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UK Chemical Nuclear Data Committee Progress Report: Data Studies During 1989

Edited by

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AEA THERMAL REACTOR SERVICES

AEA TECHNOLOGY

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UK CHEMICAL NUCLEAR DATA COMMITTEE PROGRESS REPORT: DATA STUDIES DURING 1989

Edited by

A L NICHOLS

SUMMARY

Basic nuclear data requirements for industrial application are monitored by the UK Chemical Nuclear Data Committee (UKCNDC), covering half-lives, decay data, fission yields and the content of computerised data files. While the UKCNDC Request List was reviewed at the end of 1989 to reveal new and continued requirements, funding problems have increased during the year. Difficulties in the UK nuclear power industry are reflected in the decline in experimental studies, although evaluation efforts have been maintained.

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1 INTRODUCTION

Basic nuclear data requirements for the nuclear power and reprocessing industries are monitored in the UK by the Differential and Integral Data Steering Group (DIDSG) and the UK Chemical Nuclear Data Committee (UKCNDC). Accurate knowledge of radionuclide decay data and fission product yields are necessary to improve nuclear plant performance, and are defined as the responsibility of the UKCNDC. Throughout recent years increasing difficulties have been experienced within the UK to fund and undertake experimental research programmes that will assist the nuclear industry in such work. The decline in available funding is clearly having a significant effect on the viability of maintaining the necessary expertise and laboratories within AEA Technology and the UK.

Two meetings of the UKCNDC were held during 1989, at the beginning of July and December (Chairman, A L Nichols (WTC) and Secretary, P Robb (WTC)). The UK Data Library Sub-committee (DLSC) also met twice over the same time period (Chairman, A Tobias (CEGB, Berkeley Nuclear Laboratories) and Secretary, M F James (WTC)); A Tobias has resigned from the chairmanship of the DLSC and will be replaced by M F James. This sub-committee was established in 1972 to coordinate the UK effort available for the evaluation of data for the nuclear power industry and other applications. The members are responsible to the UKCNDC for the construction and maintenance of the following computerised libraries:

(a) activation product decay data,

(b) fission product decay data,

(c) heavy element and actinide decay data,

(d) fission product yields.

Much of the progress during the year has involved the evaluation of fission-yield and decay data based on funding from the CEGB and BNFL plc. All of this evaluation effort is now linked to the European Joint Evaluated File (JEF), and improving international communications between the various data files/libraries.

Efforts are regularly made within the UKCNDC to define the requirements and priorities for nuclear data measurements and evaluations. Every 4 to 5 years the UKCNDC Request List is reviewed, data needs are redefined, and priorities are re-established. This list was reassessed at the end of 1989, and the exercise demonstrated clearly that a number of needs exist for specific chemical nuclear data involving thermal and fast reactors, reprocessing and radioactive waste management. As noted earlier, the UKCNDC was established to review data needs throughout the nuclear industry and advise upon the best methods of answering specific problems in this areas, and is uniquely placed to advise upon the feasibility of undertaking such work. It is clear that the UK is in danger of losing the expertise and abilities in such an important area of nuclear

science. Such losses would have a significant impact on future attempts to design and develop reactor systems with improved operational and safety features that are more readily acceptable within the industry and public domains.

2 MEASUREMENTS

2.1 Tritium Yields in the Fast Neutron Ternary Fission of ^{235}U and ^{239}Pu (J W McMillan, I G Jones, M F Banham and D H Rowe (Harwell Laboratory))

A programme to measure the yield of tritium in the fast neutron ternary fission of ^{235}U and ^{239}Pu was commenced over a decade ago in the UK. This involved metallic specimens of ^{235}U and ^{239}Pu, encapsulated in aluminium and irradiated in the fast neutron spectrum of ZEBRA in 1980. However, circumstances prevented further examination of the specimens at that time. Some eight years later the programme was recommenced despite some doubts concerning possible losses of tritium from the irradiation capsules. The aims were:

(a) to develop techniques for the separation and measurement of tritium, and to gain experience for possible future programmes,

(b) to obtain values for the yields of tritium in the fast neutron fission of ^{235}U and ^{239}Pu, based on post irradiation separation and measurement of tritium.

A separation method was developed based on high temperature extraction of tritium in the presence of helium carrier gas containing low concentrations of hydrogen and water vapour. The tritium and hydrogen were oxidised to tritiated water prior to cryogenic collection and measurement by liquid scintillation counting. This method was chosen to avoid the substantial aqueous dilution of the low yields of tritium inherent in more conventional methods based on acid dissolution. An unforeseen problem was the significant tritium contamination present in the carrier gas of 1% hydrogen in helium; blanks of 400 dpm tritium were encountered. These were substantially reduced by changing to a 0.1% hydrogen in helium carrier gas and preconditioning to remove tritiated water. Apparatus blanks were 6 ± 4 dpm tritium (12 observations) at the time the samples were measured.

The collection efficiency of the cryogenic trapping system was shown to be approximately 100%. Trials involving 200-1000 dpm tritium gave recoveries of 102.2 ± 0.5% (4 observations); studies involving ca 20 dpm tritium gave recoveries of 96.7% (8 observations).

The efficiency of recovering tritium from the irradiation capsules was assessed by making several successive collections, each of 90 minutes duration, and these results are listed in Table 1. The release of tritium tended to reduce more rapidly for uranium than plutonium. While some tritium recovered from

TABLE 1: RECOVERY OF TRITIUM FROM IRRADIATED CAPSULES

Sample		^{3}H dpm (corrected for blank)			
No.	Material	1st Collection	2nd Collection	3rd Collection	4th Collection
Z51	^{235}U	337.3	4.3	1.9	-
Z53	^{235}U	318.3	22.2	15.0	-
Z54	^{235}U	316.3	2.9	2.9	-
Z92	^{239}Pu	166.6	1775.6	16.2	-
Z93	^{239}Pu	250.8	28.6	6.1	3.4
Z94	^{239}Pu	200.8	75.2	29.9	15.8

the capsules was associated with the aluminium container, the average content of the irradiated blanks was 9.7 ± 4.3 dpm (5 observations). The implication is that the boron and lithium contents of the ultrapure aluminium employed were very low.

Another source of tritium contamination investigated was the initial amount present in metallic actinides. Disturbingly high levels were encountered in metallic uranium and plutonium scrap from other programmes. The single specimens of uranium and plutonium examined were found to contain 414 and 344 dpm g^{-1} respectively. The only material available from the original programme was one unirradiated capsule (Z91) which contained plutonium. The amount of tritium found for this material was much lower (22.5 dpm g^{-1}), but was still of some significance. Clearly steps may be necessary in any future work to remove tritium from the actinide source materials.

The number of fissions in each specimen was determined by a novel intact gamma-ray spectroscopy method. Corrections for counting geometry variations and self-attenuation of the gamma rays by the specimens were automatically made by employing a calibration procedure based on the known activities of the ^{235}U and ^{239}Pu in each irradiated capsule (Table 2). While the spread in the values for the number of fission per gramme of material is relatively wide, they agree within the limits of experimental error.

TABLE 2: NUMBER OF FISSIONS EXPERIENCED BY THE IRRADIATED ^{235}U and ^{239}Pu SPECIMENS

Sample			No. of Fissions	
No.	Material	Wt. (g)	per sample	per g
Z51	^{235}U	1.188	$(5.44\pm0.31) \times 10^{13}$	$(4.58\pm0.26) \times 10^{13}$
Z53	^{235}U	1.153	$(5.70\pm0.34) \times 10^{13}$	$(4.94\pm0.29) \times 10^{13}$
Z54	^{235}U	1.174	$(5.69\pm0.30) \times 10^{13}$	$(4.85\pm0.26) \times 10^{13}$
Z92	^{239}Pu	1.360	$(7.00\pm0.30) \times 10^{13}$	$(5.15\pm0.22) \times 10^{13}$
Z93	^{239}Pu	1.314	$(6.62\pm0.13) \times 10^{13}$	$(5.04\pm0.10) \times 10^{13}$
Z94	^{239}Pu	1.342	$(7.34\pm0.28) \times 10^{13}$	$(5.47\pm0.21) \times 10^{13}$

(errors are for 1 standard deviation)

The ternary fission yields for ^{235}U and ^{239}Pu were derived from the recovered tritium contents and number of fissions per specimen, and are listed in Table 3. While the results are tolerably consistent, they need to be considered in conjunction with other values for tritium yields in the fast neutron fission of ^{235}U and ^{239}Pu (see Table 4).

TABLE 3: TERNARY FISSION YIELDS FOR ^{235}U AND ^{239}Pu

Sample		Tritium Atoms at End of Irradiation	Ternary Fission Yields, Tritium Atoms per Fission	
No.	Material			
Z51	^{235}U	5.13×10^{9}	0.943×10^{-4}	
Z53	^{235}U	5.32×10^{9}	0.932×10^{-4}	$(0.91 \pm 0.03) \times 10^{-4}$
Z54	^{235}U	4.84×10^{9}	0.851×10^{-4}	
Z92	^{239}Pu	5.36×10^{9}	0.766×10^{-4}	
Z93	^{239}Pu	4.29×10^{9}	0.648×10^{-4}	$(0.69 \pm 0.04) \times 10^{-4}$
Z94	^{239}Pu	4.77×10^{9}	0.659×10^{-4}	

(errors are 1 standard error for the mean)

TABLE 4 COMPARISON OF TRITIUM YIELDS IN THE FAST NEUTRON TERNARY FISSION OF ^{235}U and ^{239}Pu

Tritium Fission Yields, Atoms per Fission		Neutron Energy (MeV)	Source
^{235}U	^{239}Pu		
0.91×10^{-4}	0.69×10^{-4}	ZEBRA Fission Neutrons	This work
1.25×10^{-4} – 1.89×10^{-4} 0.93×10^{-4}	1.41×10^{-4} 1.18×10^{-4} 1.68×10^{-4} 1.34×10^{-4}	0.5 0.75 1.0 2.0	R. Ouasti, Etude de l'emission des particules légères chargées alpha et tritons dans la fission de uranium 235, uranium 238 et plutonium 239 induites par des neutrons rapid, PhD Thesis, University of Bordeaux, 1988.
Evaluation 1.44×10^{-4} (±9.3%)	Evaluation 1.45×10^{-4} (±15%)	Fast Neutrons	R.W. Mills, M.F. James and D.R. Weaver, UK Fission Yield Evaluation 2, to be published.

The values obtained in the current experimental work are notably lower than other reported values, particularly for ^{239}Pu. Reasons for these discrepancies can be cited and discussed. Factors that could possibly lead to low values in this work include inadequate extraction and recovery of tritium, losses of tritium during sample storage, and over-estimation of the number of fissions.

While the recovery data in Table 1 suggest that tritium was more rapidly extractable from uranium than plutonium, a large fraction of the tritium would need to be present in an inert, non-extractable form to account for the low results. Experience of the extraction of tritium and hydrogen from other materials suggests that it is an unlikely explanation.

Some doubts have always existed concerning the possible loss of tritium from the irradiated capsules during their storage. Estimates can be made of the movement of tritium through the walls of the aluminium container using diffusion data as in Table 5.

TABLE 5: DIFFUSION OF TRITIUM THROUGH WALLS OF ALUMINIUM CAPSULE

Ratio of Tritium Concentration at Outer and Inner Surfaces (8.8y storage, wall 1.59mm, 20°C)	Diffusion Coefficient, 20°C ($cm^2\ s^{-1}$)	Comments
0.0026	5.0×10^{-12}	Thermally injected tritium
0.503	5.0×10^{-11}	Implanted tritium

(data from M. Nakashima, Y. Aratono and E. Tachikawa, J. Nucl. Materials 98 (1981) 27-34)

Loss of tritium depends critically on the adopted value of the diffusion coefficient. The value for implanted tritium will probably reflect unimpeded diffusion of tritium, whereas that for thermally injected tritium most probably applies where diffusion is impeded by the presence of surface oxide films. In most practical situations oxide films will be present and the lower value would be expected to apply. However, if thick surface oxide films exist on the surface, tritium losses could be substantially reduced as the diffusion of tritium in aluminium oxide could be a factor of 10^{10} lower than for aluminium. An additional factor which should reduce the release of tritium from the irradiated capsules is the hydrogen gettering ability of uranium and plutonium. The vapour pressure of hydrogen over the actinide hydrides is low at room temperature (eg. the pressure of tritium over uranium tritide is 1.6×10^{-6} mm and that of

deuterium over plutonium deuteride is 1.7×10^{-17} mm). The greater stability of the plutonium compound may explain the slower release of tritium from the plutonium samples during the extraction process. Despite the evidence for the retention of tritium within the irradiated capsules during their prolonged storage, some doubts remain. These will only be resolved by further work, probably by a further irradiation and measurement of tritium after a short storage period.

Over-estimation of the number of fissions per specimen is an unlikely explanation for the relatively low yields of tritium per fission. While minor refinement of the current values is feasible, the reduction needed to bring the tritium yield for plutonium into line with other values is unreasonably large.

If the tritium yields per fission obtained in this programme are erroneously low, the cause is most probably tritium loss during storage, although incomplete recovery could contribute for plutonium. However, throughout the history of the measurement of tritium yields in fission, there has been a tendency for values based on chemical recovery of tritium to be lower than those based on the direct measurement of emitted particles during neutron irradiation. The current results follow this trend, perhaps in an exaggerated manner.

2.2 Absolute Fission Yields of Selected Fission Products (T W Kyffin (DNPDE))

The aim is to measure Nd nuclides, ^{90}Sr, $^{95}Nb/^{95}Zr$, ^{106}Ru, ^{137}Cs, ^{144}Ce and nuclides in other chains where fission yield data are required for high burn-up samples of ^{235}U, ^{238}U, ^{239}Pu, ^{240}Pu and ^{241}Pu. Pins containing the fission yield samples have been pulled from the sub-assembly and the individual pinlets recovered. Of the 12 pinlets irradiated, two failed completely (one ^{239}Pu sample and the ^{240}Pu specimen), and two have lost their fission gas although the fuel remains intact (both ^{238}U). The remaining three ^{235}U, two ^{239}Pu, one ^{241}Pu and two dummy pinlets are complete, and are now stored in the analytical facilities at DNPDE awaiting a decision on funding. Proposals have been formulated in the hope of obtaining support for completion of the experiment.

2.3 Measurement of Alpha in PFR (A Tyrell and P Thompson (AWE))

Measurements of alpha from the PFR neutron spectrum have been completed, and the data reported in previous UKCNDC Progress reports for 1987 and 88. A final report will be prepared in 1990.

2.4 Measurement of Radionuclide Decay Data (M F Banham, A J Fudge, I Jackson and R A P Wiltshire (Harwell Laboratory))

Efforts have continued to improve the measurement facilities which include a full range of alpha-particle and gamma-ray counting and spectroscopy systems. Accreditation of the

laboratory under the National Physical Laboratory NAMAS scheme is being sought for measurements of alpha-particle emitters. Although gamma-ray measurements are not included in this scheme, several gamma-ray spectrometers are now subject to strict quality control procedures.

Work has continued in the follcwing areas:

(a) Studies of ^{93m}Nb

Production of a standard solution of ^{93m}Nb is underway, using a quantity of niobium metal irradiated for many years in the Dounreay Fast Reactor. Thus, the ^{93m}Nb specific activity is very high and radionuclide impurities, including ^{94}Nb, are very low. Calibration of this solution is being carried out in collaboration with PTB (Federal Republic of Germany) and the National Physical Laboratory. The calibrated solution will be primarily of interest in the field of fast-neutron dosimetry, but may also be of value for the calibration of x-ray spectrometry systems (16 to 18 keV).

(b) Preparation of sources for nuclear data measurements

The preparation of actinide nuclide sources for use in other laboratories continues, including ^{236}Pu, ^{227}Ac and ^{232}U.

(c) Decay scheme of ^{237}Np

The evaluation of the decay scheme of ^{237}Np has continued with new measurements in the low energy region of the gamma-ray spectrum (below 25 keV). These measurements were carried out in collaboration with Imperial College, and involved a CASE award student working at Harwell (1).

(d) Decay scheme of ^{239}Np

Measurements of half-life, P_X and P_γ are being carried out by a CASE award student at Imperial College, funded and partially supervised by Chemistry Division, Harwell.

2.5 Measurements and Evaluations of Gamma-ray Emission Probabilities (I M Lowles, T D MacMahon, L Longoria-Gandara and M U Rajput (Imperial College Reactor Centre, Ascot))

A number of specific spectroscopic measurements and evaluations have been undertaken following requests from BNFL plc and the IAEA:

(a) Measurements have been undertaken of the gamma-ray emission probabilities of ^{125}Sb, ^{154}Eu, ^{237}Np and ^{239}Np (2).

(b) Evaluations of the decay schemes for ^{125}Sb and ^{154}Eu have been completed on the basis of the published data, including experimental and theoretical conversion-electron emission probabilities.

(c) Efforts have been made to reconcile the experimental decay data for ^{237}Np involving alpha-particle, gamma-ray and conversion-electron emission probabilities (1).

(d) The principles underlying ad hoc and Bayesian data evaluation procedures have been compared (3); the Bayesian approach is recommended on the basis of the piecemeal nature of some of the ad hoc procedures.

2.6 Measurements and Reviews of Decay Data (P Christmas, D Smith, M J Woods, S A Woods, A S Munster, C W A Downey (NPL) and R D Daniels (University of Manchester))

(a) The measurement of the half-life of ^{90}Sr continues.

(b) A paper on the half-life of ^{125}I has been published in Nucl. Instrum. Methods (4).

(c) The results of the measurement of decay scheme parameters and the half-life of ^{124}I are being finalised.

(d) A paper on the gamma-ray emission probabilities of ^{201}Tl has been accepted for publication in Int. J. Appl. Radiat. Isot.

(e) Half-life tables have been updated and re-evaluated for the NPL/PTB contribution to the IAEA-CRP on X- and Gamma-ray Standards for Detector Calibration. Three extra radionuclides have been added - ^{228}Th, ^{239}Np and ^{241}Am. The tables will be published by the IAEA Nuclear Data Section.

(f) New half-life measurements are in progress for radionuclides which have been identified as not being known with sufficient accuracy, viz. ^{3}H, ^{56}Co, ^{57}Co, ^{58}Co, ^{65}Zn and ^{75}Se.

(g) A critical review of published ^{137}Cs half-life values, with recommendations on evaluation procedures, has been published in Nucl. Instrum. Methods (5).

(h) The SERC-supported collaboration with the University of Manchester has continued. A paper on the internal conversion electron spectrum following the decay of ^{244}Cm has been published in Nucl. Instrum. Methods (6). Papers are being prepared on the internal conversion following ^{241}Am decay and the very low-energy internal conversion following ^{237}Np decay.

(i) Equipment for the establishment of ^{3}H and ^{222}Rn standards has been commissioned.

3 UKCNDC DATA LIBRARY SUB-COMMITTEE

Membership during 1989:

A Tobias	BNL (Chairman)
M F James	WTC (Secretary)
A J Fudge	Harwell Laboratory
A Whittaker	BNFL plc
R W Mills	University of Birmingham
D R Weaver	University of Birmingham
T D MacMahon	Imperial College, Ascot

3.1 Data Library Development

The current status of the UKCNDC Data Libraries is summarised in Table 6. While there has been some progress in the evaluation of data for individual nuclides, there has been no effort available to incorporate these data into the UK files. It should be noted that the JEF-1 decay data and fission yield data files have been endorsed by the Differential and Integral Study Group (DIDSG) for use in the UK. All UK evaluations have been made available for use in JEF-2.

(a) Fission Product Decay Data (A Tobias (CEGB, BNL))

There is no progress to report for the UKCNDC fission product decay data files due to lack of effort. However, there has been some involvement with the JEF Working Group in assessing the proposed improvements to be made for JEF-2.

(b) Activation Product Decay Data (A L Nichols and P Robb (WTC))

Decay data evaluations for ^{51}Cr, ^{55}Cr, ^{65}Zn, ^{75}Se and ^{198}Au have been completed and evaluations of ^{45}Ca and ^{65}Ni decay scheme data are in hand. Literature data have also been collated for ^{47}Sc, ^{55}Fe, ^{55}Co, ^{58}Co, ^{59}Ni, ^{60}Co and ^{74}As.

The final official meeting of the IAEA Coordinated Research Programme on the Measurement and Evaluation of X- and Gamma-ray Standards for Detector Efficiency Calibration was held in Braunschweig, Federal Republic of Germany from 31 May to 2 June 1989. Work undertaken by the participants was reviewed in detail, and actions were agreed to resolve specific issues and problems. Initial steps were also made to establish a format and procedure for the preparation by mid-1990 of an IAEA Technical Reports Series booklet (7); the measurements and recommended data will be listed, and a IAEA data file established for issue to all interested organisations. The tables associated with the evaluation of decay data for ^{51}Cr have been modified to incorporate

the OMH measurement of P_γ in the final evaluation for the IAEA-CRP. The gamma-ray emission probabilities for ^{65}Zn have been re-evaluated following new measurements reported by PTB (ICRM Symposium, Braunschweig). An ICRM intercomparison by Jedlovszky (OMH) involves recently measured decay data for ^{75}Se from the various national standards laboratories. Earlier data have been combined with this study to produce a new recommended data set for the IAEA-CRP. Decay data have also been evaluated for ^{198}Au and ^{243}Am.

(c) Heavy Element Decay Data (A L Nichols (WTC))

A specialists' meeting was held at IAEA headquarters in Vienna from 7 to 9 November to assess progress made in the measurement of transactinium decay data. The decay data evaluated in the IAEA Technical Reports Series No 261 (1986) was reviewed; emphasis was placed on assessing the transactinium decay data identified in Part 2 of this IAEA booklet, which was produced in 1986 by the Coordinated Research Programme on the Measurement and Evaluation of Transactinium Decay Data. While most of the contents are still valid, some new measurements and additional data requirements necessitate an update. It was recommended that the IAEA issue a new edition by the end of 1990, including the changes and additions mentioned below.

The original data will be supplemented by new evaluations of ^{236}Np and daughters by A L Nichols (WTC), and ^{238}U and daughters and ^{239}Np by N Coursol (LMRI, France). New evaluations are required by C W Reich (INEL, USA) on ^{237}Np and by A L Nichols (WTC) on the half-life of ^{241}Pu and decay data of ^{243}Am. A re-evaluation of the P_γ data for ^{239}Pu is also recommended. This exercise should provide the basis for defining the final ENDF/B-V (or VI) data set to replace UKHEDD-1 in the UKCNDC library.

(d) Fission Yields (R W Mills and D R Weaver (University of Birmingham), and M F James (WTC))

A new evaluation of independent fission product yields has been completed and an independent yield library has been prepared. A cumulative yield library is also being prepared which will be available in early 1990. The existing evaluation consists of four main components, described in detail below:

(a) production of a database of experimental fission product data,

(b) checking the data for consistency with other values in the database, duplication of data and mistakes in entry,

TABLE 6: UK CHEMICAL NUCLEAR DATA LIBRARIES

Status Table - December 1989

Data	Present Studies	File Development
1 Fission Product Decay Data	Part of JEF-1 Decay Data Files, which include UK evaluations (ENDF/B-V format). UKFPDD-2 library (ENDF/B-IV format) superseded, but largely included in JEF-1.	Robb (AEEW) evaluating ^{155}Eu, ^{152}Eu, ^{151}Sm, ^{134}Cs ^{129}Sb and ^{125}Sb. P_n values for delayed neutron precursors from Swedish evaluation. Delayed neutron precursor spectrum from Kratz et al and Rudstam et al. These data will be submitted to JEF.
2 Activation Product Decay Data	Part of JEF-1 Decay Data Files, which include UK evaluations (ENDF/B-V format). UKPADD-1 in ENDF/B-IV and -V formats for 91 nuclides now superseded, but many of these evaluations are in JEF-1.	60 nuclides have been evaluated for UKPADD-2; 56 are in ENDF/B-V format. ^{51}Cr, ^{65}Zn, ^{75}Se and ^{198}Au have been re-evaluated as part of an IAEA programme and they are available in ENDF/B-V format. All evaluations will be submitted to JEF.
3 Heavy Element and Actinide Decay Data	Part of JEF-1 Decay Data Files, which include UKHEDD-1 evaluations (ENDF/B-V format).	^{236}Np, ^{236m}Np, ^{236}Pu, ^{232}U, ^{228}Th, ^{224}Ra, ^{220}Rn, ^{216}Po, ^{212}Pb, ^{212}Bi, ^{212m}Bi, ^{212n}Bi, ^{212}Po, ^{212m}Po ^{212n}Po and ^{208}Tl evaluations completed. Evaluation of ^{243}Am is underway. ^{231}Pa, ^{234}U and ^{242m}Am ^{239}U decay data and half-life have been evaluated. These data will be submitted to JEF.
4 Fission Yields	JEF-1 fission yields based on UKIFY-1 evaluation. UKIFY-2 (Mills and James) now complete and submitted to JEF-2 (ENDF/B-V format): 39 sets of evaluated independent yields for 22 fissile nuclides adjusted to satisfy conservation of nucleons and charge	Report on evaluation being written. Cumulative yields and uncertainties will be calculated.

Spectral data from the decay data files may be accessed via the retrieval system described by Tobias (RD/B/5170N81, 1981).

(c) production and use of programs to evaluate the database, fit the data to various models and use model predictions to fill gaps in the experimental data,

(d) adjustment to physical constraints and production of ENDF/B-VI formatted libraries using the fission yield data and JEF-2 decay data.

An experimental fission yield database (UKFY2) has been produced in a new format, using data from the earlier UKFY1 evaluation (and some data from the Crouch database (1981) which was not included in UKFY1), the EXFOR database and recently published papers. The database contains neutron-induced (thermal, epi-thermal, fast, 14MeV and monoenergetic) and spontaneous fission yield data which can be described as (or converted to) one of the following measurement types: direct, relative or ratio-to-ratio. Independent, cumulative and chain yield measurements are included. Yields of fission fragments were not used unless several ionic charges and kinetic energies were summed. There are currently no photofission or charged particle fission yields included in the database, although these can be added with only minor program extension.
The references are believed to be complete up to the beginning of 1989; no references or corrections have been added since 24 October 1989. The number of data from each of the 3 sources are shown in Table 7.

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TABLE 7: DATA IN UKFY2, VERSION 1

Source	Chain	Fractional Independent	Fractional Cumulative	Cumulative	Independent
UKFY1	1226	249	209	5406	289
EXFOR	1072	608	116	2151	608
new papers	33	28	29	880	54
Total (UKFY2.1)	2331	885	354	8437	951
%(EXFOR+new)	47.4	71.9	41.0	35.9	69.6

(percentage EXFOR + new data in database) = 43.1%

Weighted means of the measurements in the database were calculated: relative and ratio-of-ratio measurements were included after an initial run was made with only absolute measurements to obtain yields of standard fission products. The averaging programs also produced internal and external standard deviations, and discrepancy tables. The

discrepancy tables show yields which gave a Chi-squared of less than 10%, and such measurements were automatically down weighted using an agreed procedure. The discrepancy tables were used to debug the database, with discrepant values being checked back to original references when possible. The cumulative and independent yields were interconverted between absolute and fractional values by the main experimental chain yields before averaging.

The weighted mean chain yields and fractional independent yields were fitted to the Musgrove model (8) and the Wahl Z_p model (9) respectively. Various methods were used to fill gaps in the database within the mass range 50 to 200, and parameters of the Musgrove fits were extrapolated for systems with no data. The experimental chain yield data were given highest priority: small gaps of one or two masses were filled by a log-linear interpolation, while larger gaps were filled by the Musgrove model parameters (those predictions being normalised to agree with the experimental data). Very good agreement was found for a few masses when plotting log (chain yield) vs fission mass ($A_f=A-\bar{\nu}_p$) and these were used where possible (in only seven cases) in preference to the Musgrove predictions. Ternary products for ^{4}He and ^{3}He were calculated from functions based upon Z_f*Z_f/A_f where no experimental values were available. Other ternary products were included only when experimental data existed in the database. For fractional independent yields, the Z_p parameters were derived from the weighted average data, and the fitted Z_p parameters were extrapolated for systems with insufficient or no data to fit. These parameters were used to produce complete sets in the mass range from 50 to 200.

The complete independent yield data sets for the systems of interest were adjusted to fit physical constraints by a least-squares method (Table 8). These adjusted data sets were converted to ENDF/B-VI format. The cumulative yields will be produced from these adjusted data sets using a preliminary vision of the JEF-2 decay data. These adjusted cumulative yields will be available early in 1990, along with full documentation of the work.

TABLE 8: SYSTEMS INCLUDED IN UKFY2 EVLAUATION (21 NUCLIDES)

Maximum Fission Rate in a Power Reactor			
> 10%	1 - 10%	0.1 - 1%	Spontaneous Fission
*^{233}U TFH	*^{240}Pu F	*^{232}Th FH	^{252}Cf Sp
*^{235}U TFH	^{245}Cm TF	^{234}U F	^{242}Cm Sp
*^{238}U FH		^{236}U F	^{244}Cm Sp
*^{239}Pu TF		^{237}Np TF	
*^{241}Pu TF		^{238}Np TF	
		^{238}Pu TF	
		^{242}Pu F	
		^{241}Am TF	
		^{242m}Am TF	
		^{243}Am TF	
		^{243}Cm TF	
		^{244}Cm TF	

*Nuclides in UKFY1 and previous UK libraries
T, Thermal fission
F, Fast fission
H, 14MeV fission
Sp, Spontaneous fission

3.2 Joint Evaluated File, JEF (P Robb (WTC))

Work has continued to prepare data for inclusion in JEF-2 which is due to be released early in 1990. The possibility of using ENSDF to fill some of the gaps in JEF-1 has been explored. However, there are problems in using automatic methods to insert ENSDF data into JEF. Most of the problem data can be detected by the FISCON program, and selected ENSDF data are to be included in JEF-2. Mean beta and gamma energies of a number of short-lived nuclides have been measured, and it is anticipated that these will be included in JEF-2. If the results of these measurements are not available in time then theoretical data will be used. In addition, improved fission yield evaluations are available for inclusion in JEF-2.

4 CONCLUSIONS

4.1 Measurements of fission product yields and decay data require dedicated and specialist staff who have been suitably trained and maintained their expertise in these areas. At the present time, radiochemistry laboratories that undertake this work within the Authority are seriously threatened. The main experimentalists are based at Harwell and Dounreay, and recent actions have seriously jeopardised the feasibility of maintaining these specialist laboratories. More importantly, suitable personnel to

undertake this work have been redirected into studies that could easily undermine their abilities to undertake the type of measurements discussed above. The UK is in danger of losing expertise in critical areas of nuclear technology.

4.2 The evaluation programme during 1989 has been somewhat healthier than originally envisaged. Efforts continue to provide good quality data files for inclusion in the Joint Evaluated File (JEF), and significant progress has been made in preparing appropriate fission yield data.

REFERENCES

1. I M Lowles, T D MacMahon, M F Banham, A J Fudge and R A P Wiltshire. Reconciliation of ^{237}Np Decay Scheme Data, Nucl. Instrum. Methods Phys. Res., A286, 556, 1990.

2. L Longoria-Gandara, M U Rajput and T D MacMahon, Gamma-ray Emission Probabilities in the Decay of ^{65}Ni and ^{125}Sb, Nucl. Instrum. Methods Phys. Res., A286, 529, 1990.

3. P W Gray, T D MacMahon and M U Rajput, Objective Data Evaluation Procedures, Nucl. Instrum. Methods Phys. Res., A286, 569, 1990.

4. M J Woods and S E M Lucas, The Half-life of ^{125}I, Nucl. Instrum. Methods Phys. Res., A286, 517, 1990.

5. M J Woods, The Half-life of ^{137}Cs - A Critical Review, Nucl. Instrum. Methods Phys. Res., A286, 576, 1990.

6. J Pearcey, S A Woods and P Christmas, The Internal Conversion Spectrum Following ^{244}Cm Alpha-particle Decay, Nucl. Instrum. Methods Phys. Res., A286, 563, 1990.

7. A L Nichols, X- and Gamma-ray Standards for Detector Efficiency Calibration, Nucl. Instrum. Methods Phys. Res., A286, 467, 1990.

8. A R del Musgrove, J L Cook and G D Trimble, IAEA-169, Review paper 16, 163, 1973.

9. A C Wahl, Atomic and Nuclear Data Tables, 39(1), 1, 1988.