keV, below which gamma rays were not registered by NaI(Tl) spectrometer;
total average <Egamma> above cut-off = 2470 +/- 170 keV;
contribution to total average <Egamma> of gamma rays below the cut-off energy was defined as 119 +/- 8 keV;
therefore, total average gamma-ray energy <Egamma> = 2589 +/- 170 keV, rounded-up to 2590 +/- 180 keV (although the total average gamma-ray energy <Egamma> was modified to 2510 +/- 180 keV by Rudstam in December 1990, effectively as a private communication during the preparation of the JEF-2.2 decay-data library);
average number of gamma rays per decay = 3.26 +/- 0.19;
total average beta energy <Ebeta> = 2210 +/- 40 keV;
total average nu energy <Enu> = 2820 +/- 80 keV;
sum of 7620 +/- 200 keV.

A value of zero was adopted for the Pbeta emission directly to the ground state of Xe-136, providing the means of calculating the normalisation factor (NF) for the relative emission probabilities of the gamma transitions, along with the derivation of the absolute emission probabilities of the other beta-particle emissions populating the excited nuclear levels of Xe-136:

Sum of direct gamma population of Xe-136 ground state = 100%
Only the 1313.027-keV gamma ray is believed to populate the Xe-136 ground state directly, with a relative emission probability of 100% and total internal-conversion and ion-pair formation coefficient of 0.000941(14):

(100.0941(14))NF = 100%

NF = 100%/(100.0941(14)) = 0.9991 +/- 0.0001
with an estimated uncertainty rounded upwards to a value of +/- 0.0001.

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CONCLUDING REMARKS

A recommended half-life of (47 +/- 1) s was calculated from the measurements of Carraz et al., Erten et al., Lundan, and Western et al.

The comprehensive gamma-ray measurements of Western et al. have been primarily adopted to derive the complex decay scheme of I-136m. However, the gamma-ray and Xe-136 nuclear-level energies were adopted from the evaluation of Sonzogni (available in ENSDF). A normalisation factor of (0.9991 +/- 0.0001) was determined from the relative emission probability of the only gamma transition directly populating the ground state of Xe-136, with the emission probability of the beta- particle populating the ground state defined as zero on the basis of spin-parity considerations. Significant adjustments were made to the relative emission probabilities of the 197.32- and 381.36-keV gamma rays to avoid the derivation of large population-depopulation imbalances for the 1694.39- and 1313.027-keV nuclear levels of Xe-136 - these difficulties encompass the main gamma transitions identified with the nuclear levels below an energy of 2130 keV, which need to be investigated further and characterised with greater confidence by means of gamma-ray spectroscopy. The possibility of direct beta decay to the 1694.39-, 1313.027- and 0.0-keV nuclear levels of Xe-136 also needs to be unambiguously ruled out. Well-defined spectral data of relevance to this important area of the proposed decay scheme would require a full re-assessment of the more significant beta- and gamma emission probabilities.

Rudstam et al. carried out studies of the gross beta- and gamma spectra of I-136m, in which the beta- and gamma data were expressed in terms of fifty-two energy increments of 100 keV each, ranging from 0 to 5200 keV. A total average <Ebeta> of 2210 +/- 40 keV and total average <Egamma> of 2590 +/- 180 keV were derived from these data (although the total average <Egamma> was modified to 2510 +/- 180 keV by Rudstam in December 1990, during the preparation of the JEF-2.2 decay-data library), along with total average <Enu> of 2820 +/- 80 keV, summing to a quoted Qbeta of either 7620 +/- 200 or 7540 +/- 200 keV. A Qbeta value of (7500 +/- 110) keV has been derived from Audi and Wang (2011), which differs by ~ 0.5% from the value determined by Rudstam et al. Furthermore, the total average <Egamma> was calculated from the various discrete gamma studies to be (2137 +/- 30) keV compared with a higher value of (2510 +/- 180) keV from Rudstam et al. (private communication, December 1990), implying that the singles gamma-ray measurements exhibit a modest degree of Pandemonium.

There are a number of significant differences between the complex decay scheme derived by means of singles gamma-ray spectroscopy of Western et al. and the gross beta-gamma spectral studies of Rudstam et al. Although the measurements of Western et al. are particularly comprehensive and noteworthy, their quantification of the many high-energy gamma rays should be viewed as being potentially problematic. Thus, the evaluated discrete beta- and gamma data derived from the singles gamma-ray spectroscopic measurements have been adopted, in conjunction with a total average <Ebeta> of (2210 +/- 40) keV and total average <Egamma>

of (2510 +/- 180) keV as determined from the gross beta-gamma spectral studies of Rudstam et al. (private communication, December 1990). Future emphasis should be placed on gross beta-gamma and TAGS studies, along with comprehensive gamma-gamma and singles gamma-ray spectroscopy, in order to achieve a greater degree of agreement and consistency.

```
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END POINT(MEV)= 3.6700  SHAPE= 1  MEAN= 1.5445  INT= 0.0108
END POINT(MEV)= 3.7590  SHAPE= 1  MEAN= 1.5860  INT= 0.0020
END POINT(MEV)= 4.8920  SHAPE= 2  MEAN= 2.1015  INT= 0.0970
END POINT(MEV)= 4.9260  SHAPE= 1  MEAN= 2.1315  INT= 0.0021
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END POINT(MEV)= 5.0560  SHAPE= 1  MEAN= 2.1923  INT= 0.0720
END POINT(MEV)= 5.2380  SHAPE= 1  MEAN= 2.2775  INT= 0.1320
END POINT(MEV)= 5.6080  SHAPE= 1  MEAN= 2.4506  INT= 0.6420

   MEAN GAMMA ENERGY              =   2137.1456  KEV
   MEAN BETA- ENERGY              =   2309.5166  KEV
   BETA- + NEUTRINO ENERGY        =   5331.3105  KEV
   MEAN X-RAY ENERGY              =      3.3018  KEV
   MEAN AUGER ELECTRON ENERGY     =      0.9338  KEV
   MEAN CONVERSION ELECTRON ENERGY=     30.9229  KEV
   INTERNAL BREMSSTRAHLUNG ENERGY =     10.2699  KEV
   EFFECTIVE Q VALUE              =   7500.0000  KEV
   UNCERTAINTY IN EFFECTIVE Q (%) =      1.4667
   CALCULATED Q VALUE             =   7503.6146  KEV
   % DEVIATION                    =     -0.0482
```

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

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 this summary section by Rudstam et al. (1990) estimate of (2510 +/- 180) keV.
Above total mean beta energy derived from discrete gamma-ray studies has been replaced in this summary section by Rudstam et al. (1990) value of (2210 +/- 40) keV.
Average antineutrino energy of (2744 +/- 210) 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 gross spectral-based values adopted in the summary section.

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Also available via the UKNSF and NEA Databank web sites.