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United Kingdom Nuclear Science Forum

Progress Report

Data Studies During 2008

Edited by N P Hawkes

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Edited by N P Hawkes
Acoustics & Ionising Radiation Division

ABSTRACT

The United Kingdom Nuclear Science Forum (UKNSF) meets twice a year to discuss issues relating to the measurement and evaluation of nuclear data. Topics cover a wide range of applications in the UK nuclear industry. Links between members are maintained throughout the year, mainly through e-mail and the UKNSF website (www.uknsf.org.uk). Work of primary interest includes the measurement and evaluation of decay data (e.g. half-lives and gamma ray emission probabilities), fission yields, and neutron cross sections for fission and fusion. All known studies within the UK are summarised in this report. Specific applications and international links of relevance are also described.

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authorised by Martyn Sené, Director of Operations

Contents

1 Introduction

The United Kingdom Nuclear Science Forum (UKNSF) encourages technical discussions on the measurement and evaluation of nuclear data. Membership ranges across approximately 30 UK organisations. The Forum is funded by the Health & Safety Executive (HSE), and acts as the communication network for matters relating to the NEA Data Bank and the IAEA Nuclear Data Section.

During 2008, UKNSF members have assisted the NEA Nuclear Science Committee to formulate and progress programmes of work and to define priorities.

The Neutron Metrology Group at the National Physical Laboratory (NPL) provides the secretariat for the UKNSF, and the Forum's web site is at www.uknsf.org.uk. The Forum was chaired by R. A. Forrest of the Culham Centre for Fusion Energy during the period of this report, and the secretary is N. P. Hawkes of NPL.

The first UKNSF meeting of 2008 was held on 15th May at the Wessex Hotel, West Cliff Road, Bournemouth.

The second 2008 meeting was held at the National Physical Laboratory on 26th November.

2 Measurements

2.1 Radioactivity Metrology at NPL

Arzu Arinc, Chris Gilligan, Lena Johansson, Lawrence Jones, John Keightley, Peter Kolkowski, Andy Pearce, Neil Roberts, John Sephton, and Andy Stroak (Radioactivity Metrology and Neutron Metrology Groups, Acoustics & Ionising Radiation Division, National Physical Laboratory)

As in previous years, the National Physical Laboratory (NPL) has provided primary measurements according to the needs of the user community. The radionuclides studied were ^{3}H, ^{56}Mn, ^{64}Cu, ^{85}Kr, ^{99m}Tc, ^{134}Cs, ^{166m}Ho, ^{177}Lu and ^{210}Pb. The radionuclides ^{3}H and ^{85}Kr are significant in being gaseous; NPL is redeveloping its capability to provide primary standards of gaseous radionuclides. The radionuclides ^{64}Cu, ^{99m}Tc and ^{177}Lu are of medical significance and ^{166m}Ho and ^{210}Pb are primarily useful as calibration sources in gamma spectrometry. ^{210}Pb is also an important member of the ^{238}U natural decay chain.

The thermal neutron facility [1] of the Neutron Metrology Group was used to produce short-lived ^{56}Mn for the calibration of the manganese bath [2]. This successful trial may represent a route to producing and studying small amounts of short-lived radionuclides at NPL in future.

A dedicated ionisation chamber has been installed for half life measurements. Ongoing measurements include ^{64}Cu, ^{90}Y, ^{109}Cd and ^{177}Lu.

Financial support from the National Measurement Office (NMO) is acknowledged.

2.2 Neutron Cross Section Measurements for Hafnium Isotopes

T.C. Ware, M.C. Moxon (University of Birmingham) and C.J. Dean (Serco), in collaboration with P. Schillebeeckx, S. Kopecky and the measurement team at the Institute for Reference Materials and Measurements (IRMM), Geel, Belgium

The need for new neutron cross section measurement and evaluation is co-ordinated through the international High Priority Request List (HPRL) [3] maintained by the OECD/NEA Working Party on International Nuclear Data Evaluation Co-operation (WPEC).

In the nuclear industry hafnium is used as a neutron absorbing material to regulate the fission process. The HPRL has identified that interpretations of critical experiments with UOx fuel, conducted by the Commissariat à l'Énergie Atomique (CEA) in the AZUR zero-power reactor, have shown systematic underestimation of the reactivity worth. This is attributed to an overestimated natural hafnium capture cross section in the epithermal energy range.

To rectify this, the UK has participated in time-of-flight measurements on natural and isotopically enriched hafnium samples at IRMM, Geel, through the NUDAME project. The analysis of these measurements with the REFIT-2007 code [4] has begun with the objective of producing a new resonance range evaluation for the six natural hafnium nuclides. The use of isotopically enriched samples has allowed the allocation of resonances to the correct isotopes and extension of the resolved resonance ranges to

over 1 keV for ^{177}Hf and ^{179}Hf. This is significantly higher than those given in the current JEFF3.1 library (250 eV). Analysis with new and published measurements will continue during 2009. Results from new measurements will be added to the EXFOR database when they are fully assessed. The resultant evaluation will be submitted to the JEFF project in 2009 and will form the PhD thesis of T. Ware.

3 Nuclear Data Libraries and Data Evaluations

3.1 European Activation File development

R. A. Forrest (Culham Centre for Fusion Energy)

Fusion nuclear data work within Europe is funded by Fusion for Energy (F4E), the organisation responsible for ITER. However, there have been delays during the transition from European Fusion Development Agreement (EFDA) funding to F4E and there was no formal nuclear data programme during 2008. The Euratom / UKAEA Fusion Association has used the time to improve the 'infrastructure' for development of the European Activation System (EASY [5]) by updating of SAFEPAQ-II [6] to use the modern versions of Visual Basic (VB.NET) and Access. This rewriting will make the application easier to maintain and extend in the future. Similarly a contract on rewriting of FISPACT using FORTRAN-95 and more modern algorithms has been started.

Changes to SAFEPAQ-II (the application used to produce the EAF libraries) have been made to expand the various options available for the statistical analysis tool SACS. This feature is extensively used to test the physical consistency of the EAF libraries [7].

The update of the 'Activation Handbook' [8] has been completed. This large document (660 pages) contains importance diagrams for the stable elements using calculations made using EASY-2007. The lists of dominant nuclides and important reactions that can be extracted from these diagrams have been produced and will be used to define the future data needs for activation as regards neutron-induced cross sections and decay data. It is found that only about 3.5% of the reactions are classified as of 'major' importance and focussing on these both theoretically and experimentally will allow the next version of EAF to be produced efficiently. The Handbook also contains decay curves for five fusion relevant spectra and transmutation curves. Another important motivation for the Handbook is to enable users to obtain detailed activation data without running inventory codes such as FISPACT.

A workshop on Activation data for EAF-2009 will be held in Prague in March 2009. The presentations will be made available on the EASY-2007 web site (http://fusion.org.uk/easy2007/).

3.2 Evaluation and validation activities at the National Nuclear Laboratory (NNL)

R. W. Mills (National Nuclear Laboratory)

3.2.1 Fission Product Yield evaluations

In 2007 a review by the CEA revealed an inconsistency between independent and cumulative yields for the ^{137}I fission product yield from ^{235}U thermal neutron induced in the JEFF-3.1 file. A corrected file was placed on the feedback page in November 2007 [9]. In 2008 after testing, it was decided to incorporate this correction into the final version of JEFF-3.1.1, which is now available from the NEA.

Work continued on improving the energy dependent fission yields in UKFY4.0 [10]. The UKFY4.0 library included energy dependent fission product yield data resulting from fission induced by neutron, proton, deuteron and alpha particle induced yields for

21 nuclides (^{232}Th, ^{233}U, ^{234}U, ^{235}U, ^{236}U, ^{238}U, ^{237}Np, ^{238}Np, ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{241}Pu, ^{242}Pu, ^{241}Am, ^{242m}Am, ^{243}Am, ^{242}Cm, ^{243}Cm, ^{244}Cm, ^{245}Cm and ^{252}Cf). The range of particle energies considered was from 10^{-5} eV to 150 MeV. The required data were produced using the CYFP code developed at the Los Alamos National Laboratory for an IAEA Coordinated Research Activity (CRP) [11]. The new UKFY4.1 library [12] extends the existing library to include photon induced fission for the above nuclides and spontaneous fission yields for 39 nuclides identified in the JEFF-3.1.1 decay data library as undergoing spontaneous fission (^{230}Th, ^{232}Th, ^{231}Pa, ^{238}Pa, ^{232}U, ^{234}U, ^{235}U, ^{236}U, ^{238}U, ^{228}Np, ^{236}Pu, ^{238}Pu, ^{239}Pu, ^{240}Pu, ^{242}Pu, ^{244}Pu, ^{232}Am, ^{234}Am, ^{241}Am, ^{242m}Am, ^{242n}Am, ^{243}Am, ^{234}Cm, ^{242}Cm, ^{244}Cm, ^{246}Cm, ^{248}Cm, ^{250}Cm, ^{238}Bk, ^{240}Bk, ^{242}Bk, ^{249}Bk, ^{237}Cf, ^{238}Cf, ^{240}Cf, ^{242}Cf, ^{249}Cf, ^{250}Cf and ^{252}Cf). It should be noted that heavier nuclides exist in JEFF-3.1.1 that have a spontaneously fission decay branch, but due to their short half-lives and extremely low production in applied science it was decided that yield files were not needed. As before, the data have been generated using the CYFP code, but with some modifications to allow the photon induced and spontaneous fission to be handled. In addition to the extra data, the UKFY4.1 cumulative yields have been made consistent with the JEFF-3.1.1 decay data, by calculating them from the CYFP independent yields and decay data. It should be noted that this calculation of cumulative yields ignored decays from nuclides with half-lives of greater than 1000 years, as in the JEFF-3.1 and JEFF-3.1.1 fission yield library. The UKFY4.1 library has been released to the NEA for distribution to interested parties.

3.2.2 Inventory code validation

The decay heat produced by spent nuclear fuel is an important parameter of safety analyses for its storage, transport, reprocessing and waste management. Current decay heat validation using the UK inventory code FISPIN10 for PWR fuel is based upon 12 calorimetric measurements reported by Schmittroth [13]. Reported results using JEF-2.2 and JEFF-3.1.1 decay and fission yield libraries using the FISPIN code [14] give good agreement, the mean calculated over experimental (C/E) values being 1.03 ± 0.03 and 1.01 ± 0.03 respectively. However, the data have a limited range of irradiation (25.6 to 39.4 GWd/t), cooling (2.3 to 5.7 years) and enrichment (2.5% to 3.4%) [15 and 16]. Recently the Swedish Nuclear Fuel and Waste Management Company (SKB) carried out calorimetric measurements of decay heat from BWR and PWR assemblies at the Swedish Interim Spent Fuel Storage Facility, CLAB, at Oskarshamn [17]. These include 43 measurements of decay heat from PWR spent fuel and 66 of BWR. The PWR measurements range between 2.1% and 3.4% in enrichment, 19.7 - 51.0 GWd/t in irradiation and 13 - 23 years in cooling. This considerably extends the current FISPIN decay heat validation in irradiation and cooling. An initial assessment of the new PWR data using the FISPIN graphical user interface, FISGUI [14], with the generic PWR cross-section libraries with JEF-2.2 and JEFF-3.1 data, was produced for the NEMEA-5 conference [18]. This showed good agreement between calculation and experiment with the JEF-2.2 calculations giving a mean C/E of 0.995 ± 0.013 and JEF-3.1.1 giving 0.985 ± 0.012. The uncertainty on the heat measurements are reported as $\pm 2\%$, but it was noted that using cross-section libraries for different reactors could give rise to trends in decay heat of up to 5%. It is planned in 2009 to complete a more detailed validation exercise with both the PWR and BWR measurements with detailed reactor physics modelling to generate reactor specific cross-section libraries.

3.2.3 Acknowledgement

The financial support of the Nuclear Decommissioning Authority is acknowledged.

3.3 Decay data evaluations at NPL

Arzu Arinc and Andy Pearce (Radioactivity Metrology Group, Acoustics & Ionising Radiation Division, National Physical Laboratory)

NPL has recently participated in the International Atomic Energy Agency's Coordinated Research Programme (IAEA CRP) 'Updated Decay Data Library for Actinides'. The final Research Coordination Meeting was held in November 2008. Evaluations of ^{232}Th and ^{232}U were completed in 2008, with ^{231}Pa and ^{228}Ac in progress and due for publication at the end of 2009. Completed evaluations are available on the DDEP website, www.nucleide.org/DDEP_WG/DDEPdata.htm. The IAEA's Nuclear Data Section will also publish a summary report in 2010 containing all the evaluations and recommendations for future study.

A recent EU report [19] has highlighted the need for new staff to be trained in decay data evaluation. This reflects a recognised need globally as many of the existing evaluators approach retirement. The evaluations submitted as part of the IAEA CRP are the first evaluations completed by two newly trained evaluators. Decay data evaluation is intended to be an ongoing activity at NPL with evaluations of ^{106}Ru and ^{106}Rh planned for the next NMO-funded programme.

Financial support from the National Measurement Office (NMO) is acknowledged.

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