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Report

UK Nuclear Science Forum

Progress Report: Data Studies During 1995

Edited by A L Nichols

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1. INTRODUCTION

The UK Nuclear Science Forum (UKNSF) provides a suitable environment within the UK for technical discussions on the measurement and evaluation of primary nuclear data (e.g., neutron cross sections, decay data and fission yields). Furthermore, the Forum has the support of the UK Department of Trade and Industry and the nuclear-based Industry Management Committee (IMC) to act as the communications network for all matters relating to the NEA Data Bank and the Nuclear Science Committee. A Memorandum of Understanding is in the process of being drawn-up between the UK Department of Trade and Industry and the UKNSF to confirm the role of the Forum.

The UKNSF encompasses the functions of the Differential and Integral Data Study Group (DIDSG) and the UK Chemical Nuclear Data Committee (UKCNDC). DIDSG documents are archived at Winfrith and UKCNDC reports at Sellafield. Although complete sets are not yet available, copies of most documents can be obtained from the UKNSF Secretary.

Two meetings of the UKNSF were held in 1995 on 4 May and 14 December (Chairman, A L Nichols (AEA Technology plc, Harwell) and Secretary, R W Mills (BNFL plc)). Membership covers approximately 20 different organisations, including nuclear plant operators, vendors, regulators, non-energy applications, academia, and various data measurers and evaluators. Efforts have continued during the year to formulate an agreed, comprehensive request list for nuclear data needs within the UK; this work is almost complete, although awaiting confirmatory comments from one major contributor.

2. MEASUREMENTS

2.1 Measurement and Evaluation of Nuclear Data

(S A Woods, J L Makepeace, M J Woods, D H Woods, N E Bowles and J D Keighley (National Physical Laboratory, Teddington))

While the demand for NPL to provide recommended radionuclide decay data has continued during the period of this report, the resources available to undertake activities relating to the measurement and evaluation of nuclear data have remained at a low level. Three projects have an active status.

(i) Recommended radionuclide decay data for 53 radionuclides not covered by IAEA TECDOC-619 have been published as an NPL external report (1). The data are also available in a format suitable for PCs. These radionuclides are primarily supplied as standards by NPL.

(ii) Work has continued on the standardisation and measurement of selected decay scheme parameters of $^{243}Am/^{239}Np$ (see reference 2) and ^{237}Np. Problems with the chemistry of equilibrium solutions of ^{237}Np and daughter radionuclide (^{233}Pa) have been identified and are being investigated.

(iii) Half-life data for ^{90}Sr have been collected at NPL over a period of six years, and have been evaluated (3).

2.2 Decay Scheme Data

(S I Kafala, T D MacMahon, A Nzuruba, D Sardari and K Usman (Centre for Analytical Research in the Environment, Imperial College at Silwood Park, Ascot))

(i) The half-life of ^{233}Th has been determined by gamma-ray spectroscopy. Gamma-ray spectra of three ^{233}Th sources produced in the Imperial College reactor were measured for up to five half-lives. The decay of each of 14 of the more prominent peaks in the spectra were used to make a precise determination of the ^{233}Th half-life. The result of a careful analysis of all the data leads to a value of 21.83(4) min, which is significantly lower than the currently accepted value of 22.3(1) min (based originally on the decay of a single gamma ray from a single source).

(ii) An investigation has been carried out into reported inconsistencies in the gamma-ray emission probabilities in the decay of ^{226}Ra, and the data are being analysed.

(iii) ^{239}U beta decay and ^{243}Am alpha decay populate excited nuclear levels of ^{239}Np. Studies of these two decay processes have been completed and the data published (4).

2.3 An Epithermal Neutron Beam for Use in Boron Cancer Therapy

(D Tattam and D R Weaver (University of Birmingham))

Work continues at the University of Birmingham to produce an epithermal neutron beam for use in Boron Cancer Therapy. During 1995, higher proton beam currents have been used with a redesigned lithium target holder in order to provide higher neutron fluences at the measurement positions located at the exit from the prototype moderator assembly. Work has concentrated on foil activation in a water phantom, and there has been collaboration with workers from Harper Hospital (Detroit, USA) who have undertaken microdosimeter measurements in the phantom. The MCNP code is being used to model the assembly. Developments have included the use of heavy water and lithium salts to absorb thermal neutrons in the water tank of the moderator.

2.4 Fast Fission of Uranium 238

(M A Kellett and D R Weaver (University of Birmingham))

The aim of the project is to measure the absolute yield of delayed neutrons from the fast fission of ^{238}U. These studies involve the use of the 3 MV Dynamitron accelerator within the School of Physics and Space Research at the University of Birmingham. Using this facility neutron beams of order 1×10^9 n sr^{-1} s^{-1} with monoenergetic energies between 3 and 6 MeV (and ~100 keV energy spread) can be obtained using deuteron bombardment of a titanium deuteride target. The associated angular dependence of the target neutron yield has been measured using indium foil activation, and validated with a FORTRAN code written specifically for this purpose. The uranium foils are placed very close to the deuterium target to facilitate maximum irradiation against Dynamitron run times, and therefore a large solid angle is subtended so that the variation of the neutron flux density across the region needs to be measured.

A new high-efficiency counter comprising a piece of high-density polyethylene moderator and an array of BF_3 tubes has been constructed. The finer details of this design were

modelled using the MCNP Monte Carlo code with ENDF/B-V data files. This new counter has been calibrated against standard neutron sources (AmBe and AmLi), as well as neutron beams produced by the bombardment of a pure lithium metal target with protons to give an energy spectrum similar to that of delayed neutrons. These experiments have also been simulated with the MCNP code.

Thorough calibration of a recently acquired ^{238}U flat-plate fission chamber has been completed, and is now ready for use in the delayed-neutron production runs. A new sample shuffler system (to move the uranium between the irradiation and delayed-neutron counting positions) is currently undergoing consistency checks, and runs for delayed-neutron measurements are planned for the immediate future.

This work is being carried out with financial support from the former European Fast Breeder Reactor Programme.

2.5 Cross-Section Studies

(C J Dean (Winfrith))

The burn-up credit experiments in DIMPLE gave reactivity worths for actinides and fission products consistent with those from the MINERVE reactor at Cadarache. Analysis has shown the importance of calculating resonance shielding in the highly-doped fission product samples. The global reactivity loss from fission products and actinides was well predicted using JEF-2.2 data, but there were surprising differences (~10%) for some individual fission products e.g. ^{149}Sm.

The graphite/steel shielding experiments in NESTOR validated the prediction of spatial variation of neutron damage using the DPA/Ni ratio model in the MCBEND computer code. The experimental results have also been used to study the importance of vessel damage at thermal energies resulting from nuclear recoil in (n,γ) reactions.

Both the DIMPLE and NESTOR experimental reactors at Winfrith were shut down in June 1995.

3. DATA LIBRARIES: EVALUATIONS

3.1 Data Library Developments

The status of the UK Decay Data and Fission Yield Libraries is summarised in Table 1. Progress has been maintained in the evaluation of specific decay data (primarily activation products). These studies have been undertaken to assist in the further development of the Joint Evaluated Files (JEF).

Table 1: *UKNSF Decay Data and Fission Yield Libraries - Status Table, December 1995.*

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.	None, but see UKPADD-3.
Activation product decay data	UKPADD-3 library (ENDF/B-VI format) has been completed: comprehensive decay-scheme data for 328 activation products (and some fission products) have been evaluated for this library, including the addition of 97 further radionuclides.	Preparations are being made to evaluate the decay data of a further set of radionuclides (including some fission products) agreed through the NEA Data Bank.
Heavy element and actinide decay data	UKHEDD-2 evaluations (ENDF/B-VI format) have been submitted and absorbed into JEF-2.2.	UKHEDD-2.1 includes newly recommended decay data for Pa-234g and Pa-234m.
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.	The evaluations for UKFY-3 have been completed, and a file produced for use with JEF-2.2 decay data. A further update is envisaged when JEFF-3 decay data become available.

(a) Activation and Fission Product Decay Data - Evaluations (A L Nichols (Harwell))

Evaluations have been completed to improve the UK decay-data files for the following radionuclides, and so contribute to the continued evolution of the JEF library:

^{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, ^{103m}Rh, ^{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, ^{129m}Xe, ^{131m}Xe, ^{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, ^{183m}W, ^{201}Tl, ^{202}Tl, ^{202}Pb, ^{202m}Pb, ^{203}Pb, ^{203m}Pb, ^{203n}Pb, ^{205}Pb and ^{223}Rn.

All decay data for these radionuclides have been evaluated and incorporated in UKPADD-3 as highly consistent data files (5,6). This work was funded by British Nuclear Fuels plc.

(b) Heavy Element and Actinide Decay Data - Evaluations (A L Nichols (Harwell))

An improved version of the UK Heavy Element and Actinide Decay Data Library has been assembled (UKHEDD-2.1). Minor corrections have been made to some of the spontaneous fission data, and the new data files for ^{234m}Pa and ^{234g}Pa have been incorporated into the database (7).

All relevant references have been assembled to undertake a comprehensive evaluation of the decay data for ^{234}Th. Although ^{234}Th and ^{234m}Pa are in secular equilibrium, the recommended

decay data for ^{234}Th are believed to be inconsistent in this respect when compared with recently measured and evaluated decay data for short-lived, daughter ^{234m}Pa. Values between 0.040 and 0.048 have been adopted in previous evaluations for the absolute emission probability of the 63.30 keV gamma ray of ^{234}Th. The current re-evaluation has resulted in a recommended value of 0.037 ± 0.002, based on the most recent measurements in the late 1980s and a re-assessment of earlier studies. This specific item of work has been funded by HMIP.

3.2 Theoretical Calculations and Neutron Cross-Section Evaluations

(S I Kafala and T D MacMahon (Centre for Analytical Research in the Environment, Imperial College at Silwood Park, Ascot))

(i) Work has commenced on an attempt to carry out up-to-date calculations of internal conversion coefficients and to make estimates of the uncertainties in these data.

(ii) Experimental cross section data for the following reactions are being evaluated: ^{10}B(n,α), ^{10}B(n,total), ^{14}N(n,p), ^{17}O(n,α), ^{56}Fe total, inelastic and capture and ^{242}Pu fission and capture in the neutron energy range 10^{-5} eV to 20 MeV.

3.3 JEF-X

(R F Evans (BNFL plc))

JEF-X is a graphical interface to the JEF-2.2 database for use on X-Window based work-stations, emulating the functionality of JEF-PC (see also Section 4.2). This work began as a Birmingham University MSc project under the supervision of D R Weaver, and is now being developed at BNFL, Sellafield.

Initially the code displayed only the decay, fission product yield and grouped JEF-2.2 cross-section data, but the software has now been developed to include access to JEF-2.2 point-wise cross-section data, to overlay fission yield curves, and to output encapsulated POSTSCRIPT files.

Future work is planned to allow access to other point-wise cross-section files, and typical average cross-sections and flux spectra for different reactor types.

3.4 Fission Product Yield Evaluations

(D Hale (University of Birmingham), R W Mills (BNFL plc), D R Weaver (University of Birmingham))

The UK group remains involved in the IAEA Coordinated Research Programme on the Compilation and Evaluation of Fission Yield Nuclear Data, and the JEF programme of the NEA.

The UKFY-3 evaluation was completed in 1994, and has been written up as a PhD thesis (8). This document includes a comprehensive description of the evaluation from the collection of basic data to the production of the final evaluated nuclear data file in ENDF/B-6 format. Methods of fission product yield data analysis and modelling are also extensively examined.

A study is being made of the mechanisms that underpin fission product production; this work should allow modelling of the fine structure that appears on the peaks and valley of the mass distribution. The Wahl Ap' model will be applied to the isobaric yield data (where possible) in order to see if this approach is an improvement over the Zp model. Fission theory will be carefully examined to pursue the question of the variation of the fission yields with incident neutron energy to determine the effects on parameters such as yield of burn-up monitors and yields of nuclides significant to decay heat and disposal. The delayed neutron data will be evaluated and the possible application of these data to the adjustment of the fission yield data will be investigated. The effect of correlations in the input data used in the generation of the evaluated file will be examined to determine their impact on the actual values of the fission yields produced and on their uncertainties both within particular fissioning systems and between systems.

All of the above work is funded by British Nuclear Fuels plc.

3.5 Cross-Section Evaluations

(C J Dean (Winfrith))

Development of the fusion-orientated European Activation File (EAF) has continued at Culham and Harwell. New data are mainly based on model calculations optimised to 14 MeV values. The preliminary EAF4.2 library contains data for over 13,000 neutron/nucleus reactions, including data for many metastable nuclei. An assessment of ^{235}U data has also begun as proposed by Derrien et al for JEFF3.0.

3.6 Cross-Section Evaluation of Resonance Parameters for Cs-133

(M C Moxon (consultant to AEA Technology, Harwell))

The neutron cross sections of ^{133}Cs have been examined, and discrepancies identified for the capture cross section in the low-energy resolved resonance region. Work is being undertaken to examine and resolve these discrepancies. This work is funded by British Nuclear Fuels plc.

3.7 Processing of Cross-Section Data

(C J Dean (Winfrith))

JEF-2.2 and other evaluated data have been reformed into group cross section libraries using mainly the NJOY code. A new 1996 DICE library has been generated for MONK (criticality) and MCBEND (shielding). The group structure has been extended to 13,139 groups. More groups have been introduced at low energy to improve results for nitrate criticality benchmarks. The benchmark programme has shown the high-energy group structure to be valid for reactor shielding, providing that two sub-groups are used for the major components of steel. The 1996 WIMS library (reactor physics) includes revised resonance shielding data. A validation of the fission product and actinide representations resulted in the introduction of decay data for ^{239}Pu and ^{240}Pu. Both libraries have undergone significant benchmark testing.

Inventory code developments include the introduction of DUMP facilities into FISPIN, enabling modern post-processing tools (e.g. spread sheets) to be used to generate the required output quantities without introducing complex editing facilities into the code.

4. INTERNATIONAL COOPERATION

4.1 Data Files

(C J Dean (Winfrith))

The UK contributes to several OECD/NEA and IAEA programmes on nuclear data development: the main programme involves the Joint Evaluated File (JEF). UK representatives report back to the UKNSF and raise items of importance to members. The assembly of a new data base called the Joint Evaluated Fission and Fusion (JEFF3) file was described by the JEF chairman Ph Finck during a UK visit in April 1995. The starter file (JEFF3.0) will be based on data from the European Fusion File (EFF3) for light and structural materials, with JEF-2.2 data used for fission products, heavy elements and actinides. However a significant number of evaluations will come from other later evaluations e.g. US ENDF/B-VI library. There will be no further development of JEF-2.2 and any adjustments will be made to application libraries, including absorption of JEFF3.0 files if deemed to be appropriate.

At the suggestion of the UK nuclear industry, a significant quality assurance programme is being formalised and introduced for the assembly of JEFF3. The quality plan allows evaluation developments to take place only after the approval of the evaluator. A new data base has been developed at the NEA Data Bank to store all of the evaluated libraries.

4.2 JEF-PC: A PC-based Program to Display Data From the JEF-2.2 Library

(D R Weaver, I Baynham, D Hale and R A Weaver (University of Birmingham))

The end of 1994 saw the launch by OECD of the first version of JEF-PC. During 1995 work has been undertaken on five different areas of development.

(a) Decay chain identification: an initial point in a decay chain can be selected, and this results in the highlighting of all the daughter states accessed through either the principal or any subsidiary decay modes listed in the JEF-2.2 data file.

(b) Integral cross-section data: the cross-section module now contains an option for the display of cross sections and resonance integrals averaged over certain thermal and fast spectra.

(c) Reactor spectrum weighted group cross sections: a selection of typical reactor spectra have been produced together with the option to produce group cross sections based on these weightings.

(d) Parameters other than cross sections: included with the cross-section information in JEF-2.2 there are a number of parameters such as average cosine for scattering angle and average logarithmic energy decrement; these are now available as a separate list from the cross sections.

(e) Improved selection capabilities for the alpha and photon line option: allows the user to specify bounds on energy, intensity and half-life, thereby simplifying searches.

A number of improvements to the code have also been implemented, based on feedback from users of the published version.

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