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UK CHEMICAL NUCLEAR DATA COMMITTEE

PROGRESS REPORT: DATA STUDIES DURING 1993

Edited by A L Nichols

February 1994

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A L NICHOLS

SUMMARY

The basic nuclear data for commercial application in the UK are monitored and peer-reviewed by the UK Chemical Nuclear Data Committee (UKCNDC). Work undertaken under the auspices of the UKCNDC includes the measurement and evaluation of radionuclide half-lives, other decay parameters (e.g. transition energies and transition probabilities) and fission yields; these studies for 1993 are described in this document. Efforts are also being made to extend the technical responsibilities of the committee towards neutron cross sections, and provide a forum for the communication and debate of relevant international developments (e.g. NEA-Nuclear Science Committee and IAEA Nuclear Data Section).

Environmental and Process Engineering Department
AEA Industrial Technology
Harwell

February 1994

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1 INTRODUCTION

The United Kingdom Chemical Nuclear Data Committee (UKCNDC) has for over 20 years identified specific data needs for the UK nuclear industry. The data that fall within the auspices of the UKCNDC are normally determined by standard chemical techniques in conjunction with mass spectrometry, alpha-particle spectrometry and gamma-ray spectroscopy (e.g. fission yields and decay data). All such measurement and evaluation programmes are co-ordinated to meet data requests identified by members of the committee. An additional important aim is to produce and maintain recommended libraries of relevant nuclear data. These data files have to be assembled in a suitable form for a wide range of applications, including reactor design, fuel handling, reprocessing, waste management, shielding and transport. Such libraries need to be regularly updated so that the best data can be used with confidence.

2 MEASUREMENTS

2.1 Decay scheme data (T.D. MacMahon, A. Nzuruba, D. Sardari and K. Usman (Centre for Analytical Research in the Environment, Imperial College at Silwood Park, Ascot)).

(i) ^{239}U branching ratios: ^{239}U beta decay and ^{243}Am alpha decay both lead to excited states of ^{239}Np. Studies of the gamma-ray spectra from the two decays allow the ^{239}U beta branching ratios to be determined from the ^{243}Am alpha branching ratios. New ^{243}Am alpha-particle data have been used to re-calculate the ^{239}U beta branching ratios using the gamma-ray data measured at Imperial College some time ago.

(ii) ^{234m}Pa decay scheme: recent discussions of uncertainties in ^{234m}Pa gamma-ray emission probabilities has prompted a complete re-evaluation of all published data, and an attempt has been made to deduce a self-consistent decay scheme taking into account internal conversion coefficients.

(iii) New measurements have been reported of the relative gamma-ray emission probabilities in the decay of ^{101}Mo and ^{101}Tc (1). More than 200 gamma rays were detected in the two decays: 183 were definitely assigned to the decay of ^{101}Mo, and 30 to the decay of ^{101}Tc.

(iv) Comparisons have been carried out on the fitting of gamma-ray spectra obtained with Ge detectors (2). These studies have shown that Bayesian peak fitting techniques can reduce the uncertainties in peak intensities by a factor of up to ten in the case of closely separated doublets compared with e.g. Chi-squared techniques.

2.2 **Measurement and evaluation of decay data** (D. Smith, M.J. Woods and S.A. Woods (National Physical Laboratory, Teddington)).

During the twelve months covered by this report, the resources available to undertake activities relating to the measurement and evaluation of decay data have been greatly reduced. This is clearly shown by the absence of any NPL publications in the field over this period. However, there has been an increase in the demand for the NPL to provide recommended decay data. The current status of decay data-related work at the NPL is given below.

(i) The analysis of the data measured to determine the half-life of Sr-90 will be finalised during 1994.

(ii) Measurements of half-lives for radionuclides for which more accurate data are required, i.e. ^{3}H, ^{54}Mn, ^{57}Co, ^{65}Zn and ^{75}Se, are in abeyance until suitable renewed resources are identified.

(iii) NPL staff are reviewing the nuclear decay scheme data in evaluated data files (such as JEF-2, ENSDF, IAEA TecDoc-619 and UKPADD-2) with a view to being able to recommend the use of selected data to UK users (e.g. half-lives and principal gamma-ray emissions). Approximately 50 nuclides have initially been examined, primarily those for which NPL has supplied standards. It is expected that these recommended data will become available during 1994.

2.3 **Delayed neutron yield measurements** (M. Kellett and D.R. Weaver (University of Birmingham)).

Experiments have begun on the measurement of the yield of delayed neutrons from the fission of ^{238}U at various neutron energies using the Birmingham Dynamitron. The purpose is to resolve uncertainties in the yield of ^{238}U at energies between 4 and 6 MeV. Work during the first year has concentrated on establishing techniques for mapping the neutron field around the accelerator target and arranging for the loan of materials and detectors; good progress has been made. High levels of accuracy have been achieved for the flux mapping, using indium foils. Arrangements have been concluded for the loan of appropriate fission foils and detectors. The latter include the International Intercomparison set of fission chambers prepared by Gayther (3); and recent work has involved the cross calibration of other detectors against this set.

3 DATA LIBRARIES: EVALUATIONS

3.1 Data library developments

The status of the UK Data Libraries is summarised in Table 1. Significant progress has been made in the evaluation of specific decay data (activiation products and a limited number of fission products) and fission yields. These studies have also been undertaken to assist in the development of the Joint Evaluated Files (JEF).

Table 1: *UKCNDC Data Libraries - Status Table, December 1993.*

Data	Present status	File development
Fission product decay data	UKFPDD-2 evaluations (ENDF/B-V format) were submitted for JEF-1.1 and partially included. Some of these evaluations have been carried through to JEF-2.2.	
Activation product decay data	UKPADD-2 evaluations (ENDF/B-VI format) have been submitted to the NEA Data Bank, and will be incorporated into the future JEF-3.	Over 90 additional nuclides are being evaluated by A L Nichols (AEA), as described in Section 3.1(a) (development of UKPADD-3).
Heavy element and actinide decay data	UKHEDD-2 evaluations (ENDF/B-VI format) have been submitted and absorbed into JEF-2.2.	Decay data for Pa-234g and Pa-234m have been evaluated for incorporation into UKHEDD-2.
Fission yields	UKFY-2 has been submitted and accepted into JEF-2.2. A minor update to make the yields consistent with the JEF-2.2 decay data was completed in July 1993.	A new evaluation (UKFY-3) is being undertaken by R W Mills (see Section 3.4).

(a) **Activation and fission product decay data - evaluations under way** (A.L. Nichols (Harwell)).

An assessment by Yamamuro and Iijima has resulted in the identification of approximately 90 radionuclides from specific (n,x) reactions that will be generated in the core region (4). Evaluations are being made to improve the UK decay-data files for these radionuclides, and so contribute to the evolution of the JEF library.

Work has begun to collect and evaluate the defined data, and establish the recommended values in a data library (ENDF-6 format). The measured decay data are being extracted from the literature sources, and evaluations have begun to create and improve a number of the data files. The work is being undertaken for specific activation/fission product nuclides:

^{53}Mn, ^{60}Fe, ^{60m}Co, ^{66}Ni, ^{67}Cu, ^{81}Kr, ^{81m}Kr, ^{83m}Kr, ^{85}Kr, ^{85m}Kr, ^{83}Rb, ^{84}Rb, ^{84m}Rb, ^{86}Rb, ^{86m}Rb, ^{83}Sr, ^{83m}Sr, ^{90}Sr, ^{91}Y, ^{91m}Y, ^{88}Zr, ^{91}Nb, ^{91m}Nb, ^{92}Nb, ^{92m}Nb, ^{105}Rh, ^{105m}Rh, ^{103}Pd, ^{107}Pd, ^{107m}Pd, ^{105}Ag, ^{105m}Ag, ^{106}Ag, ^{106m}Ag, ^{111}Ag, ^{111m}Ag, ^{115}Cd, ^{115m}Cd, ^{115m}In, ^{119}Sb, ^{120}Sb, ^{120m}Sb, ^{133}Xe, ^{133m}Xe, ^{129}Cs, ^{131}Cs, ^{132}Cs, ^{131}Ba, ^{131m}Ba, ^{140}Nd, ^{147}Nd, ^{143}Pm, ^{144}Pm, ^{146}Pm, ^{147}Pm, ^{148}Pm, ^{148m}Pm, ^{149}Pm, ^{151}Pm, ^{151}Sm, ^{153}Sm, ^{149}Eu, ^{150}Eu, ^{150m}Eu, ^{156}Eu, ^{150}Gd, ^{151}Gd, ^{153}Gd, ^{175}Yb, ^{171}Lu, ^{171m}Lu, ^{172}Lu, ^{172m}Lu, ^{173}Lu, ^{174}Lu, ^{174m}Lu, ^{177}Lu, ^{177m}Lu, ^{173}Hf, ^{177m}Hf, ^{177n}Hf, ^{177}Ta, ^{183}Ta, ^{178}W, ^{201}Tl, ^{202}Tl, ^{202}Pb, ^{202m}Pb, ^{203}Pb, ^{203m}Pb, ^{203n}Pb and ^{205}Pb.

Summary comments on the various completed evaluations follow for information.

Nuclide	Evaluation	Comments
^{53}Mn	Nov 93	Half-life calculated from the measurements of Matsuda et al, and Honda and Imamura; one EC transition.
^{66}Ni	Aug 93	No comments; one β^- transition.
^{67}Cu	Aug 93	Decay scheme derived from the gamma-ray measurements of Raman and Pinajian, and Meyer et al, combined with the beta-particle studies of Easterday (ground state transition of 0.20(2) was adopted). Internal conversion coefficients were calculated from the data of Freedman et al, with a majority of the gamma-ray transitions defined as M1+ E2; four β^- transitions and six γ rays.
^{83m}Kr	Oct 93	Kr-83m decay scheme was evaluated separately, as an extension of the EC decay of Rb-83 to Kr-83m and Kr83. The decay of this metastable state is via a two gamma-ray cascade with the emission probabilities calculated from the transition probability and internal conversion coefficients derived from the measurements of Kolk et al. However, the resulting gamma-ray emission probabilities do not agree with the relative values reported by de Bruin and Korthoven. Additional studies are required to determine these emission probabilities and internal conversion coefficients with greater confidence; two γ rays.
^{83}Rb	Oct 93	The decay scheme was calculated from the measured gamma-ray emission probabilities of Brown, Vaisala et al (same as Meyer) and Grutter, theoretical internal conversion co-efficients, and estimates of the EC transition probabilities to the 9.396 keV and ground state of Kr-83 by Dostrovsky et al. The multipolarities of the 9.396, 529.66 and 789.5 keV gamma rays and the EC transition probabilities are particularly uncertain. It should be noted that Rb-83 decay is via both Kr-83m and Kr-83, with branching fractions of 0.75(3) and 0.25(3) respectively. Thus, measurements of the emission probabilities of the 9.396 and 32.147 keV gamma rays are primarily identified with the decay of Kr-83m, which has been evaluated and listed in a separate datafile.Further measurements are justified to confirm early studies, particularly in defining EC decay to the first excited and ground states of Kr-83; six EC transitions and 11 γ rays.
^{84m}Rb	Aug 93	There are a number of inconsistencies and discrepancies in the measured gamma-ray emission probabilities of Kneissl et al, Pathak et al, Slamkova et al, Erlandsson et al, Grutter, and Lakshminarayana et al. Nevertheless, a reasonably consistent decay scheme has been derived, which was based primarily on the relative gamma-ray emission probabilities measured by Grutter, and Lakshminarayana et al. Further studies are merited to confirm the recommended data; three γ rays.

Nuclide	Evaluation	Comments
^{83}Sr	Oct 93	A complex decay scheme was constructed from the gamma-ray measurements of Etherton et al, Broda et al, Poggi et al, and Grutter. Some of the gamma-ray emissions were assigned in two or more places, while other gamma rays were not included in the decay scheme (793.4, 808.7, 930.0, 1125.5, 1178.5, 1277.8, 1285.1, 1396.7 and 1777.8 keV transitions). It proved reasonable to assume that there were no direct EC transitions to the 5.25, 99.3, 389.3, 1036.6, 1044.1, 1083.3, 1086.2 and 1102.7 keV nuclear levels of Rb-83. The normalisation factor for the γ-ray emission probabilities was calculated from the relative emission probabilities populating the Rb-83 ground state and the mean value of the direct EC transition probability as determined by Etherton et al and Poggi et al (0.20(2)). All of the other EC transition probabilities were calculated from this normalisation factor, the γ-ray emission probabilities and theoretical internal conversion coefficients. Further γ-ray measurements are required to resolve some of the differences between the studies of Broda et al and Grutter, and confirm the recommended data and decay scheme; 23 EC transitions and 120 γ rays.
^{83m}Sr	Oct 93	Decay scheme derived from gamma-ray transition probability and theoretical internal conversion coefficients for 259.15 keV E3 transition; one γ ray.
^{92}Nb	Sept 93	Preiswerk and Stahelin (1951 and 1953) estimated a negatron branching fraction for Nb-92 of less than 0.0005; no relevant γ-ray emissions have been detected for this decay mode, and therefore a value of zero has been assigned. The EC decay mode was derived on the basis of an E2 γ-ray cascade and theoretical internal conversion coefficients for this cascade; 1 EC transition and 2 γ rays.
^{92m}Nb	Sept 93	The decay scheme was derived from the gamma-ray measurements of West et al, Bunker et al, Helene, and Helene and Goldman. Major EC transitions occur to the 1847.33 and 934.49 keV nuclear levels of Zr-92, with minor transitions postulated to the 2066.66, 1495.47 and 1382.83 keV nuclear levels of Zr-92 on the basis of the studies by Helene (1983) and Helene and Goldman (1985). Direct EC decay to the ground state of Zr-92 was assumed to be zero; 5 EC transitions and 6 γ rays.

Nuclide	Evaluation	Comments
^{107}Pd	Nov 93	No comments; one β^- transition.
^{107m}Pd	Nov 93	The adopted half-life of 21.3(5)sec measured by Stribel was assigned to Pd-107m from the studies of Schindewolf and Weirauch. An E3 multipolarity was identified with the single 214.9 keV gamma-ray transition; theoretical internal conversion coefficients were used to calculate the emission probability on the basis of 100% transition probability; one γ ray.
^{119}Sb	Nov 93	No comments; one EC transition and one γ ray.
^{120}Sb	Nov 93	Efforts are required to confirm fully the identification of the ground and metastable states of Sb-120. Measurements of the relative γ-ray emission probabilities by Rahmouni et al, Kiselev et al, Pan et al, Okano and Takeuchi, Liukkonen and Hattula, and Campbell et al were used in conjunction with a normalisation factor of 0.021(2) as determined by Kiselev et al to derive the proposed decay scheme. Total EC transition probabilities were calculated from these data, while positron emission probabilities had to be estimated. The resulting EC and positron emission probability data are uncertain, and further studies are required to resolve the discrepancies in the various measurements and calculations; 4 EC transitions and 3 γ rays.
^{120m}Sb	Nov 93	A nuclear level energyof 200(50) keV was estimated from the equivalent data of the Sb-118m/118 and Sb-122m/122 analogs to give a Q(EC)-value of 2880(60) keV. Further efforts are required to resolve the uncertainties in the identification of the ground and metastable states of Sb-120 as well as the nuclear level energy of the metastable state. Measurements of the relative gamma-ray emission probabilities by Rahmouni et al, Kiselev et al, Pan et al, Liukkonen and Hattula, and Iwata et al were used to derive the decay scheme on the basis of a single EC transition to the 2481 keV nuclear level of Sn-120. Greater emphasis was placed on the studies of Iwata et al who also measured the absolute emission probabilities of the gamma-ray transitions. Further measurements are merited to confirm these data; one EC transition and 5 γ rays.

Nuclide	Evaluation	Comments
^{133}Xe	Sept 93	The gamma-ray emission probabilities have been measured by Martin and Keller relative to the combined emission probability of the 79.617 and 80.997 keV gamma-ray transitions. These data have been used in conjunction with a ratio of 0.0070 for the 79.617/80.997 gamma-ray emission probabilities and the theoretical internal conversion coefficients to produce a consistent decay scheme; 3 β^- transitions and 6 γ rays.
^{133m}Xe	Sept 93	Simple decay scheme was derived from the single M4 gamma-ray transition and theoretical internal conversion coefficients; one γ ray.
^{140}Nd	Nov 93	No comments; one EC transition.
^{143}Pm	Nov 93	The simple decay scheme was derived from the measurement by Chu et al of the absolute emission probability of the 742 keV γ ray (0.385(24)), and EC decay to the first excited and ground states of Nd-143 as determined by Funk et al and Pagden et al; 2 EC transitions and 1 γ ray.
^{144}Pm	Aug 93	The decay scheme was primarily based on the gamma-ray measurements of Raman and Gove, coupled with the theoretical internal conversion coefficients. These data were used to calculate the EC decay, with no direct transition to the ground state of Nd-144 (highly forbidden); 4 EC transitions and 12 γ rays.
^{148}Pm	Oct 93	The evaluated decay scheme was based on the measurements of the relative gamma-ray probabilities by Kalfas, and the absolute emission probability of 0.222(5) determined by Cabell and Wilkins (1971). These data were used to calculate the emission probabilities of the beta-particle transitions to the various nuclear levels of Sm-148; 10 β^- transitions and 20 γ rays.
^{148m}Pm	Oct 93	The decay scheme was derived from the gamma-ray measurements of Reich et al, Greenberg and Fischbeck, Mowatt and Walker, and Kalfas. Branching fractions of 0.05 for the isomeric transition and 0.95 for the beta decay were adopted as determined by Mowatt and Walker, associated with a relatively large uncertainty; these data were used to calculate a normalisation factor of 0.888(18) for the gamma-ray transitions. Further studies are required to confirm the validity of the resulting absolute gamma-ray probabilities; 4 β^- transitions and 23 γ rays.

Nuclide	Evaluation	Comments
^{175}Yb	Dec 93	The decay scheme was determined from measurements of the relative emission probabilities of the gamma rays by Brown et al, Reierson et al, and Grigor'ev and Sergeenkov. Weighted mean values of the relative γ-ray emission probabilities were calculated and used in conjunction with a combination of theoretical internal conversion coefficients and equivalent data determined by Emery and Perlman to estimate relative transition probabilities. These data were coupled with a value of 0.865(17) for the beta-particle transition direct to the ground state of Lu-175 (Bashandy and El-Nesr) to determine the normalisation factor for the γ-ray emission probabilities. Measurements of the absolute γ-ray emission probabilities are merited; three β^- transitions and six γ rays.
^{171m}Lu	Nov 93	No comments; one γ ray.
^{172}Lu	Dec 93	An extremely complex decay scheme was derived from the gamma-ray measurements of Kaye, Sen and Zganjar, Hnatowicz et al, and Bonch-Osmolovskaya et al. These studies involved the measurement of the relative emission probabilities of over 195 γ rays; the weighted mean values were combined with theoretical internal conversion coefficients and known multipolarities to determine their relative transition probabilities. Some γ-ray transitions were placed twice in the proposed decay scheme, and their emission probabilities were apportioned from the available data or had to be assigned to specific locations in the decay scheme. Adjustments were also made to the relative emission probabilities of the 78.75, 90.6, 485.45 and 486.19 keV γ rays within the estimated uncertainties, based on population/ depopulation considerations of the relevant nuclear levels of Yb-172. Direct EC decay to the ground and first excited states of Yb-172 were assumed to be zero, and a gamma-ray normalisation factor of 0.204(16) was calculated from both the γ-ray population to the ground state and the calculated relative probabilities of the EC transitions. The decay scheme study of Bonch-Osmolovskaya et al was particularly important in the evolution of the decay scheme and EC data. A small number of γ-ray emissions were discarded, and eight transitions were not placed in the proposed decay scheme: 174.7, 990.8, 1055.4, 1125.2, 1920.7, 2127.9 and 2206 keV gamma rays. Positron emission probabilities could only be estimated and require study; 29 EC transitions and 197 γ rays.

Nuclide	Evaluation	Comments
^{172m}Lu	Dec 93	No comments; one γ ray.
^{174}Lu	Nov 93	The half-life measurement by Bonner et al of 1300(150) days was adopted, and this value needs to be confirmed by further studies. A consistent decay scheme was derived from the gamma-ray studies of Vasil'ev et al and the positron measurements of Klyuchnikov et al. Vasil'ev et al also derived an EC transition probability of 0.052 to the 1318 keV nuclear level of Yb-174, which was used in conjunction with the relative emission probabilities of 1318.4, 1241.9 and 1065.2 keV depopulating gamma rays to calculate a gamma-ray normalisation factor of 0.0514(11). Further measurements are recommended to determine the decay scheme with greater confidence and accuracy; three EC transitions and five γ rays.
^{174m}Lu	Nov 93	The recommended half-life was based on the weighted mean of the values reported by Bonner et al, Gunnink et al, and Kirschner and Ok. This value needs to be confirmed by further measurements. A consistent decay scheme was derived from the gamma-ray studies of Kantele et al and Vasil'ev et al, coupled with the theoretical internal conversion coefficients. Adjustments were made to the relative emission probabilities of the 176.65 and 272.91 keV gamma-ray transitions to produce a reasonably consistent decay scheme, while the relative emission probabilities of the 59.08, 76.47 and 126.1 keV gamma-ray transitions were calculated on the basis of population-depopulation considerations of the relevant nuclear levels. A single EC decay to the 1518.15 keV nuclear level of Yb-174 was also assumed. Further measurements are required to determine the decay scheme with greater confidence; one EC transition and 12 γ rays.

Nuclide	Evaluation	Comments
^{201}Tl	Sept 93	The decay scheme was derived from the gamma-ray measurements of Hofmann and Walcher, Debertin et al, Schuler et al, Funck et al, Plch et al, and Coursey et al. 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 various assumptions based on population/depopulation 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 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; three EC transitions and nine γ-rays.
^{202}Pb	Dec 93	Alpha-particle decay was assumed to be negligible although postulated to be possible on the basis of alpha-decay systematics; one EC transition.
^{202m}Pb	Dec 93	The decay scheme was constructed from the single set of measurements of the relative gamma-ray emission probabilities by Guile et al and theoretical internal conversion coefficients. However, a reasonably consistent data set could only be achieved by adjusting the relative emission probabilities of the 389.9, 422.2, 459.7, 490.5 and 960.67 keV gamma rays within the range of their mean uncertainties, combined with a 60% adjustment to the 129.5 keV low-intensity gamma ray (from 0.08 to 0.13(4)). The gamma-ray emission probabilities of the unresolved 240.2 and 241.1 keV transitions were derived from nuclear level calculations of population/depopulation. Furthermore, the 292.1, 532.3 and 662.4 keV γ-ray transitions were introduced on the basis of equivalent measurements of Bi-202 by Goring and Hanser, while the low-intensity 1382.85 keV gamma-ray emission has only been studied by Hanser et al. Gamma-ray studies are required to resolve the minor discrepancies in the data of Guile et al, and to confirm the proposed decay scheme (emission probabilities of specific gamma rays, the EC transition intensities and the overall branching fractions); three EC transitions and 22 γ rays.
^{205}Pb	Dec 93	Half-life re-calculated from the partial L-electron capture half-life measurement of Wing et al, which was adjusted on the basis of the measured capture ratios of Pengra et al; one EC transition.

(b) **Activation product decay data - completed files** (A.L. Nichols (Harwell)).

The decay data of various radionuclides have been evaluated on the basis of a series of well-defined specifications and the requirements of the UK nuclear power, fuel reprocessing and waste management programmes (5). These radionuclides are mainly activation products and standards that are commonly used in gamma-ray spectroscopy. Computer-based files have been generated in ENDF-6 format, including lists of the references used to produce the proposed decay scheme and comments that identify any inadequacies.

The new activation product decay data library (UKPADD-2) contains comprehensive data for 236 nuclides. This library contains recommended data for the following parameters:

(i) half-life,

(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,

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

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

The spin and parity of the decaying nuclide have been defined, and uncertainties are assigned to all evaluated data. Other data in UKPADD-2 (mean energies, discrete electrons and mean x-rays) were derived from the above data using the processing code COGEND (6,7). The component contributions to the average energies (beta, electromagnetic and heavy particle) are derived from the evaluated input data by COGEND, which has data libraries of fluorescence yields, Auger-electron energies, mean x-ray energies and electron-wave-function ratios from which capture ratios can be calculated. All data include associated uncertainties.

The library has been generated in ENDF-6 format (8). 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. 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 various decay parameters of the majority of radionuclides in UKPADD-2 have been reasonably well defined in the published literature, and were evaluated with good precision and confidence to produce consistent decay schemes.

(c) **Heavy element and actinide decay data** (A.L. Nichols (Harwell)).

Several recent measurements of the absolute emission probability of the 1001 keV gamma ray of Pa-234m have resulted in doubts concerning the recommended decay data for this radionuclide. A value of 0.00590 ± 0.00010 has been adopted in previous evaluations on the basis of a single datum generated by Bjornholm and Nielsen (1963). However, more recent gamma-ray studies by Moss (1986), Scott and Marlow (1990), Siemon et al (1992), and Lin and Harbottle (1992) are in good agreement to give a newly recommended value of 0.00835 ± 0.00011 (9). Some of these recent measurements also include new gamma-ray data for Pa-234g decay. Thus, comprehensive re-evaluations have been undertaken of the decay schemes for both radionuclides, and the resulting data will be included in the UK Heavy Element and Actinide Decay Data library, UKHEDD-2 (10). The new value for the 1001 keV gamma-ray emission of Pa-234m should provide a consistent basis for the measurement and reporting of this radionuclide in environmental monitoring programmes.

It should be noted that when the newly-recommended value of 0.00835 is applied to laboratory intercomparison data, there is a deficiency of between 17 and 29% in the Th-234 content relative to the corrected Pa-234m content. Hence, the gamma-ray abundance of the 63.3 keV emission of Th-234 needs to be reviewed and a new value recommended, in conjunction with systematic measurements to provide self-adsorption corrections for solid samples.

3.2 Evaluation of nuclear decay scheme data (G.A. Sutton, A. Taylor and P. Smedley (MAFF Directorate of Fisheries Research)).

Investigations are being made into the uranium/radium (4n + 2) series, particular interest being directed towards radium-226, and lead-214 and bismuth-214 daughters. The disparity between the analytical results from these radionuclides has raised doubts regarding the validity of the gamma-ray emission probability data quoted in the literature. Work continues to investigate this problem.

3.3 Interrogation and extraction of JEF 2 decay data

(J. Rockey, J. Blackband and D.R. Weaver (University of Birmingham), B. Potet and M. Konieczny (NEA Data Bank)).

Further work on a PC-based computer program has been sponsored by the NEA Data Bank and conducted through a Summer Vacation Studentship at the University of Birmingham. These studies in 1993 were carried out in collaboration with another student based at the Data Bank in Paris. Tasks undertaken at Birmingham included the insertion into the main program of the fission yield module reported last year. In addition, the program was extended to include information on beta spectra, based on the analysis codes of Tobias (11). The work at the NEA Data Bank included a radical restructuring of the previous code (known as NUC.EXE) and the provision of a significant number of new features. The new code is known as NUCLEUS, and it is expected to be available from the Data Bank shortly.

3.4 Fission product yield evaluations

(M.F. James (Consultant to BNF plc), R.W. Mills (BNF plc) and D. R. Weaver (University of Birmingham)).

The UK fission-product yield evaluation programme has continued with work focused on the development of a new evaluated library (UKFY3) as an update to UKFY2 (the latter is described in AEA reports AEA-TRS-1015, 1018 and 1019). Work has been completed in the following areas: expanding the experimental database (both with new data and with other types of data to aid in a greater understanding of the fission-product production process), adapting the analysis procedure to use more of the data by iteration of the relative and ratio of ratio data, and improving the technique of generating complete yield sets using mass yields rather than chain yields.

Efforts are also continuing to examine different models that can be used to explain the fission-product yield production process; these models will be used to assist in the generation of the UKFY3 file.

The UK group remains involved in the IAEA Coordinated Research Programme on the Compilation and Evaluation of Fission Yield Nuclear Data and the JEF (Joint European File) evaluation programme of the NEA.

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