Working Party on International Nuclear Data Evaluation Cooperation, Subgroup 23

Creation of the International Library of Neutron Cross-Section Evaluations for the Bulk of Fission Products

Report to the WPEC Meeting, Paris, April 19-20, 2007

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Abstract

The International Fission Product Library (IFPL, NLIB=21) contains neutron cross-section data for 219 fission products. The library went successfully through basic testing with checking codes, followed by processing with NJOY-99.161 and neutronics test runs with MCNP5. Validation was limited to a few selected materials.

1. Introduction

Objective and membership

SG23 was established in May 2004 as a follow-up of the SG21 activity [1], with the objective to create ENDF-6 formatted files, perform basic testing for all fission product (FP) materials and data validation for selected materials. It was assumed that the bulk of these files would be adopted by all major nuclear data projects.

SG23 membership:

Chairman	P. Oblozinsky, ENDF (BNL)
Monitor	R. Jacqmin, JEFF (CEA Cadarache)
ENDF	Dunford, Herman, Mughabghab, Rochman (all BNL), M. Dunn (ORNL)
JEFF	C. Dean (Winfrith), A. Trkov (IAEA, currently IJS Lubljana)
JENDL	T. Nakagawa and K. Shibata (JAEA)
BROND	V. Pronyaev and A.V. Ignatyuk (IPPE Obninsk)
CENDL	Ge Zhigang and Chen Guochang (CNDC)

Results

The International Fission Product Library (IFPL, NLIB = 21) was created. The library contains 219 materials in the range of Z = 31 – 68, including several important structural materials (Mo, Zr) and absorbers (Cd, Gd). The library was created in the course of three years as follows:

- In 2004, merging of files for 164 materials following the SG21 recommendations [1] was done.
- In 2005, merging was completed and SG23 library was extended to a full set of 219 materials. Basic testing was done and feedback collected.
- In 2006, revisions and updates of selected evaluations were done. The updated SG23 library was subject to another round of basic testing and partial validation.

2. Activities in 2006

In 2006, SG23 activities focused mostly on revisions of new evaluations produced for ENDF/B-VII.0, minor improvements in other evaluations, and testing.

Library

The sources of evaluations included in the SG23 library are summarized in Table 1. Full files were adopted primarily from ENDF/B-VII (74 materials), followed by JENDL-3.3 and CENDL-3.0. Partial evaluations in the resonance region are based mostly on the recent Mughabghab's data (another 74 materials), while majority of partial evaluations in the fast neutron energy region was taken from JENDL-3.3. This selection differs from the original SG21 recommendations, which were based on evaluations available in 2003, in cases where new evaluations become available in 2004-2006.

Table 1. Sources of 219 evaluations included in the fission product library.

Project (Data Source)	**Full File**	**Resonance Region**	**Fast Region**
ENDF/B-VI.8	1	3	13
New evaluations for ENDF/B-VII	74	74	-
JEFF-3.1	1	-	-
JENDL-3.3	47	7	56
CENDL-3.0 (not yet released)	11	-	15
BROND-2.2	1	-	-
Total number of materials	**135**	**84**	**84**

In 2006, SG23 activity focused on revisions and updates of new evaluations produced for ENDF/B-VII. In the resonance region the new MF2 evaluations for as many as 148 materials are based on the recently published Atlas of Neutron Resonances [2]. MF2 data are available also for 5 unstable isotopes, while unknown RRR data for 17 low priority isotopes were estimated. Full files produced for ENDF/B-VII combine thermal and RRR data from the Atlas of Neutron Resonances, with URR extended up to the 1st excited level, complemented with evaluations in the fast neutron region using the nuclear reaction model code Empire-2.19 [3].

Five full isotopic chains were evaluated for ENDF/B-VII, namely for elements of Ge, Nd, Sm, Gd and Dy. As an example we show in Fig. 1 capture cross sections for 8 isotopes of neodymium, ^{142,143,144,145,146,147,148,150}Nd, including the radioactive ^{147}Nd.

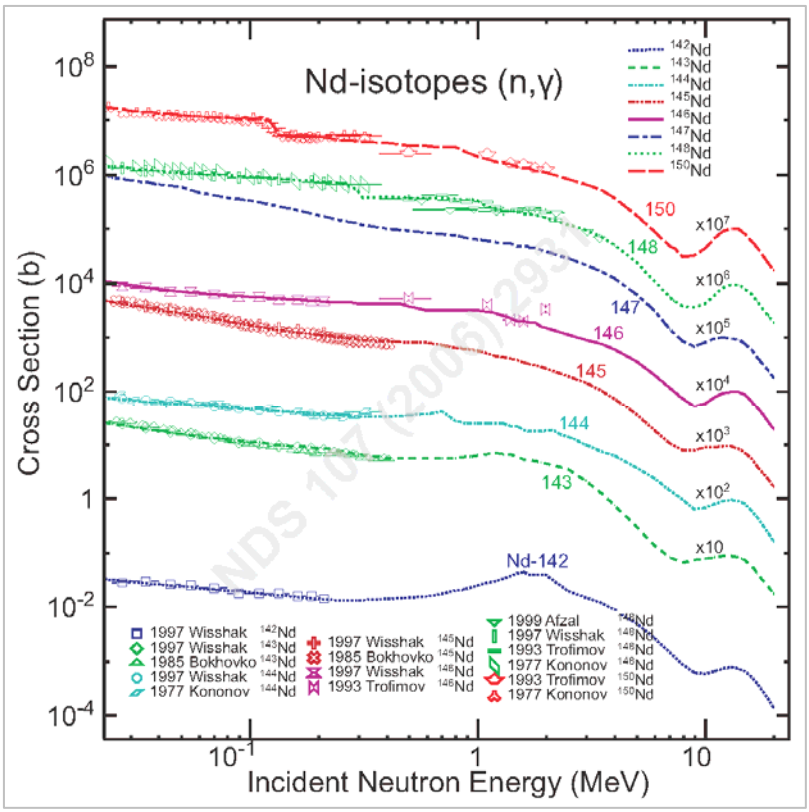

Fig. 1. Capture cross sections for a complete isotopic chain of 8 isotopes of Nd.

Data verification

Phase1 testing (data verification) was successfully completed for all 219 materials. This was done in the following three steps:

- Checking by a suite of ENDF-6 utility codes (CHECKR, FIZCON, PSYCHE) to find possible formatting problems and inconsistencies in physics.
- Processing by the latest version of the processing code NJOY-99.161 to ensure that a processed library suitable for neutronics calculations can be produced.
- Simple test runs by the Monte Carlo code MCNP5 to ensure that neutronics calculations can be performed.

Comparison with the Atlas of Neutron Resonances

Systematic comparison of thermal neutron capture cross-sections and neutron capture resonance integrals (RI) with the Atlas of Neutron Resonances [2] was done. As shown in Figs. 2 and 3 good overall agreement was achieved, although in several instances notable differences exist for the capture resonance integrals.

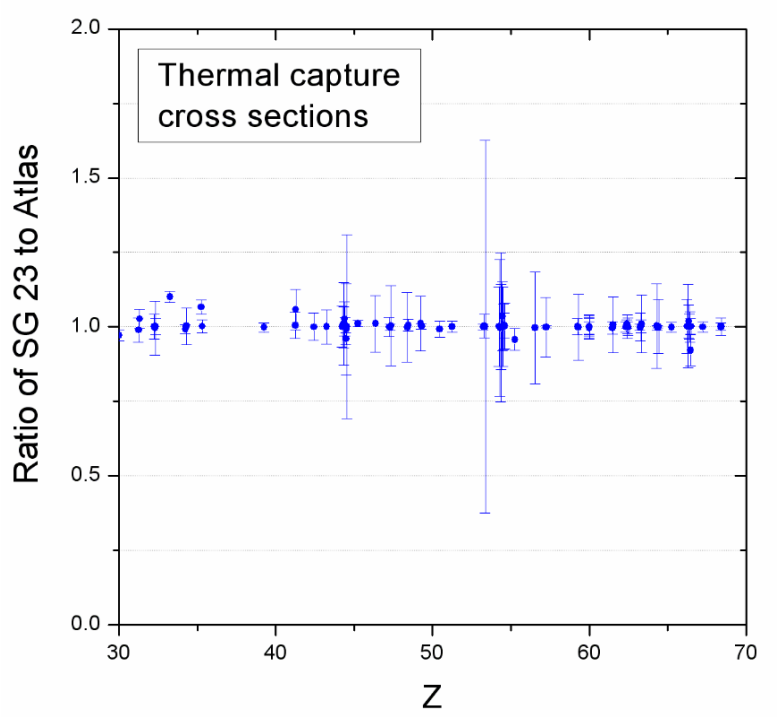

Fig. 2. Thermal neutron capture: Ratios of SG23 to the Atlas of Neutron Resonances.

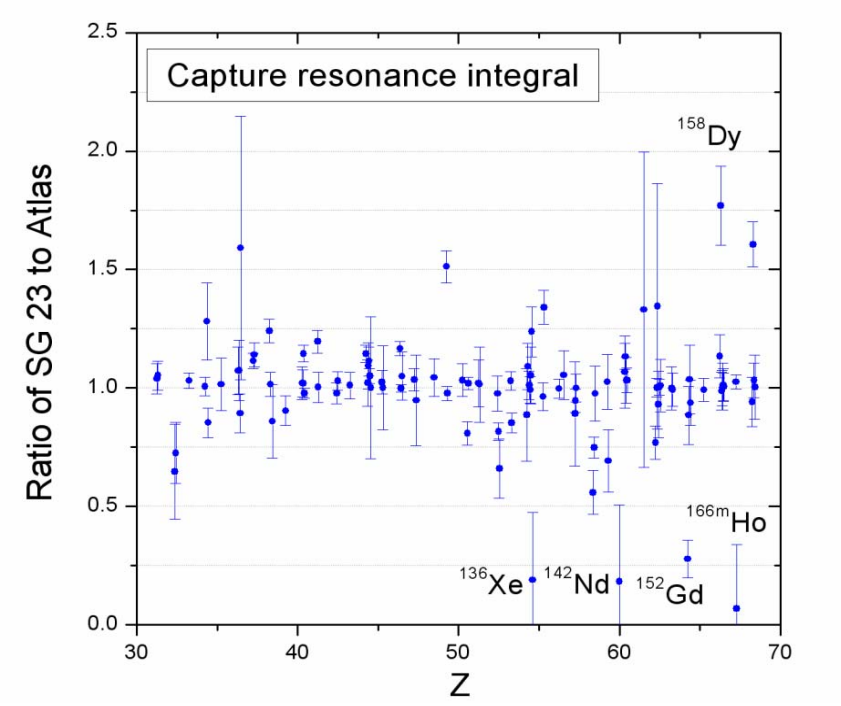

Fig. 3. Comparison of the resonance integrals for neutron capture with the Atlas of Neutron Resonances.

Thus, the ratios of capture resonance integrals for ^{136}Xe, ^{142}Nd and ^{152}Gd shown in Fig. 3 deviate from unity since there are inconsistencies between resonance parameters and resonance integral measurements and the evaluators adopted resonance parameters rather than the experimental integrals.

In the case of the capture resonance integral for ^{158}Dy the resolved resonance range is very limited (up to 86 eV) and extrapolation of the unresolved region to such low energies might be not reliable. As for ^{166m}Ho, the experiment is deemed doubtful due to the cadmium cut-off because of the ^{166m}Ho low energy resonance at 0.274 eV.

Validation

The validation activity of SG23 using integral benchmark experiments was very limited. Still, two important observations can be made, for ^{90}Zr and ^{157}Gd.

For ^{90}Zr the benchmark testing performed for ENDF/B-VII showed undesirable drop in the reactivity. Sensitivity analysis suggested that this shortage could be counteracted by the increase of the elastic cross-section. Indeed, it was shown that all suitable RIPL-2 optical potentials predict ^{90}Zr elastic cross sections significantly higher than the initial evaluation. This modification in elastic cross sections was adopted by SG23.

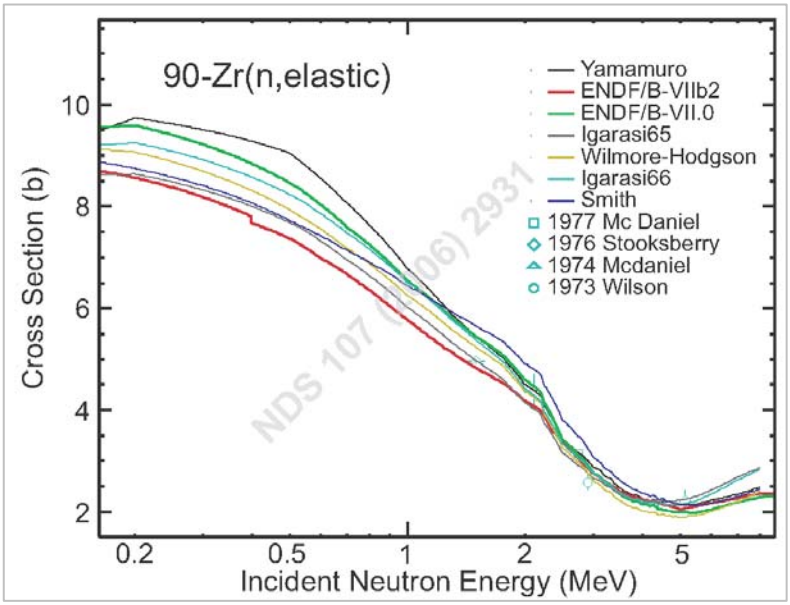

Fig. 4. Elastic cross-section for ^{90}Zr calculated with several OM potentials compared to evaluated libraries.

Benchmarking for Gd was done as a part of the extensive ENDF/B-VII.0 benchmarking exercise [5]. It was observed that Gd suffers from the similar problems as the earlier ENDF/B-VI.8 evaluation. Although no particular explanation for this continuing deficiency was offered, we note that the recent measurement of Gd [6] indicates a considerable reduction in the thermal neutron capture cross-section and significant

change in the elastic cross-section for the most important isotope ^{157}Gd. Such an important finding should be supported by an independent experiment, and therefore no modification was made in the adopted ^{157}Gd evaluation.

3. Conclusions

The International Fission Product Library (IFPL) was created, containing 219 materials in the range of Z = 31 – 68. Complete basic testing was performed and systematic comparison with the recent Atlas of Neutron Resonances was made, though the validation against integral benchmark experiments was limited. The new ENDF/B-VII.0 library [4] adopted all files included in IFPL. It is assumed that the other projects will do so for the bulk of FP materials in future.

SG23 achieved its objectives and completed its work. SG23 final report should be prepared shortly.

References

1. P. Oblozinsky *et al*, Assessment of Neutron Cross-section Evaluations for the Bulk of Fission Products (SG21 Final Report), Report NEA/WPEC-21 (NEA, Paris 2005).

2. S. Mughabghab, Atlas of Neutron Resonances: Resonance Parameters and Thermal Cross Sections (Elsevier, Amsterdam 2006).

3. M. Herman *et al*, Nuclear Reaction Model Code EMPIRE-2.19, released in March 2005, www.nndc.bnl.gov/empire.

4. M.B. Chadwick, P. Oblozinsky, M. Herman *et al*, "ENDF/B-VII.0: Next Generation Evaluated Nuclear Data Library for Nuclear Science and Technology", Nuclear Data Sheets, vol. 107, pp. 2931-3060, 2006.

5. S. van der Marck, “Benchmarking ENDF/B-VII.0”, Nuclear Data Sheets, vol. 107, pp. 3061 - 3117, 2006.

6. G. Leinweber *et al*, “Neutron Capture and Total Cross-Section Measurements and Resonance Parameters of Gadolinium”, Nucl. Sci. Eng. 154, p.261, 2006.